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Is the smartphone a performance killer?

The effect of the frequency and intrusiveness of smartphone alerts on the task performance of University students

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Abstract

Aim. The aim of this research is to answer the research question: "*What is the effect of smartphone alert's interruption frequency and the alert's intrusiveness on the task performance of University students and how does this effect differ depending on the type of task that has to be performed?"* An experimental study was conducted to gain more insight into how University students perceived the effect of the smartphone alerts' frequency and intrusiveness and their overall experience

Background. This research was conducted because the problem of multitasking is becoming more and more problematic, especially while studying. University students are increasingly interrupted by their smartphones, which is thought to decrease their task performance. It is important to discover how smartphone alerts can lead to lower task performance of University students, by looking at their frequency and intrusiveness. It is not known whether the intrusiveness of the smartphone alerts affect task performance.

Design and method. The research consisted of a 2 (one alert vs. multiple alerts) x 2 (highly intrusive alerts vs. low intrusive alerts) x 2 (problem solving vs. reading task) design, with the variables interruption frequency and interruption intrusiveness measured in two the different tasks. In this research, an experiment was used in which University students had to carry out a task and were interrupted by a smartphone (WhatsApp) in the meantime. A total of 160 University students with ages ranging from 18 to 30 have been included in the research. After the respondents finished their task, they were asked to fill in a questionnaire about how they perceived the influence of the independent variables and their overall experience.

Results. The frequency and intrusiveness have showed main effects on completion time and the number of errors. However, no interaction effects were found. The type of task had no influence on the effects of frequency and intrusiveness.

Conclusion. Results have confirmed that the number of smartphone alerts and the alert's intrusiveness have a negative effect on the task performance of University students. More education on the topic of smartphones and task performance in necessary to reduce multitasking in the educational field.

Practical implications. To change this multitasking behavior, young children, as well as University students and employees must be more educated on the fact that studying and using smartphones simultaneously has negative effects on task performance to create more awareness of these unfavorable effects.

Keywords. interruptions, multitasking, smartphone alerts, frequency, intrusiveness

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1. Introduction

The constant evolution of technology has significantly changed the way we perform our daily activities (Correa, Hinsley & De Zuniga, 2010): using technological devices is inevitable in present-day life (Mick & Fournier, 1998). Technology is here to stay for good reasons, since technology can facilitate people in different ways. According to Mick, and Fournier (1998), technology enlarges freedom, control, and help to use time more efficiently in the work field, but also our study-related activities. Rosen, Carrier, and Cheever (2013) have argued that, because of our technology-filled environment, multitasking is necessary for everyone, but multitasking is more prominently seen among students (Lenhart, Purcell, Smith & Zickuhr, 2010), since students are often dedicated to the execution of multiple tasks and activities at the same time (Czerwinski, Horvitz & Wilhite, 2004). Additionally, Monk, Trafton, and Boehm-Davis (2008) claim that for most students *"dealing with interruptions is not a problem to be overcome as much as it is an inevitable part of life"* (p. 299).

Next to our recreational activities, the use of technology currently receives more attention in our educational activities. As identified by Park (2005), students use their smartphones for all kinds of purposes: the most important purposes being immediate gratification, affiliation and reducing social anxiety. This is also a way to reduce the Fear Of Missing Out (FOMO), but these purposes are not efficiency related. However, the efficient use of time is especially valuable for University students: they want to use their time as efficiently as possible and try to do as many tasks in a short period of time. As a result of this, students are tempted to perform multiple tasks at once, which leads to multitasking – or as others call it, task switching. However, researchers are still hesitating whether it is true that technology increases freedom, control, and time-efficiency, especially in the educational field. According to several researchers, technology has never-ending benefits, which makes it likely to forget about the disadvantages of technology (Krasnova, Widjaja, Buxmann, Wenninger & Benbasat, 2015; Yang, Liu & Wei, 2016).

As previously seen, the use of smartphones has developed to become crucial for University students since the efficient use of time is getting a priority. Therefore, students frequently access their smartphones to search for available information and additional knowledge while studying. Another factor that leads to an increasing amount of multitasking is the development of our technology, especially smartphones. On smartphones, users can download a whole range of apps, which increase the possibilities of our smartphones even more and induce multitasking. However, all the apps and other functions that are installed on our smartphones send alerts when there is a new message waiting for us, when there is a missed phone call, a new email or updates about other events. The term notification has been defined as a "*visual cue, auditory signal, or haptic alert generated by an application or service that relays information to a user outside of the current focus of attention*" (Sahami Shirazi et al., 2014, p. 3056). These notifications are disruptive in the execution of a task, which may lead to difficulties in completing the task, as discussed in the following sections.

Moreover, Mick, and Fournier (1998) have argued that the unconditional use of technology will unavoidably lead to technological paradoxes. Jarvenpaa, and Lang (2005) as well as Johnson, Bardhi, and Dunn (2008) define a paradox as a situation, act, or behavior that seems to have contradictory or inconsistent outcomes: something is both liked and disliked or having both advantages and disadvantages at the same time: something is *"both X and not-X at the same time"* (Mick and Fournier, 1998, pp. 125). This illustrates that although consumers enjoy the benefits of technology, they are often frustrated by the same type of technology as well (Johnson, Bardhi & Dunn, 2008), suggesting more disadvantages to using technology.

The negative side of multitasking while executing cognitively demanding task – studying - is currently receiving more and more attention, since multitasking is becoming a big part of our lives. In order to gain more knowledge on how multitasking between studying and technology affects performance, research should be broadened. More specifically, research on the effects of multitasking between smartphones and study-related tasks needs to be further explored. Therefore, it is important to not only look at the advantages of smartphones, but more importantly to look at the accompanying disadvantages.

Especially the alerts and notifications we receive on our smartphone lead to a large problem in the execution of recreational life tasks, but also tasks related to the educational field. To explore the effect of smartphone alerts in the educational field, an experimental study with a 2 (one alert vs. multiple alerts) x 2 (highly intrusive alerts vs. low intrusive alerts) x 2 (solving insight problems vs. reading task) design will be conducted and elaborated on to answer the following question: "*What is the effect of smartphone alert's interruption frequency and the alert's intrusiveness on the task performance of University students and how does this effect differ depending on the type of task that has to be performed?"*

2. Theoretical framework

2.1 The multitasking paradox

As the name would suggest, multitasking refers to the activity of executing multiple tasks simultaneously (Judd & Kennedy, 2011). Other researchers propose more elaborate definitions of the term multitasking. According to Ellis, Daniels, and Jauregui (2010), "*multitasking refers to the concurrent processing of two or more tasks through a process of context switching"* (p. 1). Buser, and Peter (2012) claim that multitasking is simply switching back and forth between two continuing tasks, no matter if the tasks are carried out efficiently. Karpinski, Kirschner, Ozer, Mellott, and Ochwo (2013) argue that multitasking is "*the simultaneous/concurrent execution of two or more cognitive or information processing activities"* (p. 1183). Additionally, Karpinski et al. (2013) suggest that multitasking does not include activities and other processes that are entirely automated because these

activities do not require to be consciously processed (for example: walking and talking simultaneously). Even though multitasking has traditionally been seen as a useful skill to have, several studies have demonstrated that there is a significant cognitive cost associated with constant task switching and studying, which leads to a significant decrease in performance when tasks are performed simultaneously and an increase in time taken to complete tasks when they are multitasked rather than completed sequentially (Judd & Kennedy, 2011). Furthermore, past studies indicate that there is a measurable increase in the time required to complete a task when a person is performing multiple tasks at the same time compared to when the tasks are performed one after another (Appelbaum, Marchionni & Fernandez, 2008): it might be logical, when there is so much attention towards the negative aspects of interruptions, to escape any kind of distractions.

2.2 Multitasking and memory

As Salvucci, Taatgen, and Borst (2009) have argued with reference to the threaded cognition theory (Salvucci & Taatgen, 2008), one of the most remarkable characteristics of the human cognitive system is the capacity to execute two or more concurrent tasks – or simply put: multitask. However, our brain structure has a restricted information processing capacity: the human brain is only able to switch between two *distinct* information contexts. In doing so, our brain just gives the illusion that one is processing both parts of information at the same time (Ellis, Daniels & Jauregui, 2010).

There are concerns caused by task-switching and multitasking in relation to learning (Judd & Kennedy, 2011). Constant switching between different tasks leads to a great "switch loss", which means that you lose a lot of focus every time you switch between tasks (Crabbe, 2017). Due to these switching contexts, information is being processed much slower and is encoded into memory less efficiently, leading to a substantial decrease in performance (Judd & Kennedy, 2011; Oulasvirta & Salovaara, 2004): multitasking while executing a cognitively demanding task leads to a decrease in memory and attention (Ellis, Daniels & Jauregui, 2010). The way information is initially processed may determine the way in which it is used. When information is processed mindlessly, it becomes very difficult to retrieve it. For example, students who study while listening to music or using their smartphone may find it more difficult to retrieve information during their exam. It is especially difficult to retrieve mindlessly processed information after longer periods of time (Ellis, Daniels & Jauregui, 2010). Therefore, it seems clear that the interruptions and lack of full attention caused by multitasking can affect the cognitive processes that are crucial to the encoding of information into memory (Judd & Kennedy, 2011). When memory and attention are limited, University students need to prioritize tasks to increase efficiency and decrease deficits in encoding information into memory (Quinones et al., 2008).

Smartphones and performance

Due to the development in our technology, people are physically able to execute two or more activities at the same time. Unfortunately, cognitive capabilities have not increased along with this development, which may lead to a reverse effect of using technology (McFarlane & Latorella, 2002). However, these technological driven interactions and interruptions may also impact academic performance. Research has shown that regularly switching between tasks – what many people incorrectly refer to as being able to multitask (Karpinski et al., 2013) – leads to decreased learning results and eventually to lower task performance (Iqbal & Horvitz, 2010; Junco, 2012; Rosen, Lim, Carrier & Cheever, 2011). The outcome of the experiment by Junco (2012) shows that technology induced interruptions disrupt the encoding process of new information and can therefore cause difficulties when students are asked to retrieve this information. In his study, a questionnaire was used that was asking about how much time student use their smartphones and other technological devices while studying. Afterwards, these outcomes were compared to the participant's grade point average. It has been found that students who spend a lot of time using their smartphones and other communication technologies while studying had a lower grade point average (Junco & Cotten, 2011; Junco, 2012). As stated by Rosen, Carrier, and Cheever (2013), especially technologically driven task switching is perceived as extremely disruptive, which leads to an increased number of errors when retrieving information from memory. Moreover, research by Garrett, and Danziger (2007) found that task switching - multitasking - leads to a lot of interruptions which is problematic for students attempting to study new material, because encoding new information requires accessibility to one's working memory: *"a mental workspace, involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks"* (Raghubar, Barnes & Hecht, 2010, p. 110).

Additionally, another study strongly suggests that task performance is decreased by increasing task completion times when a task is performed when multitasking (Pashler, 2000). Moreover, Wood et al. (2012) identified that students who did not switch between tasks while studying performed better than those who did switch between tasks: the more task switching - or multitasking - while studying, the lower the task performance. During studying, smartphones, and more specifically instant messaging applications (WhatsApp) fight for attention and can ultimately disrupt the learning process (Wijekumar & Meidinger, 2005). Many smartphone interactions demand high amounts of cognitive as well as visual attention from users (Hinckley & Horvitz, 2001). Even though people might switch between tasks in a self-directed way, a substantial part of task switching is caused by external interruptions instead of internal distractions. In case the interruption has a contrasting context compared to the current task, it could lead to a disruption cost or switch loss (Crabbe, 2017): there is a cognitive shift to attend to the interruption, after which one must switch their attention back to the interrupted task, leading to cognitive difficulty (Mark, Gudith & Klocke, 2008). This highlights the effort that people have to put in when returning to initial tasks following an interruption, such as an instant message or a phone call. It is

assumed that people are unable to turn to the primary task straight away because the initial task context has been forgotten (Czerwinski, Horvitz & Wilhite, 2004).

2.3 Interruption frequency

Interruptions are common phenomena in our daily routines, but interruptions can also occur in other environments, especially in the life of University students. Because of this growing and evolving phenomenon, the negative effects of these constant interruptions are taken more seriously at this point. Our human performance can quickly be decreased by an overload of tasks and information that needs to be consciously processed at the same time (Ellis, Daniels & Jauregui, 2010; Garrett & Danziger, 2007; Karpinski et al., 2013; Sweller, 1994). Since there are a lot of devices that are interruptive, especially smartphones with their many functions and alerts, people are exposed to an increasing number of interruptions every day: the interruption frequency is increasing. The term interruption frequency is specified as being *"the number of tasks interrupting primary task performance"* (Lee & Duffy, 2015, p. 142). Research has found a negative relationship between interruption frequency and task quality and task performance: the more messages that are sent which interrupt the person from the task he or she is executing, the bigger the negative impact on task quality and performance (Gupta, Li & Sharda, 2013; Pielot, Church & De Oliveira, 2014; Sahami Shirazi et al., 2014).

Moreover, results have been revealed regarding the influence of the frequency of interruptions on primary task performance and a person's associated perceived workload (Gupta, Li & Sharda, 2013; Speier, Valacich & Vessey, 1999). Gupta, Li, and Sharda (2013) have found a negative correlation between the primary task quality and interruption frequency in the work field: the more frequent the messages interrupt someone from their primary task, the larger the unfavorable impact on primary task quality (Gupta, Li & Sharda, 2013). Additionally, results of this study show that the more interruptive messages were sent, the bigger the negative impact on the participant's perceived workload. Furthermore, higher levels of perceived workload are indicated when people receive notifications during phases that they are highly focused on their current task (Sahami Shirazi et al., 2014). In their study, the interruption frequency of interruptive messages was manipulated. Contradictory to the previous findings, a study by Coraggio (1990) showed no significant effect of the frequency of the interruptions on primary task performance.

As literature suggests, University students are very likely to multitask to spend their time as efficiently as possible (Lenhart et al., 2010; Rosen, Carrier and Cheever, 2013). Coping with constant interruptions and multitasking has become normal in the life of University students, to the point where dealing with interruptions is seen as an inevitable part of life (Rosen, Lim, Carrier and Cheever, 2011, p. 165). University students may be used to constant interruptions from their smartphones, and therefore think that they are not very sensitive to these interruptions, which makes them assume that they are able to multitask. As research above has shown, there are multiple contrasting findings with regards to the

interruption frequency and task performance. Since University students use their smartphones more and more during studying and encoding new information into memory which requires a lot of focus, they might be even more prone to interruptions than people in the work field and show a decrease in their primary task performance (Sahami Shirazi et al., 2014): too many interruptions lead to a fragmented attention span, making it hard to focus on one primary task (Levy, 1997).

Having said this, the following hypothesis has been established:
H1a: There is a negative relationship between interruption frequency and the completion time.
H1b: There is a negative relationship between interruption frequency and the number of errors.
H2: There is a negative relationship between interruption frequency and the overall experience: workload, frustration and anxiety.

2.4 Smartphones and notifications

Notifications are crucial elements of smartphones. As seen before, the term notification has been defined as a "*visual cue, auditory signal, or haptic alert generated by an application or service that relays information to a user outside of the current focus of attention*" (Sahami Shirazi et al., 2014, p. 3056). Especially on modern smartphones, the purpose of these notifications is to inform the user about a broad variety of activities, including incoming messages, the availability of a new update or a phone call. These smartphone interruptions break University student's focus and distract them from their primary task (Coraggio, 1990) since smartphone notification interfere more and more with our daily activities (Pielot, Church & De Oliveira, 2014). There are alerts which create sound signals to grab the person's attention, and alerts which grab attention by the tactile senses (vibrating). Vibrating smartphone alerts are useful especially when the user's auditory and visual modalities are engaged (Saket, Prasojo, Huang & Zhao, 2013). Intrusiveness refers to *"the amount of attention attracted by the notification signal"* (Quinones et al., 2008, p. 178). Considering these different alert modes, smartphone notifications can turn our smartphones into very disruptive and intrusive devices (Pielot, Church & De Oliveira, 2014).

As shown by Sahami Shirazi et al. (2014), an essential issue with smartphone notifications is that users are likely to shift their current task to their smartphone to check their notification immediately. In most cases, instant action is taken by the smartphone user, in other cases notifications are ignored, depending on the notification's signal and the user's current activity (Sahami Shirazi et al., 2014). The ease with which people can resume their suspended task also depends on the motivation from the worker (Quinones et al., 2008). Because of that, people may find it difficult to return to their initial task after they were interrupted by a notification (Czerwinski, Horvitz & Wilhite, 2004).

According to Chang, and Tang (2015), there are several reasons to choose a specific alert mode: avoiding interruptions (silent), preventing the smartphone from interrupting others (vibrate) and noticing important interruptions (sound). Furthermore, Chang, and Tang (2015) have stated that there are differences in the responsiveness to alerts depending on the alert mode. There can also be a combination of both: alerts that are both auditory and tactile: these notifications are more intrusive than only auditory signals, and therefore are less likely to be ignored (Quinones et al., 2008). When people decide on which notification signal to use, they have to decide on whether they want the signal to draw their attention, and trying not to be disturbing to others: subtlety versus intrusiveness. The consideration of subtlety versus intrusiveness refers to *"the amount of attention attracted by the notification signal"* (Quinones et al., 2008, p. 178): this is the amount of distraction caused by the smartphone alert's signal (Quinones et al., 2008). Unfortunately, it is not clear whether these different notification signals matter when receiving smartphone alerts.

Considering that there are different alert modes when it comes to the signals of smartphone alerts and their intrusiveness, the following hypothesis was established:

H3a: Auditory (sound) alert signals are more intrusive than tactile (vibrating) alert signals: exposure to auditory alerts will increase the completion time.

H3b: Auditory (sound) alert signals are more intrusive than tactile (vibrating) alert signals: exposure to auditory alerts will increase the number of errors.

H4: There is a negative relationship between interruption intrusiveness and the overall experience: workload, frustration and anxiety.

2.5 Type of task

Students are confronted with several kinds of tasks each day (McVay & Kane, 2012). Therefore, the effect of smartphone alerts might differ, depending on the task the student is currently executing. In previous research, several different tasks have been used to identify the effects of smartphone interruptions: Gupta, Li, and Sharda (2013) have used reading assignments were participants had to remember as much information as possible, and were asked to recall this information later. Others have used insight tasks, such as word-stem completion tasks (Lee & Duffy, 2015).

As stated by Byrne, and Murray (2005), many studies have identified differences between insight and non-insight tasks. Furthermore, Byrne, and Murray (2005) have also suggested that when solving an insight related problem, selective attention might be necessary: creativity to solve insight problems is needed. Solving insight problems usually requires some kind of change to the initial

interpretation of the problem and its expected solution, which can be achieved by moving the attention away from the task, let the mind wander for a few moments, and redirecting the attention back to the task: switching attention. Mind wandering may be defined as *"a shift of attention away from stimuli and mental representations associated with a person's ongoing activities"* (McVay & Kane, 2012, p. 4). From this study, it can be suggested that students who are good at solving insight problems may also be good at switching attention. On the other hand, according to McVay, and Kane (2012), reading is considered to be a very attention-demanding task. It is very important to have all the focus directed to the task: one needs to read the individual words, and then make an accurate interpretation of the information accordingly. When this focus is interrupted, and task unrelated activities take place, higher chances of error and inaccuracy are likely to occur. Both tasks, insight problem-solving tasks and reading assignments need a solid working memory and focus. Though, the disruptive effects of smartphones may differ depending on the task. This assumption has not been researched yet.

Unfortunately, there has no research been done on the question whether there are differences in the effect of smartphone alerts and the decrease in task performance, comparing the type of task that must be performed: solving insight problems or a reading assignment.

Thus, the following is assumed:

H5a: The disruptive effects of smartphone alerts on completion time are bigger when performing a reading assignment than when performing an insight problem solving task.

H5b: The disruptive effects of smartphone alerts on the number of errors is bigger when performing a reading assignment than when performing an insight problem solving task.

H6: There is a difference in overall experience depending on the task that must be performed.

Theoretical model

According to the literature study above, it appears that interruptions have an impact on learning and eventually on task performance. However, this depends on the interruption frequency and the interruption intrusiveness. In this study, it is expected that the higher the interruption frequency of the smartphone alerts and the higher the smartphone alert's interruption intrusiveness the lower the task performance of University students is likely to be. Additionally, it is expected that there is a difference in the type of task students are carrying out. Therefore, the research question of this study is: *What is the effect of smartphone alert's interruption frequency and the alert's intrusiveness on the task performance of University students and how does this effect differ depending on the type of task that must be performed?*

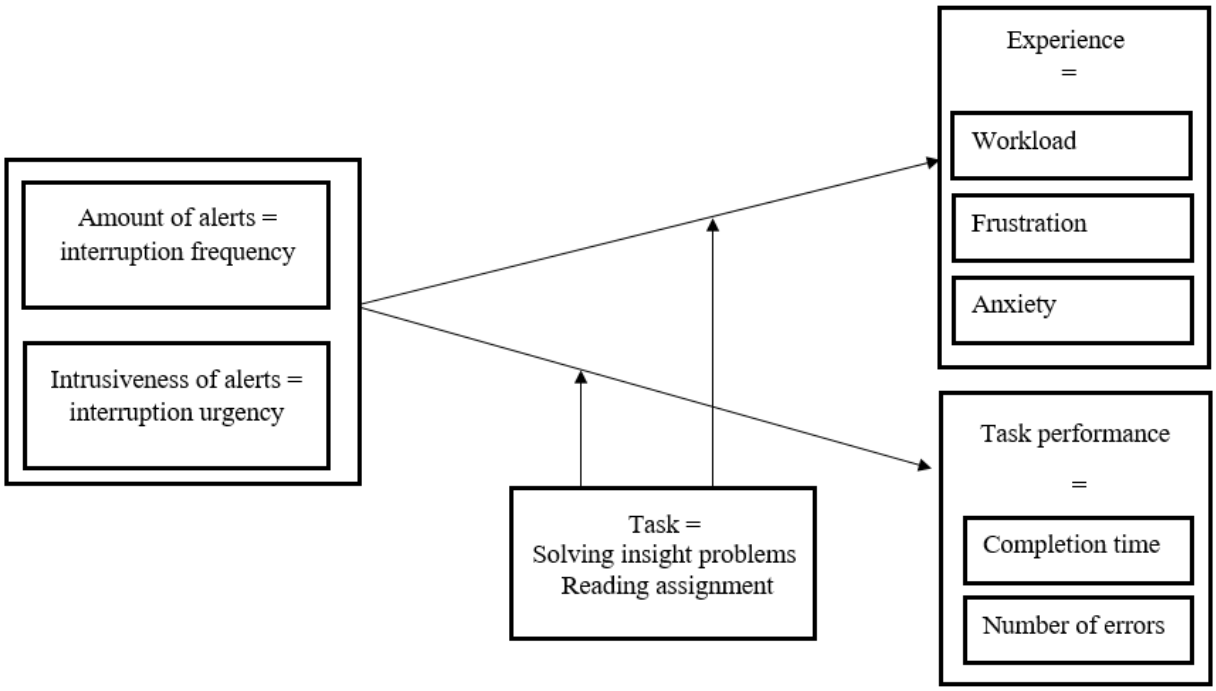

Figure 1

Overview of the research model

3. Methodology

3.1 Research design

The research model above is a schematic representation of the research with the corresponding hypotheses. The research consists of an experiment with eight experimental conditions. When conducting an experiment, the external variables can be controlled to only measure the effect of the independent variables on the dependent variable. The different components discussed in the literature review were combined towards a 2 (one alert or three alerts) x 2 (highly intrusive – sound, or low intrusive alerts - vibrate) x 2 (solving insight problems or reading assignment) experimental study. A research design with eight experimental conditions was established and is visualized below.

Table 1

The research design

Problem-solving task	One alert (interruption = 1)	Multiple alerts (interruption = 3)
Not intrusive - vibrate	Condition 1, N = 20	Condition 2, N = 20
Intrusive – loud signal	Condition 3, N = 20	Condition 4, N = 20
Reading assignment	One alert (interruption = 1)	Multiple alerts (interruption = 3)
Not intrusive – vibrate	Condition 5, N = 20	Condition 6, N = 20
Intrusive – loud signal	Condition 7, N = 20	Condition 8, N = 20

3.2 Sampling

The target group of this study consisted of University students. To achieve a valid research sample, 20 participants per condition was desired. As this study contains eight experimental conditions, a sample of 160 respondents was collected. A total of 181 University students participated in the experiment, yielding 160 valid responses which were included in this study Their ages ranged from 18 to 30 years old (M = 23.31, SD = 3.46). In total, 111 males and 49 females were included in the study. The demographics of the target group can be found in Appendix 1. Potential respondents were recruited via email, Social Media, WhatsApp messages, the University's online research platform and direct mouth-to-mouth communication (common friends and student associations). Furthermore, people at public areas of the University were asked to participate in the experiment. All the respondents who signed up to participate in this experiment were assigned randomly to one of the conditions.

3.3 Stimulus materials

Before the start of the experiment, the stimulus material was created by the researcher: some instructions, two different tasks and a questionnaire. The tasks that participants had to perform was either solving an insight problem or executing a reading assignment. Both tasks can be found in Appendix 3 and 5. The respondents received the instructions (Appendix 2 and 4), a task description and the task itself on the online program Qualtrics as well as a smartphone which was located on the table opposite to the participant.

3.4 Pre-test

Before conducting the main study, a pre-test was performed to verify the stimuli material and to test the questionnaire. A total of 10 University students participated in the pre-test (Male: N=5; Female: N=5) with ages ranging from 20 to 26 (M = 22.9, SD = 2.66). Participants were gathered through the network of the researcher and were excluded from the main experiment to prevent any bias. The participants in the pre-test received both tasks, the questionnaire and the instructions that the researcher has established. During the pre-test, participants were asked to execute one of the two tasks, while being interrupted by the researcher: either one or three times with the alert mode being either auditory or tactile. The first thing that the respondents were asked was to give feedback on the instructions they have been given. Examples of questions are *"The instructions I received were clear to me"* and *"I know what to do after reading the instructions".* Furthermore, questions about the alert's frequency and the alert's intrusiveness were asked to validate the research materials.

Manipulation check: frequency of the alerts

The first manipulated variable in this study is the frequency of the smartphone alerts. According to Lee, and Duffy (2015), the interruption frequency should not be too high, since that could possibly lead to unintended annoyance. Therefore, they argue that the best measures for task interruption are as follows: one single interruption or three interruptions. To measure the perceived interruption frequency of the smartphone alerts, there are six items used in the questionnaire. A new scale was designed and tested in which the perceived interruption frequency was addressed and measured. These items were inspired by the scale used in a study by Coraggio (1990). Some of the questions that were included in the questionnaire are "*The signal of the smartphone alerts was very bothersome", "I had trouble concentrating because of the interruption's signal", "The signal negatively affected my focus"* and *"The alert's signal frustrated me"*, which had to be scored on a 5-point Likert scale ranging from completely disagree to completely agree.

Manipulation check: intrusiveness of the alerts

As noted before, intrusiveness is operationalized as "*the amount of attention attracted by the notification signal"* (Quinones et al., 2008, p. 178). To measure the intrusiveness of the smartphone alerts, four items have been used in the questionnaire. The items in this scale must be scored on a 5-point Likert scale ranging from completely disagree to completely agree. Some examples of items are "*The signal of the smartphone alerts was very bothersome", "I had trouble concentrating because of the interruption's signal", "The signal negatively affected my focus"* and *"The alert's signal frustrated me".*

The influence of both manipulated variables was tested in one of the two tasks designed for this study: solving insight problems or executing a reading assignment, because, interruptions are thought to have a different effect depending on the task one is executing (Byrne & Murray, 2005; McVay & Kane, 2012).

Results of the pre-test

After the pre-test was conducted, the results have been considered when finalizing the instructions, both tasks and the questionnaire. Participants in the pre-test have indicated that the instructions they have been given were clear and participants know what to do after reading them. Some of the participants had difficulties with unlocking the phone. Therefore, instructions about how to unlock the phone have been added to the instructions. Another point of concern was, that in the pre-test, the tasks were executed on a printed version. Unfortunately, in the main study it would be impossible to give each participant their task in hardcopy. Therefore, the choice has been made to include the tasks in the Qualtrics program as well.

Outcome of the manipulation checks

Frequency of the alerts

When looking at the perceived interruption frequency, it has become clear that three interruptions (M=3.40, SD=.55) were perceived to be marginally more significant than one interruption (M=2.80, SD=1.30), p = .07

Intrusiveness of the alerts

Differences were found between the perceived intrusiveness of the smartphone alerts. The outcome of the pre-test has shown that the intrusive (auditory) signals (M=4.40, SD=.55) were perceived to be more intrusive than non-intrusive (tactile) signals (M=3.60, SD=1.52), p = .02

Type of task

According to see whether there are differences in the effect of the smartphone interruptions, the perceived frustration, the focus and the perceived workload for both task have been compared. The outcome of this comparison has shown that the perceived levels of frustration were higher among the students who participated in task 2: the reading assignment, which according to literature is a more attention-demanding task than solving insight problems (M=2.40 in the insight problem solving task, M=2.80 in the reading assignment). Furthermore, the levels of focus were compared between the two tasks. Findings of this comparison have shown that students found it harder to focus on task 2 as well: the reading assignment (M=4.00 in the insight problem-solving task, M=4.20 in the reading assignment). Additionally, resulting from the pre-test, the completion time of both tasks is approximately the same. The average completion time for solving insight problems was 5 minutes and 10 seconds, and for the reading assignment was 4 minutes and 53 seconds. Therefore, these two tasks are comparable and used in the main experiment. Also, the perceived workload of the tasks was shown to be approximately the same: both tasks have a workload which is average. The tasks were perceived to be not too easy and not too hard (M = 3.00). Lastly, the questionnaire was pre-tested to find out whether respondents thought the questions were clear, the wording was correct and other feedback was considered. Changes have been made according to the feedback received.

3.5 Procedure of the main experiment

A controlled laboratory experiment was conducted to investigate the effects of smartphone alert's interruption frequency and intrusiveness on the task performance of University students. After gathering participants for the experiment, all participants were randomly assigned to each of the eight conditions, where all conditions had the same sample size: N = 20. In these conditions, there are different combinations of the alert's frequency and intrusiveness. To test whether the number of alerts and the intrusiveness of these alerts have an influence on task performance of University students, participants must execute one of the two performance tasks: they will have to solve some insight problems or execute a reading assignment. The experiment was conducted in a quiet room to rule out the external distractions as much as possible. Before the experiment was started, the research was approved by the Ethical Commission of the University of Twente. Furthermore, all participants signed a form of informed consent.

During the experiment, the participants received an iPad with the instructions, the task, the questionnaire and a smartphone on which the interruptive messages were sent. After the iPad was presented to the research respondent, the instructions were shown as well as how to unlock the smartphone. When there were no more additional questions, the experiment was started. The researcher

left the room during the experiment to exclude as many outside interruptions as possible. The researcher sent these messages using another smartphone by using WhatsApp Messenger. Furthermore, after the performance task is over, participants are asked to fill in a short questionnaire. The duration of the experiment, including the time to fill in the questionnaire, was 15 minutes at maximum. The scheme of sending the alerts is visualized in Table 2.

Table 2

Interruption scheme divided per minute in each frequency condition

	One alert (interruption = 1)	Multiple alerts (interruption = 3)
Minute 1		Hi, sorry for interrupting you. Can you please write down your email address on the consent form in front of you? This way I can enter you in the giveaway of the VVV vouchers!
Minute 2	Hi, sorry for interrupting you. Can you please write down your email address on the consent form in front of you? This way I can enter you in the giveaway of the VVV vouchers!	
Minute 3		I apologize for bothering you again, but I just forgot to ask you to write down the time you've started the experiment (00:00).
Minute 4		
Minute 5		Sorry for interrupting you one more time, but I wanted to ask you to write down the month that we are currently in on top of the form as well.

3.6 Measurement instruments

The first part of this study is an experiment where participants have to fulfill one of the two performance tasks: solving insight problems (inspired by https://www.123test.nl/iqtest/), or a reading assignment where participants have to read an article and fill in a quiz at the end. These can be found in Appendix 3 and 5. The aim is to identify what the effect of the independent variables (interruption frequency, interruption's intrusiveness and type of task) is on the dependent variable: task performance.

Task performance is operationalized by the task completion time and the number of errors made in the execution of the task: Coraggio (1990) defines these measurements as the TMM: Time Measured Model, and the QMM: Quality Measured Model. To be able to identify the unfavorable effects of interruptive smartphone alerts in this study, the task completion time is measured in seconds. Additionally, the number of errors committed by participants were analyzed. The task completion time and the error rate can be considered as quantitative and qualitative measurements to measure task performance (Lee & Duffy, 2015).

3.7 Measures

In the second part of the research, participants were asked to fill in a questionnaire. The survey consists of two parts containing a total of seven constructs, which are explained in this paragraph. The first part measured the construct general evaluation, frustration, anxiety, workload, interruption frequency, interruption's intrusiveness and the level of self-control. The second part of the questionnaire contained demographical questions to create a balance in the number of men and women and their ages. The items in the questions were measured on a five-point Likert scale, ranging from totally disagree to totally agree. The different constructs are discussed in the following section. The complete questionnaire is presented in Appendix 6.

Perceived workload

The perceived workload of participants was measured with two items. These items were inspired and adapted from Gupta, Li, and Sharda (2013). The items used are: *"the task required a lot of mental focus"* and *"The task required a lot of thinking effort".* ($\alpha = .78$)

Frustration

To measure the feeling of frustration experienced by the participants, three items have been used. These items were inspired by, and translated from Tansik, and Routhieaux (1999) and the DASS-scale by De Beurs, Van Dyck, Marquenie, Lange, and Blonk (2001). Examples of questionnaire items are *"I felt frustrated", "I felt annoyed"* and *"I felt irritated".* ($\alpha = .86$)

Anxiety

To measure the level of anxiety experienced by the research participants, four items were included. These items are: *"I felt worried", "I felt afraid", "I felt scared"* and *"I felt concerned".* ($\alpha = .85$)

Interruption frequency

To measure the perceived interruption frequency, three items have been used. These items were inspired by the scale used in a study by Coraggio (1990). The items included are: *"The amount of smartphone alerts affected my focus negatively", "The amount of smartphone alerts made me feel frustrated"* and "*I was interrupted by the smartphone alerts so much that it was hard to focus on the task until the end"*. ($\alpha = .80$)

Interruption's intrusiveness

To address the perceived interruption's intrusiveness, four newly created items have been included. The items in this construct are: "*The signal of the smartphone alerts was very bothersome", "I had trouble concentrating because of the interruption's signal", "The signal negatively affected my focus"* and *"The alert's signal frustrated me".* ($\alpha = .85$)

Table 3
Reliability statistics

	Cronbach's Alpha	M	SD	# of items
Workload	.78*	3.797	1.823	2
Frustration	.86*	2.408	3.564	3
Anxiety	.85*	1.853	3.375	4
Frequency	.80*	2.734	3.168	3
Intrusiveness	.85*	3.045	4.036	4

* Cronbach's Alpha > .70

4. Results

After all the data was collected, the data were imported into the IMB SPSS statistics program. To analyze the data, ANOVA analyses were performed for each independent variable to see their effect on the dependent variable: task performance, divided in completion time and number of errors. By using ANOVA, the main effects between the different variables was showed and interpreted. Furthermore, the interaction effect between the independent variables was explored.

Table 4

Overview of the ANOVA analyses for the dependent variables

		df	F	Sig.
Interruption frequency	Workload	1	.232	.631
	Frustration	1	12.274	.001*
	Anxiety	1	.141	.708
	Completion time	1	10.663	.001*
	Number of errors	1	.106	.746
Interruption's intrusiveness	Workload	1	.692	.407
	Frustration	1	.257	.613
	Anxiety	1	2.250	.136
	Completion time	1	.022	.833
	Number of errors	1	4.233	.041*
Type of task	Workload	1	4.236	.041*
	Frustration	1	.077	.782
	Anxiety	1	.009	.925
	Completion time	1	7.317	.008*
	Number of errors	1	.012	.914

* significance level of $p < .05$

Manipulation checks

Interruption frequency

A two-way between-groups analysis of variance (ANOVA) was conducted to explore the effects of the alert's interruption frequency. A statistical significant main effect was found in the frequency of interruptions: $F(1,152) = 44.41$, $p = .000$, showing that three interruptions are perceived to be more than one interruption ($M = 3.21$, $SD = .96$ versus $M = 2.23$, $SD = .91$). This confirms the effectiveness of the interruption frequency manipulation, showing that three interruptions were indeed perceived as more frequent compared to one interruption. The main effect of the type of task, was statistically significant: $F(1,152) = 5.67$, $p = .018$, showing that during the reading assignment, the alerts were perceived to be

more frequent than the insight problem solving: (M = 2.90, SD = 1.10 versus M = 2.55, SD = .99). Lastly, there were no interaction effects found.

Interruption intrusiveness

An ANOVA with interruption intrusiveness as dependent variable revealed a main effect of the interruption frequency F(1,152) = 13.42, p = .000, showing that three interruptions are perceived to be more intrusive than one (M = 3.34, SD = .98 versus M = 2.78, SD = .97). Also, there was a significant main effect of intrusiveness: F(1,152) = 2.06, p = .05, showing that an interruption causing a sound signal is more intrusive than a signal causing vibration (M = 3.37, SD = 1.07 versus M = 2.95, SD = .94). This confirms the effectiveness of the interruption intrusiveness manipulation, revealing that auditory signals were indeed perceived as more intrusive compared to tactile signals. Furthermore, no interaction effects were found.

Type of task

A two-way between-groups analysis of variance (ANOVA) was conducted to explore the effects of the type of task on the completion time and the number of errors. There was a statistical significance found in the type of task on the completion time: F(1,152) = 7.32, p = .008. This shows that participants take longer to finish the reading assignment, compared to solving insight problems (M = 397.59, SD = 96.16 versus M = 347.39, SD = 141.84). However, the main effect of the type of task on the number of errors is surprisingly not significant.

4.1 Overall experience

Workload

An ANOVA with workload as dependent variable revealed a main effect of the type of task F(1,152) = 4.24, p = .041, showing that the workload in solving insight problems, was perceived to be higher than in a reading assignment: (M = 3.94, SD = .88 versus M = 3.65, SD = .92). This confirms the effectiveness of the type of task manipulation, confirming that both tasks have a different perceived amount of workload. The main effects of interruption frequency and interruption intrusiveness both showed no statistical significance. Furthermore, no statistically significant interaction effects were found: (F > .10)

Perceived levels of frustration

An ANOVA with level of frustration as dependent variable revealed a main effect of the interruption frequency on the level of frustration: F(1,152) = 12.27, p = .001, showing that three interruptions lead to more frustration than one (M = 2.09, SD = .97 versus M = 2.73, SD = 1.30). The main effects for interruption intrusiveness and the type of task on the level of frustration did not yield

significant results. There was no significant interaction effect between the independent variables: all F > .10

Perceived levels of anxiety

A two-way between-groups analysis of variance (ANOVA) was conducted to explore the effects of interruption frequency, the interruption's intrusiveness, and the type of task on the perceived level of anxiety. However, there are no significant main effects found on the alert's intrusiveness on the level of anxiety (all F > .10). Moreover, the were no interaction effects found.

4.2 Task performance

Completion time

A two-way between-groups analysis of variance (ANOVA) was conducted to explore the effects of interruption frequency on the completion time of the task. A statistical significant main effect was found in the frequency of interruptions on the completion time: $F(1,152) = 10.66$, $p = .001$, showing that three interruptions lead to a longer completion time than one interruption ($M = 402.79$, $SD = 134.$ versus $M = 342.19$, $SD = 103.82$). Also, there was a statistical significance found of the type of task on the completion time: $F(1,152) = 7.32$, $p = .008$. This shows that participants take longer to finish the reading assignment, compared to solving insight problems ($M = 397.59$, $SD = 96.16$ versus $M = 347.39$, $SD = 141.84$). No significant effect has been found of interruption intrusiveness on completion time. Additionally, there were no statistically significant interaction effects: all F > .10

Number of errors

An ANOVA with number of errors as dependent variable revealed a main effect of the interruption intrusiveness on number of errors: $F(1,152) = 4.23$, $p = .041$, showing that intrusive alerts lead to more errors than non-intrusive alerts ($M = 3.34$, $SD = .98$ versus $M = 2.78$, $SD = .97$). However, the main effect of interruption frequency, and the type of task on the number of errors is surprisingly not significant. Also, there were no interaction effects found: all F > .10

5. Discussion of results

In this chapter, the central research question will be answered. An overview of the hypotheses is presented in Table 5 to see whether the proposed hypotheses were confirmed or rejected. Considering the outcomes of the study, theoretical and practical implications are discussed to explain what these results contribute to. After that, the limitations of this study are presented and suggestions for future research are proposed. Finally, a conclusion is given.

Table 5
Overview of the main findings in the study

Hypothesis	Supported or rejected
H1a: There is a negative relationship between interruption frequency and the completion time.	Confirmed
H1b: There is a negative relationship between interruption frequency and the number of errors.	Rejected
H2: There is a negative relationship between interruption frequency and the overall experience of the task.	Partially confirmed
H3a: Auditory (sound) alert signals are more intrusive than tactile (vibrating) alert signals: exposure to auditory alerts will increase the completion time.	Rejected
H3b: Auditory (sound) alert signals are more intrusive than tactile (vibrating) alert signals: exposure to auditory alerts will increase the number of errors.	Confirmed
H4: There is a negative relationship between interruption intrusiveness and the overall experience of the task.	Rejected
H5a: The disruptive effects of smartphone alerts on completion time are bigger when performing a reading assignment than when performing an insight problem solving task.	Confirmed
H5b: The disruptive effects of smartphone alerts on the number of errors is bigger when performing a reading assignment than when performing an insight problem solving task.	Rejected
H6: There is a difference in overall experience depending on the task that must be performed.	Partially confirmed

The aim of this research was to identify the effects of the interruption frequency of smartphones alerts, the intrusiveness of the alerts and the type of task that must be performed on the task performance of University students (completion time and the number of errors). The findings show that these variables indeed influence the task performance of University students. Significant evidence has been

found that the frequency of the smartphone alerts, their intrusiveness and in which task these alerts are received have an effect on the task performance: the completion time and the number of errors.

Overall experience

With regards to the overall experience, it was hypothesized that there is a negative relationship between the interruption frequency and the overall experience, and that there is a negative relationship between the alert's intrusiveness and the overall experience as well. Looking at the results connected to the overall experience, H2 is partially supported. When the interruption frequency increases, only the amount of frustration significantly increases. Workload and anxiety are not influenced by interruption frequency. Following, a look has been taken at the relationship between the alert's intrusiveness and overall experience. As can be seen from the results, the intrusiveness of the alerts has no effect on perceived workload, frustration and anxiety. Therefore, H4 was rejected. Finally, it was hypothesized that the is a difference in the overall experience depending on the type of task. As can be seen from the outcomes, there is only a difference is the perceived amount of workload. The type of task does not affect the level of frustration or the level of anxiety. Because of the results, H6 was partially confirmed. The results might suggest that students are used to multitasking, since their levels of anxiety are not increased with more interruptions, more intrusive alerts or depending on the task they must perform.

Interruption frequency

It was hypothesized that the higher the frequency of the smartphone alerts, the lower the task performance of University students. The findings of this research show that the interruption's frequency indeed plays a significant role with regards to the task performance of University students. Interruption frequency was expected to influence task performance, since research has identified that the more interruptions a person experiences, the more disruption is caused when encoding information into memory which leads to more time to complete a task and more errors (Judd & Kennedy, 2011; Oulasvirta & Salovaara, 2004). Results show that when the interruption frequency increases, the completion time increases accordingly. This could be explained because students need to redirect their focus back from the smartphone to their task, which takes some time to do this effectively. Very surprisingly, when there is an increasing amount of interruptions, the number of errors do not increase, which is contradictory to previous research. When interpreting these contradictory results, a plausible explanation is that the interruption frequency is not accountable for more errors, because especially University students are used to being interrupted multiple times during the execution of a task, or that tasks presented to them were not complex enough and it is thus not very likely that students make mistakes. Because University students are so used to these interruptions, it might be the case that this group is very well-trained in task switching. Additionally, results have shown that when the interruption

frequency increases, the levels of frustration also increase, even though this effect does not lead to a longer completion time, neither to a higher number of errors. Furthermore, there is an effect of frequency on frustration, but a higher level of frustration does not lead to a decrease in task performance: we are so used to being interrupted, that we can cope with higher levels of frustration. When considering these results, H1a is confirmed, while H1b is rejected: there is an effect of interruption frequency on the completion time, but no effect was found on the number of errors.

Interruption's intrusiveness

According to the outcomes of the study, the interruption's intrusiveness has an influence on the task performance of University students. The research results point out that when the interruptions are intrusive (produce a loud noise), the number of errors that are made increase significantly. This means that the alert's signal indeed makes a difference in its disruptiveness. These findings are in line with the findings of Chang, and Tang (2015) and Quinones et al. (2008), who stated that auditory signals are perceived to be more intrusive and disruptive. When interpreting these findings, it is confirmed that the intrusiveness of signals affects the task performance of University students: the number of errors increase. Additionally, it does not make a difference whether the alerts are tactile or auditory when looking at the completion time. It was argued by Quinones et al. (2008) that intrusive alerts lead to a higher level of distraction and frustration. However, as seen in the outcomes of this study, a higher level of frustration does surprisingly not affect task performance. Furthermore, there is no significant effect of the alert's signal on the level of frustration. Summarizing these results, H3a is rejected, while H3b is confirmed: there is a significant effect of the interruption's intrusiveness on the number of errors, while there is no effect of the interruption's intrusiveness on the completion time. Adding this variable to the study, it contributes to the scarce knowledge of the effect of the alert's signal on student's task performance.

Type of task

The results of the study show that the task performance of University students is also influenced by the type of task they are performing. According to the results, when being interrupted while performing a reading assignment, the completion time severely increases. These findings are in line with the findings by McVay, and Kane (2012), who stated that reading assignments require more focus, so when being interrupted it takes some time to be able to continue with the assignment, which may take some time. Therefore, when executing a reading assignment, students are more prone to experience negative effects on task performance when being interrupted in the meantime. Surprisingly, the number of errors is not influenced by the type of task that is performed. Therefore, H5a is confirmed, while H5b

is rejected: there is a significant effect on the completion time, while there is no effect on the number of errors.

The results of the study show that there is a negative effect of smartphone alerts on task performance. Switching between smartphones and the initial task leads to a significant decrease in a person's task performance: it increases completion time and the number of errors. Therefore, it is argued that multitasking in a study environment has negative effects. As identified in this research, is does not matter how many times a person is interrupted, the alerts signal that is chosen and it does not matter what kind of task one is executing: the negative effects are still very visible on the task performance. Furthermore, it was proven that encoding information into memory (executing the task) was significantly more difficult when a person is interrupted by a smartphone, even though one may claim that he or she is able to multitask because one is used to it and will perform equally as good when not interrupted. In short: multitasking leads to a decrease in task performance.

5.1 Implications

Theoretical implications

This study supports the already existing studies in the field of interruptions and their effect on memory and performance, making the outcomes and the corresponding theories more valid and valuable. Additional knowledge in this field has been presented, which can lead to a better understanding of the effect of smartphone and task performance. Furthermore, this research is an example where the theory of several studies is combined with new research: adding new variables in this research. The variable "intrusiveness" and "type of task" have not yet been included in research to see their effect on the study related task performance of University students. The outcomes of this study can help the research of other scholars by notifying that interruption frequency, the interruption's intrusiveness and the type of task are proven to have negative effects on the task performance of University students. By adding intrusiveness and the type of task as new factors, the available research in this field is widened and deepened with regards to the alert's signal and its effect. To the best of my understanding, the factors used in this study were not researched before. Because of that, the outcomes of this research provide additional information to the already available information on the topic of smartphones and interruptions. Furthermore, these outcomes lead to directions for further research, which is elaborated on in the next chapter.

Practical implications

This research holds practical implications for marketers. Because of the negative effect of interruption frequency, intrusiveness of the alerts in different tasks, it would be a good idea to launch a campaign to create awareness of the negative effects of smartphones in the educational field. As we have seen in the recent campaign of the Dutch insurance company InterPolis, about the use of smartphones in traffic, creating awareness for divided attention between smartphones and driving has had a great impact on society. To create awareness about the negative effects of the use of smartphones in the educational field, a campaign similar to the InterPolis campaign could be launched. This way, the topic of interruptions and studying will gain more attention, and will hopefully lead to the recognition that using smartphones while studying has negative effect on task performance, it will teach us that full attention is needed to gain high grades and do well on performance tests.

Furthermore, this study holds implications for parents as well. Arguably, parents allow young children too much to use their phone and multitask when studying or doing homework. Parents may be unaware of the fact that using smartphones while doing homework decreases task performance. When multitasking becomes normal at such a young age, it can be problematic in the future. To change this multitasking behavior, parents have to be educated on the fact that studying and using smartphones has negative effects on their task performance.

5.2 Limitations and further research recommendations

Even though this study shows to have clear outcomes, the study included several limitations that should be addressed and can then be improved for further research.

The first limitation which should be addressed is the fact that the experiment did not take place in a laboratory setting. Students might have been distracted from other factors during the experiment, for example people walking by, lights turning on and off, or noises from outside. Because the experiment was conducted in the buildings on campus, not all distractions could be prevented. This could be ensured in a laboratory setting.

The second limitation that is worth to be addressed is related to the Fear Of Missing Out (FOMO). The Fear Of Missing Out is established when a person gets a lot of notifications from his or her friends' activities. One may get the feeling that they are missing out on the fun his or her friends are having. This feeling is induced by receiving social media related notifications. Therefore, alerts related to social media may enlarge the unfavourable effects of the interruption's frequency and intrusiveness. This research has not used manipulated social media notifications, but task related notifications. Therefore, it is not clear what the effect of social media related notification are on overall experience and task performance of University students.

After conducting this research, some recommendations for future research are proposed. The first recommendation is to explore the effect of interruption frequency, the interruption's intrusiveness and the type of task on the task performance of University students in a classroom setting. As Rosen et al. (2011) have argued, that in a classroom the problems of interruption might be strengthened. When a whole group is checking their phone constantly, you might feel the pressure to do the same because you don't want to miss out on the things that are going on. Therefore, it is interesting to find out whether the interruption frequency, the interruption's intrusiveness and the type of task have the same effects on task performance in a classroom setting.

Secondly, another study on the effect of interruption frequency, the interruption's intrusiveness and the type of task on the task performance of University students can be conducted with a bigger sample, preferably representing the population of all the University students in the Netherlands. This would yield more reliable results and make the results generalizable. Then, more knowledge is available which can be used to propose possible interventions.

Third, it would be interesting to conduct such research with different target groups. Relatively young people (ages ranging from 18-30) were part of this study. Because young people have a lot of knowledge on how to work with all kinds of technology (Carroll, Howard, Vetere, Peck, Murphy, 2002), they are more used to being interrupted by technology, especially smartphones. Therefore, it is interesting to see whether the results are the same for a target group with older people, who did not grow up with technologies such as smartphones. It might be the case that interruptions have a larger negative effect on the task performance of older people, because they are a lot less used to working with technologies, such as smartphones, but this should be further elaborated on.

The final future research proposition is to execute this study over a longer period of time. This could be done by giving the respondents a task to carry out, while interrupting them. After a month, these respondents have to answer a few questions about the task they have been given. Doing this, it can be identified whether the interruptions of the smartphone alerts have the same effect over time.

5.3 Solutions

Unfortunately, there are no clear solutions to stop students from switching between their phone and their study material. A possible solution could be to change the smartphone technologically. There are a lot of ways to prevent alerts from coming in. It could be a possibility to create a "study mode" on your smartphone. When this mode is activated, no notifications come in.

Another solution to stop students from switching between their smartphone and their study material is education. Parents of young children, as well as University students and employees must be more educated on the fact that studying and using smartphones simultaneously has negative effects on

task performance to create more awareness of these unfavorable effects. That way, children from a young age are aware of these negative effects and are stimulated to avoid interruption while studying or performing other cognitively demanding tasks.

6. Conclusion

The focus of this research pointed at identifying the effects of the frequency of smartphone alerts, the intrusiveness of these alerts and the effects of these alerts depending on the task that must be performed. Accordingly, the following research question was established:

"*What is the effect of smartphone alert's interruption frequency and the alert's intrusiveness on the task performance of University students and how does this effect differ depending on the type of task that has to be performed?*"

This study proved that there are main effects of the interruption frequency, the interruption's intrusiveness and the type of task that must be performed on the task performance of University students (completion time and number of errors). The frequency of the smartphone alerts leads to a decrease in completion time, the intrusiveness of the alerts lead to a higher amount of errors and the completion time is increased when being interrupted while performing a reading assignment. Previous research suggests that multitasking – or task switching – is impossible. Not totally surprisingly, this research adds to this by proving that switching between studying and smartphones indeed has a negative effect on the task performance of University students.

The results of this study can be very confusing to people who believe that students are very well able to multitask between studying and their smartphones. Results have confirmed that the number of interruptions, the interruption's intrusiveness and the type of task that must be performed have a negative effect on the task performance of University students, which is problematic. This is in line with other research on this topic that has claimed that multitasking – or task switching – is impossible.

Unfortunately, we cannot stop University students from multitasking and switching between studying and using their smartphones. To change this multitasking behavior, young children, as well as University students and employees must be more educated on the fact that studying and using smartphones simultaneously has negative effects on task performance to create more awareness of these unfavorable effects. That way, children from a young age are aware of these negative effects and are stimulated to avoid interruption while studying or performing other cognitively demanding tasks and consider the outcomes of this research.

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Appendix 1: demographic characteristics of the research sample

Demographic characteristics of the sample and distribution over the conditions

Demographic characteristic	Condition 1 N = 20	Condition 2 N = 20	Condition 3 N = 20	Condition 4 N = 20	Total N = 80	Total percentage
Male	14	12	13	13	52	65
Female	6	8	7	7	28	35
18	1	2	2	1	6	7.5
19	-	-	1	1	2	2.5
20	2	-	3	-	5	6.25
21	4	2	2	2	10	12.5
22	1	1	1	3	6	7.5
23	4	3	4	2	13	16.25
24	1	7	1	3	12	15
25	-	4	2	2	8	10
26	3	-	2	2	7	8.75
27	2	7	-	1	10	12.5
28	1	-	2	3	6	7.5
30	1	-	-	-	1	1.25
	Condition 5 N = 20	Condition 6 N = 20	Condition 7 N = 20	Condition 8 N = 20	Total N = 80	Total Percentage
Male	15	15	13	14	59	73.75
Female	5	5	7	6	21	26.25
18	-	1	1	-	2	2.5
19	-	2	2	2	6	7.5
20	2	-	1	-	3	3.75
21	1	5	3	5	14	17.5
22	3	1	-	1	5	6.25
23	4	2	4	4	14	17.5
24	4	4	-	2	10	12.5
25	2	1	3	3	9	11.25
26	1	2	3	3	9	11.25
27	1	1	1	-	3	3.75
28	2	1	-	-	3	3.75
30	-	-	2	-	2	2.5

Appendix 2: instructions for the problem solving task

Welcome! Thank you for participating in this experiment and helping me graduate!

First of all, please shut down your smartphone.

For this experiment, you will be completing a short task, which you will find when clicking ‘next’.

The researcher will leave the room during the experiment. She leaves a smartphone on the table, just in case she needs to contact you (because she will have to check on the progress of other participants as well).

Hence, you are asked to open the incoming message when you may receive one.

After you’ve completed the task and the quiz afterwards, you will find a questionnaire with regards to the task you’ve just completed. The data will be analyzed anonymously.

If there are any remaining questions, don’t hesitate to ask them now.

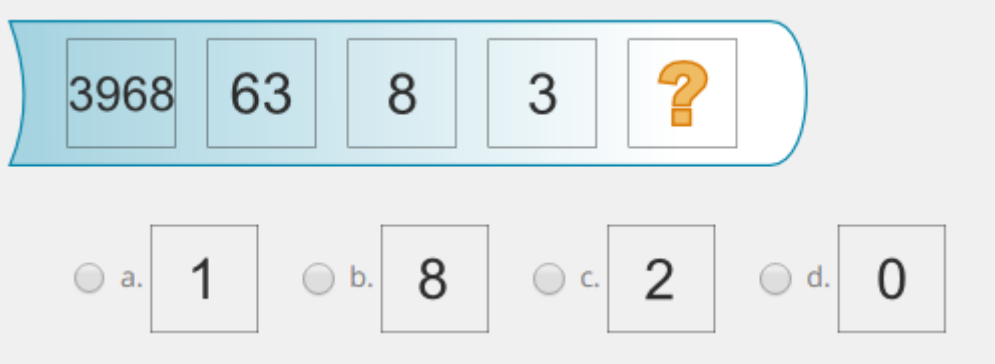
Thank you and good luck!

Appendix 3: problem-solving task

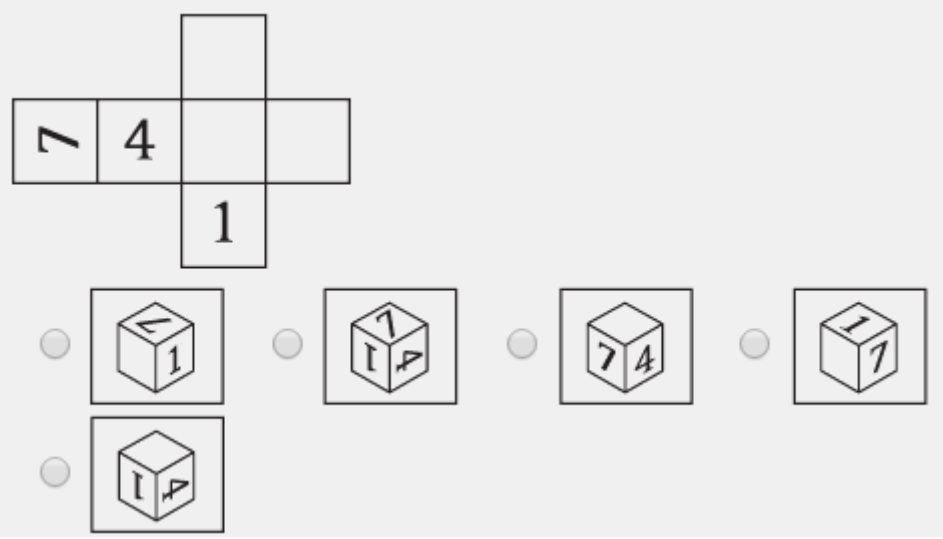
Please complete the following exercises.

1. What is the next image in line?

2. Look at this sequence of numbers. Now tell me, which number is next?



3. Take a look at the following image. What do you get when you fold the cube?



4. What is the correct answer to the next case.

Tom has a new set of golf clubs. With club number 8, he hits approximately 100 meters. With the number 7, he can hit up to 108 meters. With club number 6, Tom hits the ball 114 meters. How far can Tom hit the golf ball with club number 5?

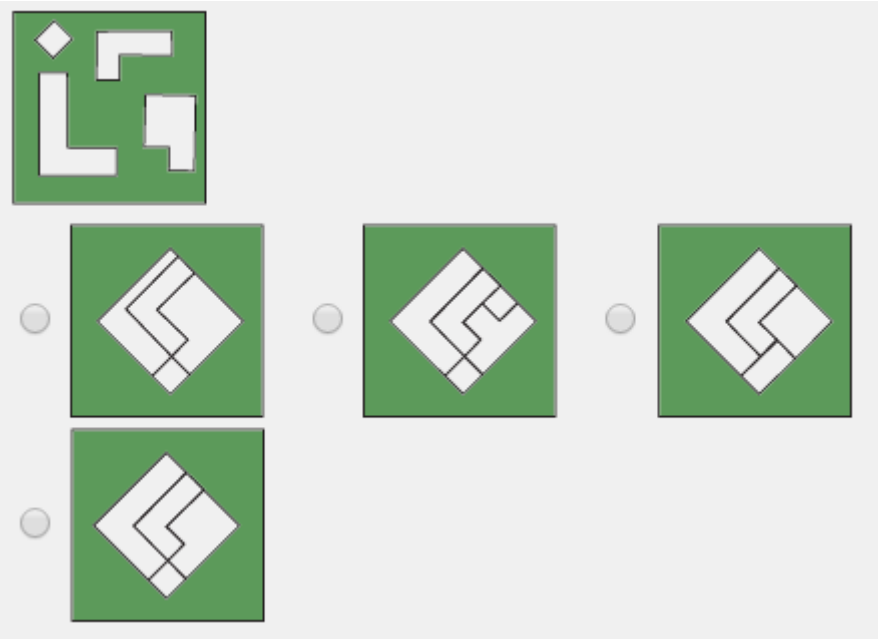
A) 122 meters

B) 120 meters

C) 118 meters

D) 116 meters

5. Look at the following figures. Which shape can be created when you put the puzzle pieces together?



6. Which word does not belong here?

A) Cow

B) Sheep

C) Pig

D) Goat

7. Which word does not belong here?

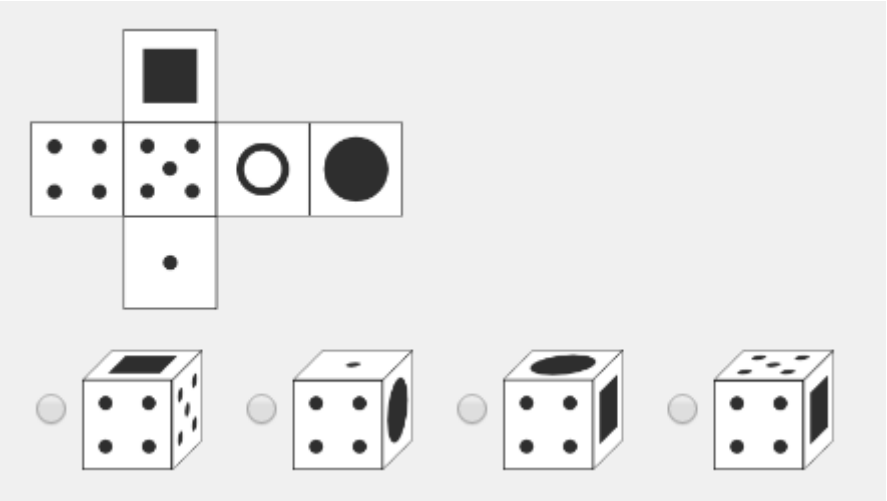
A) Telephone

B) Wheel

C) Antenna

D) Engine

8. Which cube can NOT be folded?



Appendix 4: instructions for the reading assignment

Welcome! Thank you for participating in this experiment and helping me graduate!

First of all, please shut down your smartphone.

For this experiment, you will be completing a short task, which you will find when clicking ‘next’. You will have to read this article called '**The hype about China’s newest city'.** After you've read the article, there will be a short quiz. Therefore, I would like to ask you to read the article very carefully.

The researcher will leave the room during the experiment. She leaves a smartphone on the table, just in case she needs to contact you (because she will have to check on the progress of other participants as well).

Hence, you are asked to open the incoming message when you may receive one.

After you’ve completed the task and the quiz afterwards, you will find a short questionnaire with regards to the task you’ve just completed. The data will be analyzed anonymously.

If there are any remaining questions, don’t hesitate to ask them now.

Thank you and good luck!

Appendix 5: the reading assignment

The hype about China's newest city
Faced with overcrowding in Beijing, China plans to build an annex

Until the start of this month, no one had ever heard of Xiongan. Today, it is the most talked-about place in China. When the government announced on April 1st that it would create "Xiongan New Area" as a metropolis from scratch, it immediately set off a frenzy. Housing prices in the zone, about 100km (62 miles) south-west of Beijing, more than tripled overnight before authorities ordered a halt to property transactions. Local hotels were booked up and roads packed with cars as prospective investors flocked to what is still largely farmland. The shares of companies such as local cement-makers and real-estate developers soared in value. State media extolled the promise of the city, touting it as a new chapter in China's urban development. What is all the fuss about?

The government's intention is to make Xiongan an annex of Beijing, to take pressure off the Chinese capital, which is struggling to cope with a population of more than 20m people. Beijing's traffic jams are horrendous, its subways overloaded and its water supply running low. In recent years planners have encouraged people to move away from the centre, to suburbs and nearby cities. The creation of Xiongan marks an escalation in these efforts: China wants to make it a model city, with a clean environment, fast transport and high-tech industries, to attract millions of people. The hope is that a big slice of Beijing's "non-capital functions", from businesses to universities, will move to Xiongan. Initially, it will cover 100 square km, nearly twice the size of Manhattan. Eventually, the aim is to reach 2000 square km, more than twice as big as New York city or Singapore.

There are no blueprints yet and details are hazy, but it is sure to entail a massive amount of investment. The three counties that will be converted into Xiongan are mainly made up of scrubby fields and drab towns. Analysts at UBS, a bank, reckon that as much as 4trn yuan ($580bn) could be spent on building Xiongan over the next two decades—hence the rally in construction-related shares. But punters might be getting ahead of themselves. Given the size of the Chinese economy, Xiongan will, even in the most bullish assessments, add less than half a percentage point to annual GDP growth while it is being built. And that is if all goes well. The government has pointed to Shenzhen, a southern metropolis, and Pudong, Shanghai's financial district, as examples of successful urban developments that it hopes to replicate. Yet there are also plenty of new areas—notably, Binhai in Tianjin, just east of Xiongan—that have failed to take root.

One problem that has plagued these urban projects is changes in government leadership. When they lose their sponsors, they often also lose their funding. Xiongan should fare better in this regard. It appears to have strong backing from Xi Jinping, China's powerful president who is on the cusp of another five-year term. The bigger concern is whether it will actually be a smart investment. Rather than creating a new city, it might be cheaper and more efficient to improve Beijing's design and infrastructure. More subway lines, denser neighbourhoods and better water conservation are all needed. Upgraded transport links to nearby cities would also help. But China has the political will and the financial muscle to start afresh and build a city from the ground up. Next stop: Xiongan.

The Economist (2017). The hype about China's Newest City. *The Economist Newspaper*

Questions regarding the article 'The hype about China's newest city'

1. What was the name of the new Chinese city the article is talking about?
a) Pudong
b) Xiongan
c) Xi Jinping
d) Tianjin

2. What is the <u>main</u> reason that this new Chinese city is being build?

a) Because China wants to have a city that is comparable to Singapore

b) It should become the new capital of China within five years

c) To take pressure of Beijing because of its growing population

d) It should become a model city with a clean environment and high-tech industries

3. How many districts are combined in the new Chinese city?

a) Three

b) Four

c) Two

d) Six

4. On which date did the Chinese government announce that there would be an new Chinese city?

a) April 1st

b) January 1st

c) January 31st

d) February 1st

5. Why is the change in government leadership an important factor in urban projects?

a) Because the president of China doesn't think this new city is the solution to the problem of the growing population in Beijing

b) Because when these urban projects lose their sponsors, they also lose their funding which makes the project impossible to complete

c) Because the GDP doesn't grow as fast in new cities

d) Because China secretly doesn't have the financial power to start urban projects

6. What is the biggest concern of this project of building a new city?

a) That the projects loses its funding and therefore will not be completed

b) The new city might become bigger than Beijing and will also be overpopulated in the future

c) No one wants to move away from Beijing to the new city

d) That it might be cheaper and more efficient to improve Beijing's design and infrastructure in order to be able to cope with the growing population

7. Analysts at the UBS bank have made an estimation of the amount that it will cost to build this new city. The estimated amount is …

a) $580 billion

b) $680 billion

c) $500 billion

d) $750 billion

8. What are some problems that Beijing faces due to the its overpopulation?

a) Traffic jams, overloaded subways and water supplies running low

b) Energy shortages, traffic jams and water supplies running low

c) Traffic jams, water supplies running low and financial muscle

d) Overloaded subways, low financial muscle and traffic jams

Appendix 6: the questionnaire

Thank you for filling out this survey! Please fill out this survey about your experiences during the experiment. This survey is treated anonymously.

This questionnaire will present you with some statements. I politely ask you to read these statements carefully and indicate your level of agreement with this statement on a 5 point scale, ranging from completely disagree to completely agree. Please fill them in as accurately as possible.

General evaluation of the task

I enjoyed the task I had to perform.
Completely disagree O O O O O completely agree

The task was easy to understand
Completely disagree O O O O O completely agree

The task was interesting
Completely disagree O O O O O completely agree

I would like to do the task again
Completely disagree O O O O O completely agree

I learnt something new from the task
Completely disagree O O O O O completely agree

Perceived level of frustration during the experiment

During the task, I felt …

Anxious
Completely disagree O O O O O completely agree

At ease
Completely disagree O O O O O completely agree

Calm
Completely disagree O O O O O completely agree

Frustrated
Completely disagree O O O O O completely agree

Tense
Completely disagree O O O O O completely agree

Annoyed
Completely disagree O O O O O completely agree

Impatient
Completely disagree O O O O O completely agree

Irritated

Completely disagree O O O O O completely agree

I noticed that I was very frustrated by the smartphone alerts

Completely disagree O O O O O completely agree

The smartphone alerts were <u>not</u> annoying to me

Completely disagree O O O O O completely agree

It was hard to focus on the task because of the smartphone alerts

Completely disagree O O O O O completely agree

It was easy for me to concentrate during the task despite the smartphone alerts

Completely disagree O O O O O completely agree

<u>Perceived level of anxiety during the task</u>

During the task I felt …

Worried

Completely disagree O O O O O completely agree

Afraid

Completely disagree O O O O O completely agree

Scared

Completely disagree O O O O O completely agree

Concerned

Completely disagree O O O O O completely agree

I felt relieved when the task was over

Completely disagree O O O O O completely agree

<u>Perceived workload</u>

The task was too demanding

Completely disagree O O O O O completely agree

The task required a lot of mental focus

Completely disagree O O O O O completely agree

The task required a lot of thinking effort

Completely disagree O O O O O completely agree

Interruption frequency

I was interrupted a lot by the smartphone alerts

Completely disagree O O O O O completely agree

The amount of smartphone alerts affected my focus negatively

Completely disagree O O O O O completely agree

The amount of smartphone alerts made me feel frustrated

Completely disagree O O O O O completely agree

I was interrupted by the smartphone alerts so much, that is was hard to focus until the end

Completely disagree O O O O O completely agree

It was easy to gain back my focus after I was interrupted by the smartphone

Completely disagree O O O O O completely agree

Interruption intrusiveness

The signal of the smartphone alerts were very bothersome

Completely disagree O O O O O completely agree

I had trouble concentrating because of the alert's signal

Completely disagree O O O O O completely agree

The signal negatively affected my focus

Completely disagree O O O O O completely agree

The alert's signal frustrated me

Completely disagree O O O O O completely agree

Level of self-control

In general …

I am easily distracted

Completely disagree O O O O O completely agree

I consider my actions very carefully

Completely disagree O O O O O completely agree

I am able to critically evaluate the outcome of my actions

Completely disagree O O O O O completely agree

The last part of this questionnaire consists of some demographical questions.

What is your gender?

O Male
O Female

What is your age?

____