Sensitivity to push notifications at problematic smartphone users using ERP

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ABSTRACT

A Smartphone is an advanced mobile device used throughout the world. Smartphones have become an essential device for managing work, study, and relationships. However, smartphone overuse is a rapidly emerging social issue. Most previous studies regarding smartphone overuse have entailed surveys or behavioral observation studies. In this study, we used ERP to investigate differences between individuals who demonstrate problematic smartphone use and those who demonstrate general smartphones use. ERP and Go/No-go tasks were used to objectively measure the influence of push notifications on task performance. Subsequently, a difference in ERP was observed between the two groups. Especially, both groups demonstrated a greater latency and lower amplitude in N200 with regard to the effects of push notification during tasks. The Non-risk group experienced no significant effect on task performance with exposure to push notifications before the task, whereas the Risk group demonstrated effects on task performance under the same conditions.

Author Keywords

Event-related potentials (ERP); N200; P300; smartphone; push notification; addiction;

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; K.4.2.Social Issues; J.3.Life and Medical Sciences, Health, Medical Information Systems;

INTRODUCTION

A smartphone refers to a smart device that features various user-friendly functions, including internet, camera, games, banking, navigation, and even health management applications that surpass the communication-based functions of conventional cellphones. In 2015, smartphone distribution ratings reached 90.8% in the United Arab Emirates, 87.7% in Singapore, 86.1% in Saudi Arabia, and 83% in South Korea, indicating a rapid worldwide increase in recent years. Able to quickly provide users with various types of information and enable access to seemingly boundless content, smartphones are renowned for their ability to access anything, at anytime and anywhere [8] . Thus, smartphones have become well established as tools of convenience. However, the phenomenon of smartphone addiction has emerged as a significant social issue in recent years, interfering with daily life due to excessive and/or inappropriate use [1]. Smartphone problematic usage refers to a behavioral addiction in which an individual uses content such as SNS, internet browsing, and mobile games for an excessive amount of time, such that it interferes with daily life. This is inherently similar to Internet addiction. The excessive use of smartphones negatively affects users in a number of ways, including psychological disorders (e.g. sleep disorders, attention deficit disorder) and physical disabilities (e.g. carpal tunnel syndrome, and forward head posture etc.) [5, 9]. Kim et al. [7] investigated the influence of push notifications from SNS, multimedia message services (MMS), or applications (apps) as a contributing factor to the excessive use of smartphones. In the present study, a push notification refers to an auditory or tactile alarm used to provide users with information regarding the status of applications or to notify the user of incoming data. While the major advantage of push notifications is that data can be instantly delivered, information is typically provided regardless of the users need, and is often superfluous in nature. Indeed, Kim et al. [7] reported that the duration and frequency of smartphone use increased with the frequency of push notifications, concomitant with an increased risk of smartphone addiction. However, since most studies regarding smartphone problematic usage have been conducted based on questionnaire-based surveys or behavioral observations [5, 6], these results rely on the opinions and perspective of the subject, and therefore might be unreliable or biased. As a function of this, the current study used electroencephalography (EEG) as an objective measurement tool, to minimize the influence of subjective bias. EEG is widely used in behavioral research, as it provides a high temporal resolution of neural processing events related to behavior[10]. The event-related potential (ERP) components N200 and P300 were analyzed in order to study EEG responses to a specific stimulus. ERPs measured in Go/Nogo tasks reveal differences consisting of a negative displacement (N200) and a subsequent positivity (P300) in Nogo ERP as compared to Go ERP[2, 4].P300 refers to a positive peak detectable in the interval between 300-350 ms after the presentation of auditory stimuli and between 350-450 ms after presentation of visual stimuli. The maximum amplitude appears at the parietal electrode sites, and as a component of ERP, it is considered an important index for the study of information processing in the brain with regard to cognitive psychology [12, 14]. Comparatively, N200 refers to a stimulus-induced negative peak observed in the interval between 250-400 ms (or 180-325ms) after stimulus onset. N200 is largest in the frontal and central regions, and is divided into the following three components: N2a, N2b, and N2c. N2a does not require direct concentration on the stimulus, and does not appear in conjunction with the P3 component. By contrast, N2b and N2c require concentration on the stimulus, and occur with P3a and P3b, respectively [11]. These factors reflect cognitive functions, including allocation of attention and concentration [3] . A short latency in this context refers to superior cognitive ability, while a higher amplitude refers to a higher level of concentration. Therefore, by evaluating the amplitude and latency of N200 and P300, the present study aimed to study the influence of push notifications on attention and cognitive abilities in smartphone risk and non-risk groups during task performance.

METHODS

Subjects

Participants were recruited using guidance for a study that aimed to analyze EEG variation according to the colorfulness of a video, a step taken to ensure that subjects were blind to the nature of the study. A pre-survey was conducted using questions from the smartphone problematic usage scale (hereafter referred to as the S scale) developed by the Korean National Information Society Agency in 2011 [13]. Subjects received an explanation regarding the content of the study, excluding exposure to push notifications, and instructions about filling in a consent form prior to the experiment. Data from 14 subjects was included in the experimental analysis, with six participants placed the risk group (male, three, female, three; mean age, 22 years) and eight in the non-risk group (male, three; female, five; mean age 22.6 years).

Experiment Procedure

EEG caps were used to record brainwaves during the experiment. The same Go/No-go task (approximately 18 min) was performed in Tasks 1 and 2, and a push notification was delivered twice while performing Task 1. Vibration push notifications were used for all subjects in order to prevent variations in responding based on notification sound. The first push notification (hereafter referred to as PN1) was applied during performance of the Go/No-go task in Session 1, and the second push notification (hereafter, PN2) was presented during the rest time before starting the Go/No-go task in Session 3 (Figure 1). Push notifications were delivered using an experimental device. The device was placed behind the subjects so that they were clearly able to recognize the push notification, but were unable to check it. Subjects watched a video during the rest between the first and the second tasks. A push notification was not applied during the second task so data could be recorded for use as a control (hereafter, PN3). In all experiments, subjects performed the tasks in a separate space with an illumination intensity of zero, to enable them to focus on the task.

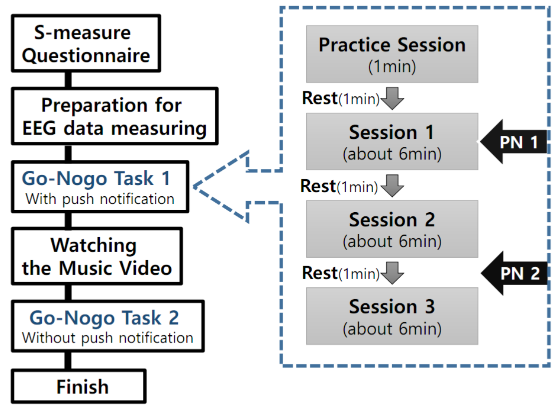

Figure 1. Experimental Procedure

Go/No-go Task

We conducted simple and easy Go-Nogo task to minimize the differences between subjects caused by difficulty level of the task and to reduce contamination of the results from smartphone push notifications. Various figures appeared in the center of a screen with a white background, (Figure 2), and trials were designed so that subjects pressed number 1 when the color of the figure was yellow, and pressed nothing when it was green. The length of stimulus presentation was set to 150 ms, and each session was composed of 186 trials, with 148 go trials and 38 no-go trials. Subjects were allowed 1 min of practice prior to the main trial, which was composed of three sessions. Each session was performed for 6 min, with a 1 min rest between sessions. Therefore, the task duration lasted approximately 18 min.

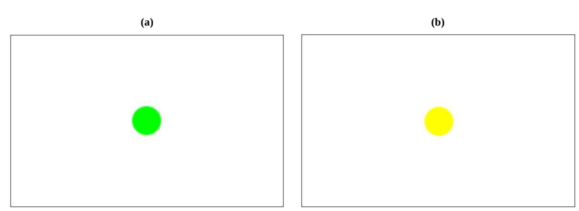

Figure 2. Go/No-go Task: (a) Example of Go Task; (b) Example of No-go Task

RESULTS AND DISCUSSION

Subjects in the present study performed tasks composed of repeated trials to investigate the influence of push notifications on task performance with regard to a risk group for smartphone addiction, and a non-risk group. We reported trends in the data because our sample size is small for statistical analysis. Analysis of the N200 component of the ERP indicated that the risk group demonstrated lower amplitudes and longer latencies during the Go/No-go task than the non-risk group. Push notifications received during the task caused a reduction in concentration and cognitive abilities, and produced a lasting effect on the PN2 and PN3 sessions. The concentration and cognitive function of the non-risk group also declined in response to push notification delivery during the task, but unlike the risk group, the following PN2 and PN3 sessions were not significantly affected. The reactions of the non-risk group to push notifications were transient, unlike those of the risk group, suggesting altered cognitive function between the two groups. Analysis of the P300 component indicated that the risk group was more affected by push notifications than the non-risk group, though no distinct trend was detected. In general, push notifications received during task performance affected both the risk group and the non-risk group, wherein the risk group exhibited a longer duration of cognitive impairment than the non-risk group. Analysis of Go/No-go task performance demonstrated higher error rates and shorter reaction times in all sessions for the risk group compared with the non-risk group. Accordingly, the non-risk group featured no significant difference between sessions, while the risk group demonstrated the highest error rate and the shortest reaction time at PN1. This suggests that, while push notifications produced no significant effect on task performance in the non-risk group, push notifications caused significant changes in the performance of the risk group. However, while N200 and P300 were evaluated under the same conditions in the present study, no consistent data was obtained for P300. The N200 component reflects a response to No-go trials in the Go/No-go task. As a function of this, the difficulty in obtaining P300 data might have arisen due to the experimental design, where the aim of presenting natural push notifications to the subject did not provide a strong enough stimulus to induce a clear decline in cognitive ability, the factor represented by P300. In addition, the present study replicated the same Go/No-go task in all sessions to create an experimental environment in which only the push notifications were not controlled. However, it will be necessary to adjust the composition of the task, taking into account the fact that task performance improves with repetition. Figure 3 is a detailed results of ERP and Figure 4 is a detailed results of Go/No-go Task.

CONCLUSIONS AND FUTURE WORKS

While smartphone problematic usage has been predominantly studied through surveys and behavioral pattern analysis, the present study aimed to investigate this phenomenon using ERPs as an objective measure. The influence of smartphone push notifications on task performance were investigated according to the risk of smartphone problematic usage. Our findings demonstrated that individuals in the smartphone risk group and the non-risk group demonstrated sensitive reactions to smartphone push notifications during tasks. While the performance of the non-risk group on subsequent tasks was not significantly affected by push notifications, these sig-

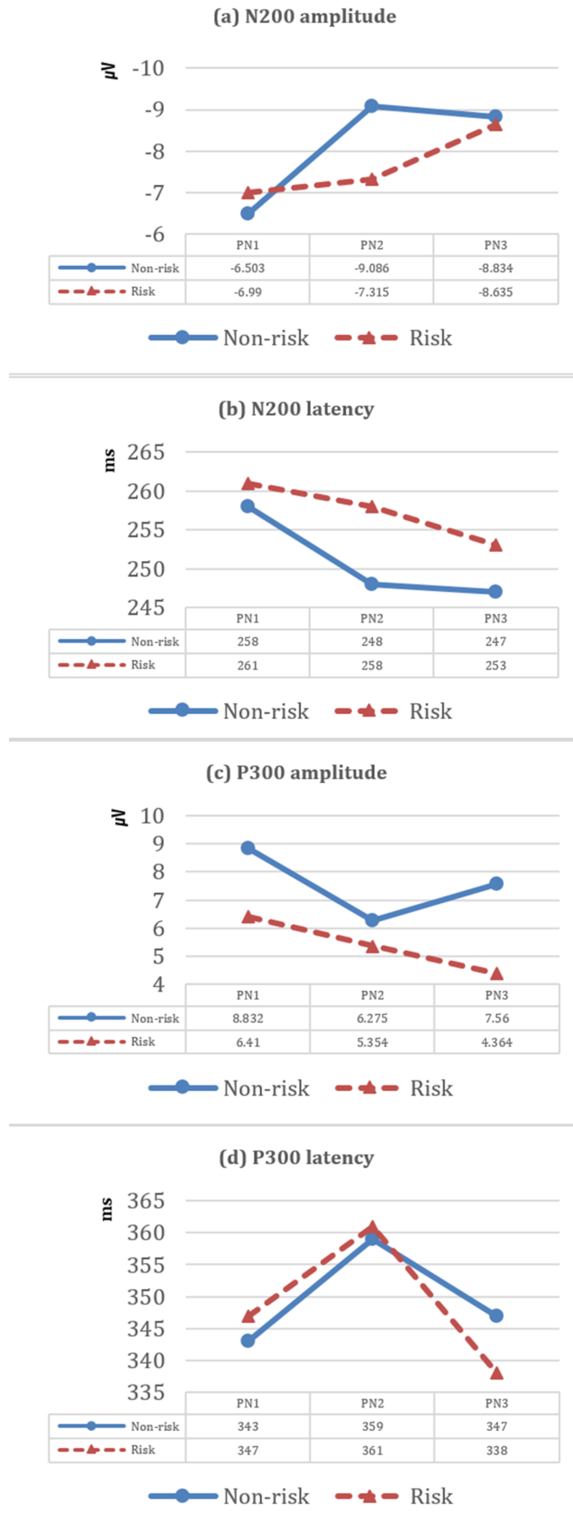

Figure 3. The results of ERP: (a) The amplitude of N200; (b) The latency of N200; (c) The amplitude of P300; (d) The latency of P300

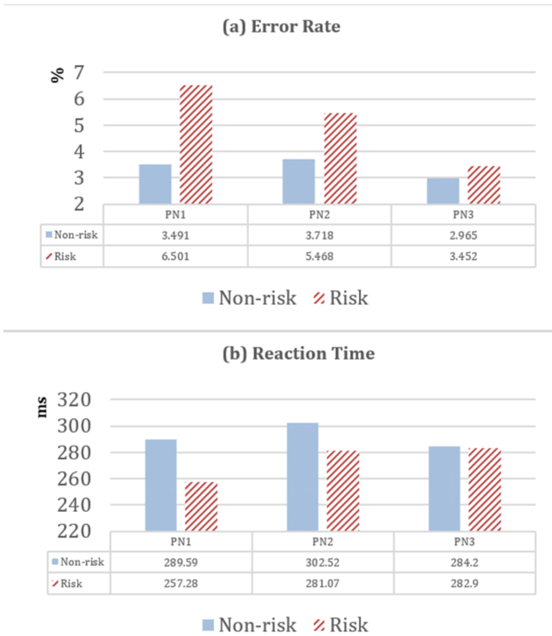

Figure 4. The results of Go/No-go task: (a) The result of error rate; (b) The result of reaction time

nificantly affected performance on subsequent tasks in the risk group. The present study utilized ERPs to demonstrate that smartphone push notifications are associated with a significant decline in task performance in individuals at risk of smartphone addiction. The decline in task performance negatively affected both cognitive function and concentration. Future research, might further evaluate the behavioral effects of smartphone problematic usage, particularly with regard to the influence of push notifications. While the present study used a single type of push notification, future studies using various types will be required to investigate sensitivity and/or bias to different push notifications. In addition, we assess the situation of the subjects through a preliminary research and focus on the real and individual push notification. Moreover, our findings present another aspect of the negative impact of smartphones on social behavior and cognitive function. Excessive smartphone use influences a variety of cognitive mechanisms, posing a threat to both social functioning and productivity. Therefore, the present study provides evidence to underline the impact of smartphone problematic usage on both mental health and interpersonal relationships, an issue that requires further research.

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