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MEASURING SMARTPHONE USAGE TIME IS NOT SUFFICIENT TO PREDICT SMARTPHONE ADDICTION

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ABSTRACT

Usage time is a major criterion to determine whether a user is addicted to their smartphone, and many smartphone apps aiming to decrease smartphone addiction have been developed with this criterion in mind. However, this rule of thumb is based on an incorrect assumption that develops from studies on internet addiction. Our study tests how applicable this rule truly is, through correlation and discriminant analysis on smartphone usage patterns. Using a self-diagnosis scale for smartphone addiction (S scale for short) and smartphone usage tracker, we collected S scale scores and smartphone usage patterns from 195 undergraduate participants. The statistical results indicate that 1) smartphone addiction is highly correlated with communication but not entertainment and 2) solely measuring the total usage time is not enough to predict whether a smartphone user is addicted. Our results imply that additional measures to capture richer information on smartphone-related activities are necessary for developing anti-addiction apps.

Keywords: *Smartphone addiction, Smartphone usage time, Smartphone usage pattern, Fisher's linear discriminant analysis, Communication*

1. INTRODUCTION

Technology overtakes our daily lives if we lose our control over it. Many people get anxious if they cannot use their phone, even if only for a few minutes. In Korea, it is reported that 16.2% of total smartphone users are addicts; this number is rapidly increasing, even as the number of internet addicts is declining [1]. Often, it is treated the same as internet addiction and considered to be caused by "over-involvement with a game" [2],[3]. Even though smartphone addiction has become a major threat to our mental health, little progress has been made in understanding this addiction.

Smartphone addiction is generally understood as a dependence syndrome that shows various problematic behaviors or clinical disorders in daily life [4]. It comprises of a wide spectrum of problematic behaviors that ranges from excessive texting [5] to social isolation [6] or social anxiety [7]. That is, it has many facets of problematic behaviors not only at the personal and social levels but also those at the levels of technology dependency [4] and clinical disorders [8]. On the basis of these conceptualizations and perspectives, smartphone addiction scales have been developed to measure problematic behaviors and psychological attitudes associated with technology dependency and its clinical consequence.

It seems that there are clearly distinctive approaches in the measurement of smartphone addiction – questionnaire-based scale [9] and smartphone app tracker [10]. A smartphone addiction questionnaire is generally designed to measure daily life disturbance, withdrawal, tolerance, and virtual world orientation characteristics as main factors of the smartphone addiction diagnostic scale [11]. Meanwhile, anti-smartphone addiction apps incorporate tracking features such as the total amount of data consumption or usage time [12]. Those apps track a user's usage of a device and allow him/her to set daily limits; the app notifies the user if the device is overused.

Most studies on smartphone addiction methodologically rely on surveys [13],[14],[15]. To conduct such a survey is cumbersome: it requires a series of activities such as distributing and collecting questionnaires and evaluating users' attitudes. In addition, users' responses rely on their subjective recall and do not sufficiently capture their actual smartphone-related behaviors. Even though the smartphone app tracker precisely

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quantifies the amounts of smartphone usage and easily obtains the statistics of the smartphone usage patterns, the studies based on the app trackers simply show a general tendency of smartphone usage patterns. These two methodological approaches are independently used in their academic areas. It is not clearly understood how the surveys' measure of smartphone addiction is related to smartphone usage.

A few researchers have attempted to analyze smartphone addiction in terms of smartphone usage—data they obtained from log files—and establish a relationship between smartphone inventory and usage behaviors [16],[17]. However, these experiments had an extremely small sample size [16] and focused on uncovering a correlative relationship, not classification or regression.

Based on the issues raised above, this paper investigates smartphone addiction with regards to smartphone usage patterns obtained from real smartphone users via a smartphone usage tracker app. This study aims to discover the relationship between smartphone addiction diagnostic scale (S scale) and smartphone usage patterns, to characterize smartphone addiction in terms of categorical usage patterns of smartphone, and to discriminate smartphone addicts from non-addicts using Fisher's linear discriminant analysis.

2. METHODS

2.1 Participants

A total of 195 undergraduate and graduate students participated in the experiment. Participants were aged from 18 years to 30 years. 124 participants were males and remaining 71 were females. The participants were recruited through the web posting services of the university where the authors belong to. Only participants who owned an Android smartphone were selected, since the smartphone application we used to collect usage patterns only works on the Android platform. Participants were paid 10,000 Korean won (approximately 9.5 USD) upon completion of the smartphone usage data collection and subsequent survey. All participants provided written informed consent prior to the study.

2.2 Apparatus

2.2.1 Smartphone usage tracker

A smartphone app called "Smartphone Usage Tracker" was used to collect users' smartphone usage patterns [18]. It is a free app that can be obtained in Google Play. This app monitors the usage time of each individual app and averages them to get total usage time per day. It can graphically show how much time is spent on your smartphone and can also allow users to send the averaged usage data through e-mail.

2.2.2 Smartphone addiction self-diagnosis scale

We used a modified version of smartphone addiction self-diagnosis scale (called "S scale"), originally developed by the National Information Society Agency [19], to measure smartphone addiction. This scale divides users into three groups—highly risky users (addicted users in this study), tentatively risky users (risky users in this study) and normal users—on the basis of their measured score. The scale is composed of 15 questions that are classified into 4 sub-categories: disturbance of adaptive functions, virtual life orientation, withdrawal, and tolerance. Each question is rated according to a 4-point scale. For instance, some examples of the questions in the sub-categories are given below:

- Disturbance of adaptive functions: My school grades (or work productivity) dropped due to excessive internet use.
- Virtual life orientation: Using a smartphone is more enjoyable than spending time with family or friends.
- Withdrawal: I get restless and nervous when I am without a smartphone.
- Tolerance: Spending a lot of time on my smartphone has become a habit.

2.3 Procedure

The experiment was composed of two procedure steps. First, participants were asked to install the smartphone usage tracker app on their phone. They were instructed not to delete this application for at least 15 days and to send their average smartphone usage patterns to a researcher via e-mail. Second, after a few days, the participants were asked to fill out the S scale survey. A series of statistical analyses were carried out on the data collected using both smartphone usage patterns and the S scale.

3. RESULTS

Two statistical analyses were carried out to investigate the correlative relationships between smartphone app usage patterns and S scale score, and also between categorical app usage patterns and S scale score. We attempted to differentiate between smartphone addicts and normal users

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utilizing only the patterns of smartphone usage.

3.1 S Scale Scores of 3 Groups – Normal, Risky and Addicted

The S scale scores of participants were collected using S scale questionnaires composed of 15 questions. The result of the score is presented in Table 1. The participants were divided into 3 groups – normal, risky and addicted groups. The lower 67.7% of the participants, whose S scale scores ranged from 6 to 29, is classified into the normal groups, the 18.5% of participants, whose S scale scores ranged from 29 to 33, placed between the normal and addicted groups is classified into the risky groups, and the higher 13.8% of the participants, whose S scale scores ranged from 34 to 44, is assigned to the addicted group. The mean of S score for the normal group is 22.56 (SD = 5.05), the mean of S score for the risky group is 31.13 (SD = 1.19) and the mean of S score for the addicted group is 36.87 (SD = 2.70).

This grouping is a little bit arbitrary. Since the smartphone addiction is measured along the S scales score, it is hard to say there is a clear cut between normal and addicted groups. We simply considered the upper 18.5% of participants as smartphone addicts and remaining 81.5 % of participants is considered as either normal or risky group.

Table 1: The means of S Scale Score for 3 participant groups – Normal, Risky and Addicted Groups – placed with Their Number of Cases, Proportions, Means and Standard Deviations (SD)

Group	N	Proportion	Mean	SD
Normal	132	67.7%	22.56	5.05
Risky	36	18.5%	31.13	1.19
Addicted	27	13.8%	36.87	2.70

3.2 Smartphone Application Usage Pattern

Fig. 1 presents a histogram of the most-used 13 apps, compiled using the collected smartphone usage data through the smartphone usage tracker app. The mean of smartphone app usage time is 182.06 minutes per day. The figure places messenger (52.98 min), web browsers (40.01 min), SNS (22.91 min), games (17.78 min), video (15.88 min), and web toon/web novel (14.85 min) in descending order from left to right.

Actually, the participants reported that they installed much more apps than those daily used in their smartphone. That is, a few of installed apps are dominantly used. As shown in Figure 1, the participants spend most of their time to use a messenger, web browser, SNS and smartphone game.

[Figure 1 should be here]

3.3 Correlation between S Scale Score and Smartphone App Usage

In order to investigate the relationship between S scale score and smartphone app usage time, we carried out the correlation between them. Table 2 presents the correlation coefficients and their significance levels between S scale scores and smartphone app usage time for each app. We found that the S scale score correlates with total usage time of a device (ρ = .287, p < .001), and time spent using web browsers (ρ = .278, p < .001), messenger apps (ρ =.172, p < .05), and SNS apps (ρ =.156, p < .05), but is not correlated with time spent using game (ρ = .013, P = .858) and video apps (ρ = .033, P = .654).

Table 2: The Correlation Coefficients and Significance Levels between S scale score and Smartphone Usage Time for Participants' Smartphone Apps.

Apps	Coefficient (ρ)	Significance level
Total	.287	.000
Web Brower	.278	.000
Messenger	.172	.017
SNS	.156	.031
Storage	.116	.108
Photo/camera	.111	.124
Dictionary	.103	.155
Memo	.103	.157
Calculator	.089	.222
Commerce	.075	.304
Account	.066	.362
Mail	.065	.369
Downloader	.060	.410
Cartoon/Novel	.046	.523
Video	.033	.654
Game	.013	.858

For a further correlation analysis between S score and app categories, smartphone apps are grouped into three categories – communication, entertainment, and information. The grouping of apps was done according to Google app categories. For instance, messenger, SNS and mail apps are grouped into the communication category. Photo/camera, cartoon/novel, video and game apps are assigned to the entertainment category. Web browser, dictionary, memo, calculator, commerce, account are grouped into the information category. This analysis was performed to figure out which smartphone activity is associated with smartphone addiction. The result of the correlation analysis is given in Table 3. We found that the S scale score is correlated with communication (ρ = .194, p < .01) and information (ρ = .271, p < .001), but not entertainment (ρ = .088, p = .225).

Table 3: Correlation between S scale score and Smartphone Apps Categorical Usage Time. The Correlation Coefficient and Significance Level Are Placed along with Its App Category.

App category	Apps	Correlation Coefficients	Significanc e Levels
Communicati on	Messenger SNS Mail	.194	.007
Entertainment	Photo/Cam era Cartoon/No vel Video Game	.088	.225
Information	Web Browser Dictionary Memo Calculator Commerce Account	.271	.000

3.4 Linear Discriminant Analysis of Smartphone Addiction Using Smartphone Usage Patterns

To test whether a participant can be properly classified into a normal or addicted user using smartphone usage patterns, a linear discriminant analysis was carried out. For this purpose, we firstly divided the participants into two groups — normal and addicted, and the risky group was discarded. This was done to make the groups be more distinctive. So, according to the S scale score, lower 132 participants were assigned to the normal group and the upper 27 participants were assigned to the addicted group. In some sense, it is assumed that the S scale value is the ground truth, and thus a statistical model is required to accurately classify smartphone usage patterns into corresponding classes.

With the factors corresponding to the 10 largest eigenvalues obtained from factor analysis, we performed Fisher's linear discriminant analysis [20] on the smartphone usage patterns. This method is commonly used in statistics and pattern recognition to find a linear combination of features that characterizes or separates two or more classes of object. The classification result from the linear discriminant analysis with 10 factors is compared with that from the linear discriminant analysis with the total amount of usage time only.

Table 4 presents the comparative results. It is not surprising that the Fisher's linear discriminant analysis with 10 factors (79.9% correct response) outperformed that with only total smartphone usage time (66.0% correct response). However, it should be noted that the analysis showed the normal group has a higher correct response rate (84.8%) than those (55.6%) from the addicted group (Fig. 2) in the linear discriminant analysis with 10 factors. In contrast, 12 of 27 (44.4%) smartphone addicts are misclassified to the normal group. Only 15 of 27 (55.6%) smartphone addicts are correctly classified into the addicted group. The gray bar in Fig. 2 indicates the correct classification, but the black bar indicates the incorrect classification. In comparison of Fisher's linear discriminant analysis with 10 factors, the classification performance of the analysis with the total usage time only is clearly worse. That is, 68.9% of normal participant is correctly classified whereas 31.1 % of normal participants is incorrectly classified. For smartphone addicted group, 48.1% of addicted participants is classified into the normal. Only 51.9% of addicted participants is correctly classified.

[Figure 2 and Table 4 should be here]

4. DISCUSSION

Our research in this paper focuses on how to characterize smartphone addiction in terms of smartphone usage pattern and what factors differentiate smartphone addicts and non-addicts. Also, our research attempted to show the relation between the survey-based score and the smartphone usage pattern. The experimental results raised some important issues that are worth to discuss here.

4.1 Smartphone Addiction is Communicatively Addicted

The correlation study (Tables 2 and 3) shows that smartphone addiction is highly correlated with smartphone apps intended for communication and information, but not those intended for entertainment. Smartphone addicts can thus be described as wanting to be in constant communication with others, even when, in some senses, there is no need [21], [22]. It should be noted that increased smartphone usage does not necessarily enhance relationships with family members or friends. On the contrary, smartphone addiction can negatively impact communication skills [23]; it may actually cause a breakdown in communication, as users spread their attention to many people in different social networks at the same time. Communication thus becomes shallow and never concentrated [24], [25].

Unlike internet addiction, which is understood to be an addiction to gaming [26],[27], smartphone addiction does not show any statistically significant correlation with the usage time on game apps. This is due to smartphones' function as a communication device. People daily use their phone to communicate with their friends and family. When it comes to entertainment, the device's small display and keyboard make it not ideal for gaming. Moreover, its multimedia processing and memory size limits its usability and engagement. A recent study of elementary students in South Korea showed similar results and indicates that SNS usage is a stronger predictor of smartphone addiction than game usage [28].

4.2 Does Total Usage Time Sufficiently Explain Smartphone Addiction?

The engineering approach to smartphone addiction seems based in the belief that smartphone addiction and smartphone usage time are tightly coupled. This approach conceptualizes smartphone addiction as an excessive use of smartphones that interferes with users' daily lives. So, a smartphone user can be considered as an addict if his/her usage time exceeds a predefined usage time amount. Accordingly, recent research shows that the overuse of smartphones can be used to model smartphone addiction, to develop smartphone addiction inventories, and to discover the influential factors of smartphone addiction [12],[13],[14]. Most anti-smartphone addiction apps, therefore, monitor how much time a user spends on his/her smartphone and allows the user to set daily time limits.

Our study, however, demonstrates that this strategy is not good enough to predict whether a user is addicted. The classification accuracy of discriminant analysis using only total smartphone usage time was 66.0%, but 10 factors improved the accuracy to 79.9% (Table 4). This means that smartphone application usage patterns need to be considered as well as total usage times. Some apps significantly influence smartphone addiction, while others do not.

Even though the correct classification rate for the normal group significantly improved, when the smartphone applications usage patterns were used, the addicted group classification still remained poor. As shown in Fig. 2, only 55.6% of smartphone addicts were correctly classified. One possibility for this misclassification is that the usage time does not capture psychopathological symptoms, such as compulsive smartphone usage or interpersonal conflict. This implies that measuring smartphone usage time alone is not sufficient to predict smartphone addiction. It would be necessary to measure more variables that captures rich phenomenon of smartphone addiction. For instance, smartphone addiction is more likely to correlate with the frequency of smartphone usage (daily use count) or repetitive login than the duration of use (daily time spent on the smartphone) [16], [17]. Therefore, additional measures such as number of screen touches, repetitive logins, etc. would better reflect the compulsive behaviors. A further study with these measures will shed some light on smartphone addiction.

4.3 Is The S Scale Score Precise Enough for Ground Truth?

Throughout our statistical analysis, it is assumed that the S scale score is considered as the ground truth that independent variables should be mapped to. This means that the S score is accurate enough for the classification of the smartphone usage patterns (training data set), and thus is used for a criterion in decision making of whether a statistical model correctly classifies an input pattern or not [29], [30],[31].

However, as implied by the term 'self-diagnosis', the S score is based on the subjective evaluation on smartphone addiction. So, it is possible for our participants to over-estimate or under-estimate their smartphone addiction. It seems that some participants are likely to under-estimate their addictivity of smartphone in the S scale survey, even though their smartphone usage patterns clearly indicated that they overuse their smartphone.

The ground truth problem includes many complex issues that cover the selection of proper constructs, the reliability of a questionnaire and the validation of a statistical model [32]. The discrepancy between the surveyed data and smartphone-generated data might be caused by some of them. So, our speculation would be tested by introducing more question items in the survey that are tightly associated with the smartphone usage patterns.

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5. CONCLUSION

In summary, we explored the smartphone addiction under the relationship between the S scale score and smartphone usage patterns. Our research efforts attempted to reveal what features of smartphone usage patterns is associated with smartphone addiction and how smartphone addiction can be characterized in terms of smartphone usage patterns. Our research effort also extends to establish a linear discriminant analysis model to map the smartphone usage patterns to the normal or addicted groups.

This study provides an interesting insight into the relation between a survey-based approach and a device-based approach on the smartphone addiction. We try to reveal the discrepancies between these two approaches. Even though the smartphone usage pattern is more accurate, it is limited in representing the multifacet nature of smartphone addiction. On the other hand, the credibility of the self-diagnosed survey would be speculated because of its subjective nature.

Nonetheless, our current methodology is limited in the variety of smartphone activity variables and the collection duration of participants' activities. These limitations may fail to show richer smartphone addictive behaviors and more stably converging usage patterns. For a future study, our research work will be dedicated to employing more smartphone activity patterns and the latent constructs that underlies smartphone-addictive behaviors and their clinical effects with sufficiently long data collection duration. It is also hoped that our research will contribute to help people who suffers from this technology-abused syndrome.

6. ACKNOWLEDGMENTS

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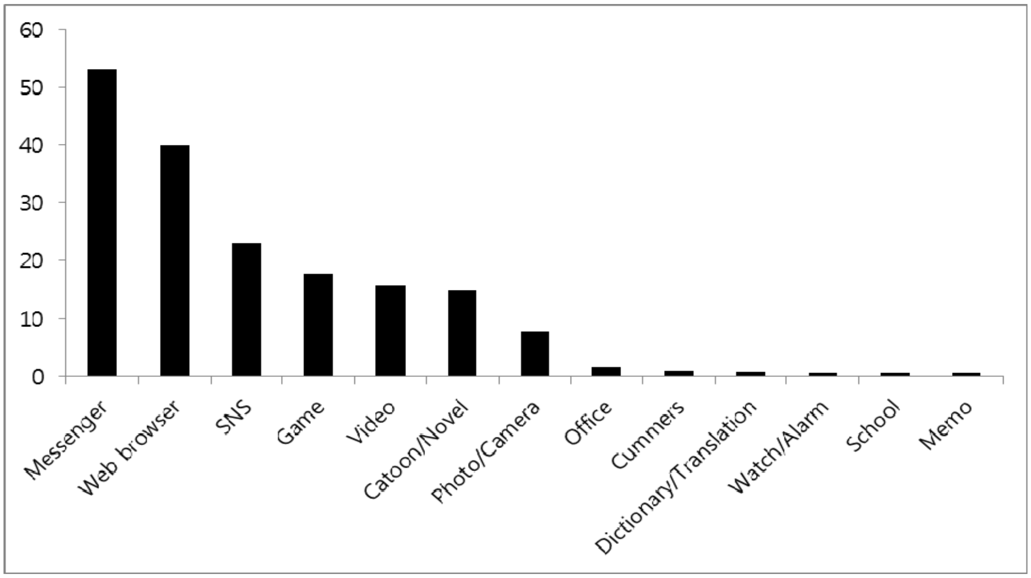
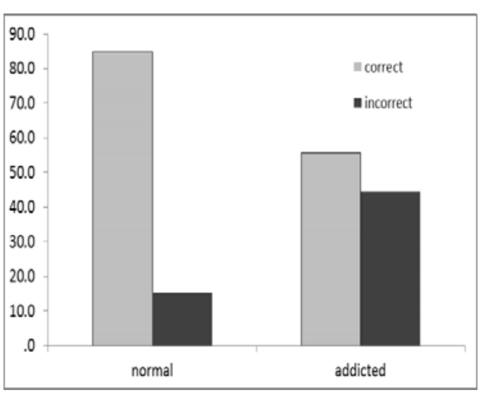


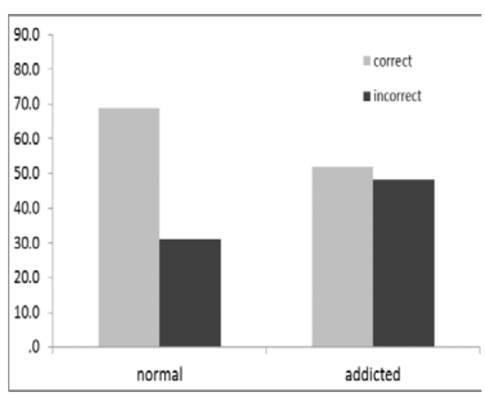
Figure 1: Daily usage Time of Smartphone Applications

Table 4: Classification Results Obtained from Fisher's Linear Discriminant Analysis

factor	S scale	predicted normal		predicted addicted		total		classification accuracy
		N	%	N	%	N	%	%
10 factors	normal	112	84.8	20	15.2	132	100.0	79.9
	addicted	12	44.4	15	55.6	27	100.0	
Total smartphone usage time	normal	91	68.9	41	31.1	132	100.0	66.0
	addicted	13	48.1	14	51.9	27	100.0	



1) 10 factors



2) Total usage time factor only

Figure 2: Classification Accuracy of Smartphone Addiction Measured with Fisher's Linear Discriminant Analysis