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Time distortion associated with smartphone addiction: Identifying smartphone addiction via a mobile application (App)

Yu-Hsuan Lin [a, b], Yu-Cheng Lin [a, b], Yang-Han Lee [d], Po-Hsien Lin [e], Sheng-Hsuan Lin [f], Li-Ren Chang [g], Hsien-Wei Tseng [d, h], Liang-Yu Yen [d], Cheryl C.H. Yang [a, b, c], Terry B.J. Kuo [a, b, c, i, *]

[a] Institute of Brain Science, National Yang-Ming University, Taipei, Taiwan
[b] Sleep Research Center, National Yang-Ming University, Taipei, Taiwan
[c] Brain Research Center, National Yang-Ming University, Taipei, Taiwan
[d] Department and Graduate School of Electrical Engineering, Tamkang University Hospital, New Taipei City, Taiwan
[e] Department of Psychiatry, Koo Foundation Sun Yat-Sen Cancer Center, New Taipei City, Taiwan
[f] Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA
[g] Department of Psychiatry, National Taiwan University, College of Medicine, Taipei, Taiwan
[h] Department of Computer and Communication Engineering, De-Lin Institution of Technology, New Taipei City, Taiwan
[i] Institute of Translational and Interdisciplinary Medicine, National Central University, Taoyuan, Taiwan

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ABSTRACT

Background: Global smartphone penetration has brought about unprecedented addictive behaviors.
Aims: We report a proposed diagnostic criteria and the designing of a mobile application (App) to identify smartphone addiction.
Method: We used a novel empirical mode decomposition (EMD) to delineate the trend in smartphone use over one month.
Results: The daily use count and the trend of this frequency are associated with smartphone addiction. We quantify excessive use by daily use duration and frequency, as well as the relationship between the tolerance symptoms and the trend for the median duration of a use epoch. The psychiatrists' assisted self-reporting use time is significant lower than and the recorded total smartphone use time via the App and the degree of underestimation was positively correlated with actual smartphone use.
Conclusions: Our study suggests the identification of smartphone addiction by diagnostic interview and via the App-generated parameters with EMD analysis.

1. Introduction

The excessive use of smartphones has emerged as a significant worldwide social issue as smartphone penetration has increased. Smartphone addiction consists of four components, tolerance, withdrawal, compulsive symptoms, and functional impairment in our previous factor analysis of Smartphone Addiction Inventory (Lin et al., 2014), which are all variants on aspects of Internet addiction (Block, 2008); this is because a main characteristic of the smartphone is the use of Internet-based applications. However, the portability of the smartphone distinguishes smartphone use from "traditional" Internet use via a computer and this results in different symptoms for smartphone addiction and internet addiction (Lin et al., 2014). It is accepted that a significant degree of time distortion is one of the addictive properties of internet use (Greenfield, 1999) and based on this, side information of an individual's smartphone use is necessary when carrying out a clinical assessment. However, frequent short-period smartphone use is very hard to estimate according to the reports of others. Thus a mobile application (App) that automatically detects smartphone use is likely to improve the accuracy of any assessment of smartphone addiction. On the other hand, two core symptoms of addiction, compulsion and tolerance, which are manifest as an increase in smartphone use, are based on the use time estimation. However, fluctuations in smartphone use usually consist of

* Corresponding author. Institute of Brain Science, National Yang-Ming University, No. 155, Sec. 2, Li-Nong St., Beitou, Taipei 11221, Taiwan. Tel.: +886 2 28267058; fax: +886 2 28273123.
E-mail address: cchyang@ym.edu.tw (T.B.J. Kuo).

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multiple periodic components, and may increase in a non-stationary and/or non-linearly manner. Empirical mode decomposition (EMD) analysis using the Hilbert Huang Transformation provides an adaptive algorithm that is able to decompose a complex time series of smartphone use into a set of intrinsic oscillations, which are called intrinsic mode functions (IMFs); these oscillate at different time scales and are orthogonal to each other (Huang et al., 1998; Wu et al., 2007). The aims of this study are: firstly, to develop and validate proposed diagnostic criteria for smartphone addiction based on interviews by psychiatrists; second, to examine the relationship between smartphone addiction and the parameters generated by the App using novel EMD analysis, as well as two other criteria relevant to time estimation, excessive use and tolerance; and thirdly, to test the differences between actual and self-aware smartphone use time. We hypothesize that time distortion, which has been explored with online game players (Rau et al., 2006), will play an important role, not only in the underestimation of smartphone use, but also will affect reliability and validity when identifying smartphone addiction.

2. Methods

2.1. Participants

In total, 79 young adults were recruited from the Department of Electrical Engineering and Department of Computer and Communication Engineering of two universities in Northern Taiwan between December 2013 and May 2014. The recruitment strategy was based on the potential higher penetration rate of smartphone use among these students. Of these, 57 were male and 22 were female, with a mean age of 22.4 ± 2.3 years. All participants in this study used a smartphone with an Android operation system. They installed a novel App on their smartphones that recorded their smartphone use for at least three weeks. After the researchers had checked the App data, the participants were interviewed by the psychiatrist. The study was approved by the Institutional Review Board of National Taiwan University Hospital. The investigation was carried out in accordance with the latest version of the Declaration of Helsinki.

2.2. Procedures

First, we propose diagnostic criteria for smartphone addiction. The psychiatrists' diagnostic interview validated each candidate criterion of smartphone addiction by their clinical global impression (CGI). The sensitivity, specificity, and diagnostic accuracy of candidate diagnostic criteria were evaluated between the CGI-positive and CGI-negative groups. The diagnostic accuracy indicated the percentage of all correct decisions, which is the result of dividing the number of true positives and true negatives by the number of all decisions. The candidate diagnostic criteria with low diagnostic accuracy were excluded from further analyses. The cutoff point of the diagnostic criteria to differentiate the smartphone-addictive subjects with non-addictive ones was then determined by the best diagnostic accuracy and the receiver operating characteristic curve (ROC). Finally, the diagnostic criteria for smartphone addiction were constructed. Thus, the participants were classified as smartphone addicts or non-addicts based on the criteria.

Next, we examined the relationship between smartphone addiction and the App-generated parameters. The “smartphone addiction” determined by the criteria was a binary variable, whereas the App-generated parameters were continuous variables. We used the ROC analysis to identify which App-generated parameters can predict the smartphone addiction. Similarly, we examined which App-generated parameters can predict two criteria relevant to time estimation, tolerance (criterion 3) and excessive use (criterion 7). We demonstrated the differences between actual and self-aware smartphone use time in order to interpret the role of underestimation in the diagnosis of smartphone addiction.

2.3. Diagnostic criteria for smartphone addiction

We developed twelve candidate diagnostic criteria to identify the characteristic symptoms of smartphone addiction based on the Diagnostic Criteria of Internet Addiction for College Students (DC-IA-C) (Ko et al., 2005, 2009) and on the research diagnostic criteria of Internet gaming disorder in Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, 2013). Three qualified psychiatrists, Lin YH, Lin PH and Chang LR, experienced in substance-related disorder and Internet addiction made a CGI with respect to the existence of smartphone addiction according to their clinical experiences and the concepts of addiction proposed by West (2001). The inter-rater reliability was evaluated by the Fleiss-kappa approach. Next, the sensitivity, specificity, and diagnostic accuracy of the twelve candidate diagnostic criteria for smartphone addiction were evaluated between the CGI-positive and CGI-negative groups.

2.4. Designing the mobile application (App) for recording smartphone use

A smartphone addiction App was designed and implemented for the Android operating system and after this App is implemented on a smartphone it operates in the background without interrupting normal smartphone communication. The App records all smartphone behaviors such as power on, call in, call out, program on, clock alarm, screen on/off notification, etc. The App saves all recorded behavior data in a log file. Using the MATLAB program the log file data was analyzed and debugged and only the screen-on and screen-off behavior data was saved after the MATLAB operation. An epoch starts from screen on and ends at screen off. The daily use count (frequency) and the total daily time spent on the smartphone (duration) are obtained from the data. We then calculated the median of the duration per epoch, rather than the mean of the duration per epoch every day; this is because the duration of the epoch does not present as a normal distribution (Fig. 1). The deployment of the App lasted for at least three weeks and we validated the fact that the App did not have a significant impact on the battery life of the participant phones. All the participants were blinded to the locally stored records in order to decrease the effects of “biofeedback”, which might result in self-recognition and control. Instead, the usage records were archived at the server database. The three psychiatrists were also blinded to the App records to avoid confounding the clinical global impression.

2.5. Empirical mode decomposition (EMD) and the trend in smartphone use

A powerful data analysis method for nonlinear and non-stationary data has been developed by Huang et al. (1998). This technique, known as the Hilbert–Huang Transform (HHT), is based on empirical mode decomposition (EMD) and the Hilbert Transformation. Unlike Fourier-based time series analysis, EMD holds no a priori assumption as to the underlying structures of the time series and is therefore suitable for analyzing time series that consist of multiple periodic components. The decomposition is based on the simple assumption that any data consist of a finite number of

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