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The reciprocal longitudinal relationships between mobile phone addiction and depressive symptoms among Korean adolescents

Sangmin Jun

Department of Industrial Psychology, Hoseo University, 12 Hoseodae-gil, Dongnam-gu, Cheonan, Chungnam, 330-996, Republic of Korea

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ABSTRACT

This study aimed to (a) explore the stability of changes in mobile phone addiction and depressive symptoms across time and (b) clarify the direction of reciprocal longitudinal relationships between mobile phone addiction and depressive symptoms among Korean adolescents. We analyzed three-year longitudinal data from the Korean Children and Youth Panel Survey conducted by the National Youth Policy Institute in Korea. A total of 1877 valid responses from 2011 to 2013 were analyzed using autoregressive cross-lagged modeling. We found that each mobile phone addiction and depressive symptom in earlier years was associated with increasing severity in these conditions consistently over the three years. In addition, we found that the relationships between mobile phone addiction and depressive symptoms were bidirectional over the three years. The significant implications for these findings in the context of adolescent behavior are also discussed.

1. Introduction

Mobile phone addiction has increased among Korean adolescents. According to national surveys, 29.2% of teenagers were potential addictive users of mobile phones compared to that of individuals in their twenties (19.6%) and thirties (11.3%) (Ministry of Science, ICT and Future Planning of Korea, 2015). Mobile phone addiction, a behavioral addiction analogous to gambling and Internet addiction, can be defined as the excessive and uncontrolled use of mobile phones (Billieux, 2012; Choliz, 2010; Jun & Choi., 2015). Kim, Seo, and David (2015) suggested the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV) from the American Psychiatric Association list the following as cognitive symptoms of mobile phone addiction: obsessive thoughts about mobile phones (craving), overuse of mobile phones (tolerance), anxiety when not using mobile phones (withdrawal), unsuccessful efforts to cease excessive mobile phone use, and feeling other activities that used to be fun are no longer enjoyable. The Ministry of Science, ICT and Future Planning of Korea (2015) described the main factors in adolescent mobile phone addiction as tolerance, cognitive or behavioral disorders that interrupt daily lives, and withdrawal. Further, mobile phone addiction leads to serious health problems such as stress, sleep disturbances, headache, and brain tumor (Hardell & Carlberg, 2009; Zhao, Zou, & Knapp, 2007). Adolescents are especially vulnerable to mobile phone addiction because of their level of cortical development (Gogtay et al., 2004), their greater interest in mobile technology, and their superior skills in using mobile phones compared to adults (Chóliz, 2010; 2012). The mobile phone addiction problem is by no means confined to Korean adolescents. The prevalence of mobile phone addicted teenagers in European countries—such as Switzerland, Spain, and the UK—has been estimated at 10–30% (Billieux, Van der Linden, d'Acremont, Ceschi, & Zermatten, 2007; Lopez-Fernandez & Freixa-Blanxart, 2014; Sánchez-Martínez & Otero, 2009). Chen (2004) indicated that 25% of American college students recognized they were addicted to mobile phones. In addition, 21.4% of Iranian youth and 27.4% of adolescents in Hong Kong have been classified as mobile phone addicts (Babadi-Akashe, EshratZamani, Abedini, Akbari, & Hedayati, 2014; Leung, 2008).

Mobile phone addiction is common among adolescents in industrialized countries, and it creates serious problems in their daily lives. Mobile phone addiction has been related to financial problems (Billieux, Van der Linden, & Rochat, 2008; James & Drennan, 2005), health problems (Kundi, 2010; Thomée, Harenstam, & Hagberg, 2011; Toda & Ezoe, 2013), and psychological problems (Augner & Hacker, 2012; Beranuy, Oberst, Carbonell, & Chamarro, 2009; Bianchi & Phillips, 2005; Bickhan, Hswen, & Rich, 2015; Park, Kim, & Hong, 2012). Depressive symptoms in particular are some of the most serious psychological problems in

E-mail address: smjun@hoseo.edu.

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adolescents; the relationship between depressive symptoms and mobile phone addiction is a critical issue because such symptoms may lead to substance abuse (Goodman & Huang, 2002), school failure (Chilse, Miller, & Cow, 1980; Egger, Costello, & Angold, 2003; Hollis, 1996; Jun, 2015; Sánchez-Martínez & Otero, 2009), and even suicide (Klerman, 1987; Lewinsohn, Rohde, Kelein, & Seely, 1999).

Although depressive symptoms can be fatal in adolescents with mobile phone addiction, there have been few studies exploring the association between mobile phone addiction and depressive symptoms using standard instruments to measure the severity of depressive symptoms (Yen et al., 2009). Many studies have focused on some limited psychological variables—such as self-esteem, extraversion, and impulsivity—but not depressive symptoms (Bianchi & Phillips, 2005; Billieux et al., 2007; Butt & Phillips, 2008; Park et al., 2012; Walsh, White, Cox, & Young, 2011). Billieux (2012) reviewed existing articles and found that due to the lack of a theoretical framework, the etiology of mobile phone addiction is not obvious, and various psychological variables are included in research models in the previous studies. Based on a synthesis of previous empirical studies, Billieux (2012) proposed an integrative model to depict the pathways to problematic mobile phone use (e.g., addiction symptoms), that is, a pathway model (PM). The PM has four pathways: (1) the impulsive pathway, (2) the relationship maintenance pathway, (3) the extraversion pathway, and (4) the cyber addiction pathway; the final outcome variable is negative affect (e.g., depressive symptoms, anxiety). Billieux (2012) showed that mobile phone addiction was ultimately associated with depressive symptoms. In addition, a few pioneer studies have explored the co-relationship between mobile phone addiction and depressive symptoms with other psychological factors such as chronic stress among adolescents (Augner & Hacker, 2012; Chen, 2004; Sanchez-Martinez & Otero, 2009; Thomée et al., 2011).

However, it is interesting that the direction of relationship between mobile phone addiction and depressive symptoms is mixed. Some studies have found that mobile phone addiction affects depressive symptoms, whereas other studies have found that depressive symptoms influence mobile phone addiction. Some studies targeting Korean adolescents have illustrated that depressive symptoms are the crucial predictor of mobile phone addiction (Koo, 2012; Lee, 2009; Yang & Park, 2005). It has been shown that severe depressive symptoms can be caused by academic stress and peer relationship difficulties among Korean adolescents, resulting in mobile phone addiction (Lee, 2009; Park & Baik, 2004). Yen et al. (2009) discovered that adolescents in Southern Taiwan who have significant depressive symptoms are more likely to suffer from serious mobile phone addiction. Using univariate and multivariate logistic regression analyses, Toda and Ezoe (2013) revealed that depressive symptoms independently influence the degree of mobile phone dependency among Japanese youth. A few previous studies have focused on examining depressive symptoms as a predictor of mobile phone addiction (Babadi-Akashe et al., 2014; Kim, Bae, & Hyun, 2007; Kim et al., 2015).

In contrast, some researchers have shown that mobile phone addiction affects depressive symptoms (Bickhan et al., 2015; Han & Lee, 2010; Ko, 2012; Kumar, 2014). Bickhan et al. (2015) found that excessive mobile phone use might lead to the development of depressive symptoms among young adolescents in the northeastern USA. According to a review paper by Kumar (2014), the excessive use of mobile phones might decrease personal contact in real life and thus increase social isolation, which can lead to depressive symptoms. Ko (2012) found that tolerance, dependency, and obsession in mobile phone use increases the severity of depressive symptoms.

These results indicate that the association between mobile phone addiction and depressive symptoms has not been fully explained. Actually, a pioneer study on Internet addiction has shown through longitudinal analysis that there may be a bidirectional relationship between compulsive Internet use and psychological problems in adolescents (Van den Eijnden, Meerkerk, Vermulst, Spijkerman, & Engels, 2008). Therefore, the direction of the relationship between mobile phone addiction and depressive symptoms should be clarified. In order to examine the reciprocal effects in this relationship, it is necessary to analyze the longitudinal data on mobile phone addiction and depressive symptoms measured at multiple time points. However, longitudinal analyses have rarely been performed to investigate how these effects change across time. Previous studies on cross-sectional data have limitations in terms of isolating the direction of the relationship between mobile phone addiction and depressive symptoms. A pioneer study attempted to identify the longitudinal relationships between mobile phone addiction and depressive symptoms and showed that mobile phone addiction among Korean adolescents affected subsequent depressive symptoms (Jun, 2014). However, the researchers failed to identify additional consecutive relationships because they used only two-year longitudinal data, and they did not use the standard measures of depressive symptoms (Jun, 2014). Thus, more longitudinal studies are needed to examine the reciprocal relationship between mobile phone addiction and depressive symptoms in adolescents.

Based on the results of longitudinal studies on mobile phone addiction (Jun, 2014) and depressive symptoms (Bae, 2000; Rushton, Forcier, & Schectman, 2002), we proposed a causal relationship between past mobile phone addiction/depressive symptoms and future mobile phone addiction/depressive symptoms. The following hypotheses were developed:

H1. Mobile phone addiction at an earlier age positively affects mobile phone addiction at a later age.

H2. Depressive symptoms at an earlier age positively affect depressive symptoms at a later age.

Although the direction of the relationship between mobile phone addiction and depressive symptoms is uncertain, most studies agree these two constructs affect each other positively (Bickhan et al., 2015; Ko, 2012; Kumar, 2014; Lee, 2009; Toda & Ezoe, 2013; Yang & Park, 2005; Yen et al., 2009). We thus proposed a causal directional association between mobile phone addiction and depressive symptoms over time. The following hypotheses were developed:

H3. Mobile phone addiction at an earlier age positively affects depressive symptoms at a later age.

H4. Depressive symptoms at an earlier age positively affect mobile phone addiction at a later age.

In order to test our hypotheses, we used an autoregressive cross-lagged modeling and three-year longitudinal data on Korean adolescents. The purpose of the current study was to examine the longitudinal reciprocal effects of mobile phone addiction and depressive symptoms among Korean adolescents.

2. Methods

2.1. Participants

This study analyzed three-year longitudinal data from the Korean Children and Youth Panel Survey (KCYPS) conducted by the National Youth Policy Institute in Korea. The KCYPS is a national and longitudinal panel study that collects data on school and family lives, cultural activities, the use of mass media, and problematic

behaviors in Korean adolescents. The sample was chosen using stratified multistage cluster sampling based on 2009 school statistics collected by the Ministry of Education in Korea. The KCYPS was established in 2010 and conducted every year from September to December.

We used data from the second (2011; Time 1), third (2012; Time 2), and fourth (2013; Time 3) years of the KCYPS. The first year of the survey (conducted in 2010) was excluded because it did not include depressive symptom variables. Survey participants were only included in the study if they had used mobile phones during the three consecutive years from which the data were taken. Surveys from a total of 1877 adolescents (943 girls and 934 boys) were used. The participants were 8th graders in 2011 (Time 1), 9th graders in 2012 (Time 2), and 10th graders in 2013 (Time 3). Their average age ranged from 13.89 years (SD = .34) in Time 1 through 15.89 years (SD = .34) in Time 3. Their average yearly household income was $40,573.91 (SD = 21,857.17) in Time 1, $42,063.82 (SD = 23614.09) in Time 2, and $42,242.09 (SD = 23,076.26) in Time 3. A total of 218 adolescents (75 girls, 143 boys) were excluded from the study, as they did not report mobile phone use more than once during the three years the study was conducted. There was a significant gender difference between the excluded participants and included participants: The ratio of excluded boys (65.6%) was higher than the ratio of included boys (49.8%) (χ^2 = 19.608, $p < .001$). Differences in age, grade, and yearly household income were not statistically significant between these groups.

2.2. Measures

2.2.1. Mobile phone addiction

Mobile phone addiction was measured using the seven items established by Lee et al. (2002) in the KCYPS: “I am using my mobile phone more often,” “I feel nervous without a mobile phone when I go out,” “I am worried when I do not hear from anybody on my mobile phone,” “I do not care how time flies when I am using a mobile phone,” “I cannot stand being bored without a mobile phone when I am alone,” “I feel isolated when I do not have a mobile phone,” and “I cannot live without a mobile phone.” Each item was rated on a scale from 1 (*never true*) to 4 (*always true*). Cronbach's alpha coefficients were .896 at Time 1, .895 at Time 2, and .885 at Time 3. In order to reduce estimated error and achieve multivariate normality and continuity of the data, the seven items were divided into three variables, that is, three observed variables in the structural equation model, based on Bandalos and Finney (2001). In the exploratory factor analysis, only one factor was found, and we allocated each item to the observed variables according to the ranking of the factor loadings, which meant that (a) the first and seventh items, (b) the second and sixth items, and (c) the third, fourth, and fifth items were each organized as one observed variable (Russell, Kahn, Spoth, & Altmaier, 1998). This process was applied to Times 1, 2, and 3.

2.2.2. Depressive symptoms

We measured depressive symptoms using the ten items from the Korean Manual of Symptom Checklist (Kim, Kim, & Won, 1984), as used in the KCYPS: “I am feeling low these days,” “I feel depressed and sad,” “I have lots of concerns,” “I cry all the time,” “I have made mention of suicide,” “I often blame myself,”“I feel lonely,” “I have no interest in anything,” “I have a negative view of my future,” and “Everything is difficult for me.” These items were rated on a scale of 1 (*never true*) to 4 (*always true*). The Cronbach's alpha coefficients for these items were .901 at Time 1, .906 at Time 2, and .889 at Time 3. The ten items were classified as three observed variables at Times 1, 2, and 3 based on the same procedure of organizing the observed variables of mobile phone addiction mentioned previously. In the case of depressive symptoms, every item belonged to one factor in the exploratory factor analysis, such as that of mobile phone addiction.

2.2. Correlations and normality of variables

The correlations and descriptive statistics of mobile phone addiction and depressive symptoms at Times 1, 2, and 3 are presented in Table 1. The correlation coefficients among the six variables demonstrated that mobile phone addiction at Times 1, 2, and 3 was positively related to depressive symptoms at Times 1, 2, and 3, respectively. These results correspond to the theoretical relationships between mobile phone addiction and depressive symptoms proposed by the PM (Billieux, 2012). Next, as a preliminary analysis, we evaluated the normality of each variable using kurtosis and skewness according to the guideline of normality, which illustrated that kurtosis values under four and skewness values under two were acceptable (Kim, Kim, & Hong, 2009). As shown in Table 1, the normality assumption was satisfied for all variables. These analyses were conducted using IBM SPSS ver. 20.0.

2.3. Statistical analysis

2.3. Autoregressive cross-lagged modeling

To assess the longitudinal and reciprocal relationships between mobile phone addiction and depressive symptoms, autoregressive cross-lagged modeling (ACLM) was performed in this study. In the ACLM, the scores at time *n-1* (prior time) explain the scores at time *n* (later time), which means that the parameter values at Time 2 depend on the parameter values at Time 1 (Bast & Reitsma, 1997; Curran & Bollen, 2001). There are two kinds of longitudinal reciprocal relations in the model: the autoregressive relation and the cross-lagged relation. First, the autoregressive relation shows the parameter values determined by regressing the measure at a later time (*t*) onto the same measure at a prior time (*t-1*). Second, the cross-lagged relation represents the reciprocal influence of one construct at a prior time (*t-1*) on another construct at a later time (*t*), which controls for the autoregressive influence of the one construct at a prior time (*t-1*) on itself at a later time (*t*) (Hong, You, Yo, & Woo, 2010). As a result, the outcome construct at a later time (*t*) can be predicted by the same construct at a prior time (*t-1*) and by the other construct at a prior time (*t-1*).

In the present study, mobile phone addiction at Time 2 was predicted by both mobile phone addiction at Time 1 and depressive symptoms at Time 1. In addition, depressive symptoms at Time 2 were predicted by both depressive symptoms at Time 1 and mobile phone addiction at Time 1. In summary, our bivariate autoregressive cross-lagged models are presented as follows: mobile phone addiction $_i$[t] = β_0[t] + $\beta_1$mobile phone addiction $_i$[t-1] + $\beta_2$depressive symptoms $_i$[t-1]+r_i[t]; depressive symptoms $_i$[t] = γ_0[t] + $\gamma_1$depressive symptoms $_i$[t-1] + γ_2 mobile phone addiction $_i$[t-1] + ε_i[t].

As outcome variables, mobile phone addiction $_i$[t] and depressive symptoms $_i$[t] presented the measure of the mobile phone addiction and the depressive symptoms at a later time (*t*). β_0[t] and γ_0[t] were the measures of intercepts at a later time (*t*). Mobile phone addiction $_i$[t-1] and depressive symptoms $_i$[t-1] were the measures at a prior time (*t-1*) and the predictors of the outcome variables. β_1 and γ_1 were the autoregressive coefficients, and β_2 and γ_2 were the cross-lagged coefficients mentioned above. r_i[t] and ε_i[t] were the residuals at a later time (*t*). Overall, the path-diagram of our autoregressive cross-lagged model is represented in Fig. 1. To conduct the ACLM, we used structural equation modeling (SEM) performed by AMOS ver. 16.0. Additionally, we used full information maximum likelihood (FIML) to handle missing data.

Table 1
Correlations among main variables and descriptive statistics.

		1	2	3	4	5	6
1	Mobile phone addiction T1	–					
2	Mobile phone addiction T2	.550***	–				
3	Mobile phone addiction T3	.415***	.508***	–			
4	Depressive symptoms T1	.266***	.207***	.152***	–		
5	Depressive symptoms T2	.195***	.270***	.219***	.486***	–	
6	Depressive symptoms T3	.172***	.242***	.340***	.399***	.493***	–
Mean		18.87	18.14	18.28	30.80	30.14	31.15
SD		5.21	5.06	4.78	6.06	6.25	5.60
Range		7–28	7–28	7–28	10–40	10–40	10–40
Kurtosis		–.437	–.286	-.126	–.415	–.362	–.447
Skewness		–.255	–.087	–.154	–.247	–.194	–.184

Note: T1 represents Time 1; T2 represents Time 2; T3 represents Time 3.
***$p < .001$.

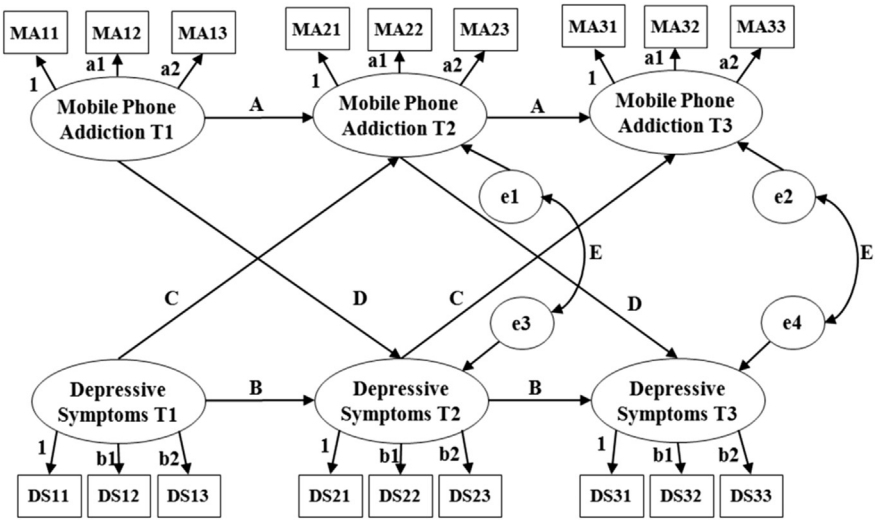

Fig. 1. Autoregressive cross-lagged model. *Note*: Ovals show latent variables; Boxes show observed variables; MA represents mobile phone addiction; DS represents depressive symptoms; Error terms are excluded for simplicity.

2.3. Testing invariance across time

To statistically evaluate the autoregressive and cross-lagged effects, this study explored the assumptions of metric invariance, configural invariance, and invariance of error covariance. We compared the model fit indices of eight nested models, which were organized by adding invariance constraints in hierarchical order. The baseline model was Model 1, which had no invariance constraints. In Fig. 1, we indicate the metric invariance, configural invariance, and invariance of error covariance across time using letters on the paths. Lower-case letters (a1, a2, b1, and b2) on the factor loadings represent the metric invariance. We tested the metric invariance by constraining the factor loadings to be equal across time. The assumption of metric invariance on each latent variable should be satisfied in order to ensure that the items of mobile phone addiction and depressive symptoms (e.g., MA12, MA22, and MA32) were understood and responded by participants in the same way over time (Steenkamp & Baumgartner, 1998). By imposing a1 and a2 on Model 1 (the baseline model), this study organized Model 2 for comparison with Model 1. We also constructed Model 3 by imposing b1 and b2 on Model 2 to compare with Model 2.

Next, the upper-case letters on the paths (A and B) between the same latent variables across time show the configural invariance on the autoregressive coefficients. Also, C and D between the other latent variables over time show the configural invariance on the cross-lagged coefficients. For example, we set the autoregressive coefficients on mobile phone addiction T1 → mobile phone addiction T2 and mobile phone addiction T2 → mobile phone addiction T3 to be equal with A. Additionally, we restricted the cross-lagged coefficients on depressive symptoms T1 → mobile phone addiction T2 and depressive symptoms T2 → mobile phone addiction T3 to be equal with C. Once configural invariance was achieved, the identity of the autoregressive and cross-lagged effects over time was shown (Kim et al., 2009). In this study, we formed Model 4 by imposing A on Model 3 and constructed Model 5 by imposing B on Model 4 in order to examine the configural invariance of the autoregressive effects. We then organized Model 6 by adding C to Model 5 and organized Model 7 by imposing D on Model 6 to test the configural invariance of the cross-lagged effects between the two variables over time. Lastly, E—which was the upper-case letters on the correlation paths (i.e., e1 ↔ e3; e2 ↔ e4) between the structural errors (e1, e2, e3, and e4) across time—represented the invariance of error covariance. The invariance of error covariance should be established to exclude the causal influence over time when we examine the reciprocal relationships between mobile phone addiction and depressive symptoms (Kim et al., 2009). Model 8, the last model, was made by adding E to Model 7 to evaluate the invariance of error covariance.

We then compared the model fit indices of all eight models sequentially to choose the final approved model, which is discussed

in the results section. The χ^2 value is sensitive to sample size, inflates type 1 error, and applies strict standards for rejecting the null hypothesis (Bollen, 1989; Jöreskog & Sörbom, 1996). Therefore, we used three indices: the comparative fit index (CFI), the non-normed fit index (NNFI), and the root mean square error of approximation (RMSEA) to compare model fit (Hong, 2000; Kim et al., 2009). The values of CFI and NNFI over .9 demonstrate a good fit (Bentler, 1990; Tucker & Lewis, 1973). RMSEA values under .08 are acceptable, and those below .5 show a good fit (Browne & Cudeck, 1993). To satisfy the assumptions of metric, configural, and error covariance invariance, the model with more invariance constraints should be improved with better or equal fit indices. Additionally, differences in CFI (ΔCFI) values between the models must be under .01 (Cheung & Rensvold, 2002).

3. Results

To examine the assumptions of metric invariance, configural invariance, and invariance of error covariance, we compared the fit values for a series of eight nested models one by one, which is reported in Table 2.

First, Model 1 with freely estimated parameters showed the acceptable fit values, which indicated both (a) the causal relationships between mobile phone addiction and depressive symptoms and (b) that the influences between each construct over the three years (i.e., mobile phone addiction at a prior time → mobile phone addiction at a later time; depressive symptoms at a prior time →depressive symptoms at a later time) were significant. Second, the fit values of Model 2 were better than those of Model 1 and the ΔCFI values of Model 1 and 2 were the same. In addition, Model 3 had more acceptable fit indices than Model 2, with a negligible difference in ΔCFI value (<.01). These results showed that Model 2 was better than Model 1, and Model 3 was advanced compared to Model 2. Thus, each metric invariance of mobile phone addiction and depressive symptoms was achieved, which demonstrated that mobile phone addiction and depressive symptoms were understood and responded by participants to be the same across the three years. Third, Model 4 was improved compared to Model 3, with better NNFI value and the same RMSEA and CFI values as Model 3. All fit indices between Model 5 and Model 4 were equal, which means that Model 5 was advanced compared to Model 4. Thus, each configural invariance of autoregressive effects on mobile phone addiction and depressive symptoms was established. The results reveal that each autoregressive effect of mobile phone addiction and depressive symptoms was identical across the three years, and changes in the two constructs were stable. There were no differences in any fit indices between Model 6 and Model 5. This means that Model 6 is better than Model 5, and the configural invariance of cross-lagged effect from depressive symptoms at a prior time to mobile phone addiction at a later time was established.

Table 2
Fit indices for invariance comparison test.

Model	χ^2	df	NNFI	CFI	RMSEA
1	1288.728***	124	.922	.944	.071 (.067–.074)
2	1290.975***	128	.925	.944	.070 (.066–.073)
3	1310.705***	132	.926	.943	.069 (.066–.072)
4	1315.710***	133	.927	.943	.069 (.065–.072)
5	1322.909***	134	.927	.943	.069 (.066–.072)
6	1323.520***	135	.927	.943	.069 (.065–.072)
7	1323.698***	136	.928	.943	.068 (.065–.072)
8	1323.886***	137	.928	.943	.068 (.065–.071)

***$p < .001$.

Model 7 had better fit indices than Model 6 and an identical CFI value; thus, Model 7 was an improvement over Model 6. The configural invariance of cross-lagged effects from mobile phone addiction at a prior time to depressive symptoms at a later time was also established. These results indicate that the cross-lagged effects of the two relationships—such as depressive symptoms at a prior time →mobile phone addiction at a later time and mobile phone addiction at a prior time →depressive symptoms at a later time—were identical across the three years.

Model 8 was more advanced than Model 7 because Model 8 had the same fit values as Model 7. Thus, the invariance of error covariance was established. The results show that the longitudinal reciprocal relationship between mobile phone addiction and depressive symptoms could be observed and defined without potential accidental associations over time. Finally, Model 8 was the most improved model because it was the simplest and had the best fit indices. Thus, we selected Model 8 as the final approved model of this study. The final model met all assumptions of metric invariance, configural invariance, and invariance of error covariance.

The estimated structural regression coefficients (based on the final approved model) are shown in Table 3. As predicted in H1, mobile phone addiction at Times 1 and 2 positively affected mobile phone addiction at Times 2 and 3, respectively. This demonstrates that the autoregressive effect of mobile phone addiction was significant across the three years. Also, as hypothesized in H2, each depressive symptom at Times 1 and 2 positively influenced depressive symptoms at Times 2 and 3, which shows that the autoregressive effect of depressive symptoms was significant over the three years. In other words, the severities of both mobile phone addiction and depressive symptoms increased consistently across the three years.

The relationships between mobile phone addiction and depressive symptoms across time were significant in both directions. Each measure of mobile phone addiction at Times 1 and 2 positively influenced depressive symptoms at Times 2 and 3, respectively, and depressive symptoms at Times 1 and 2 affected mobile phone addiction at Times 2 and 3, respectively. Thus, cross-lagged relationships between mobile phone addiction and depressive symptoms (i.e., mobile phone addiction [*t-1*] →depressive symptoms [*t*], depressive symptoms [*t-1*] →mobile phone addiction [*t*]) were significant, and both H3 and H4 were accepted. The results clarify that mobile phone addiction and depressive symptoms had bidirectional relationships over the three years.

4. Discussion

The current study examined the autoregressive cross-lagged effects between mobile phone addiction and depressive symptoms across three years using nationally representative data on Korean adolescents. We strictly evaluated the autoregressive cross-lagged model with assumptions of metric, configural, and error covariance invariance, and our final model satisfied all of these assumptions. This study illustrates changes in mobile phone addiction and depressive symptoms and the direction of the longitudinal relationships between these changes across three years.

The findings in the longitudinal data show that mobile phone addiction and depressive symptoms changed persistently across the three years. Mobile phone addiction in one year was a significant predictor of mobile phone addiction in the subsequent year. Likewise, depressive symptoms at a previous time predicted depressive symptoms at a later time. These results support previous studies showing that (a) depressive symptoms

Table 3
Structural regression analysis results in the final approved models.

Parameter	B	Se	CR	β
Mobile phone addiction T1 → Mobile phone addiction T2	.565	.016	36.253***	.595
Mobile phone addiction T2 → Mobile phone addiction T3	.565	.016	36.253***	.586
Depressive symptoms T1 → Depressive symptoms T2	.528	.016	36.284***	.522
Depressive symptoms T2 → Depressive symptoms T3	.528	.016	36.284***	.577
Mobile phone addiction T1 → Depressive symptoms T2	.136	.028	4.896***	.080
Mobile phone addiction T2 → Depressive symptoms T3	.136	.028	4.896***	.083
Depressive symptoms T1 → Mobile phone addiction T2	.034	.009	3.751***	.060
Depressive symptoms T2 → Mobile phone addiction T3	.034	.009	3.751***	.063

***$p < .001$.

worsen over time among adolescents who feel depressed (Bae, 2000; Rushton et al., 2002), and (b) mobile phone addiction of adolescents intensifies over time (Jun, 2014). By testing autoregressive effects using longitudinal data, we found that mobile phone addiction and depressive symptoms in adolescents at an earlier time were important predictors for the same conditions at a later time. This indicates that if mobile phone addiction or depressive symptoms occur in early adolescence, these states are maintained consistently in late adolescence. Therefore, we should focus on educating adolescents about the proper usage of mobile phones from an earlier age in order to prevent mobile phone addiction in advance. For example, it is helpful to prevent adolescents from overusing mobile phones to access games or social network services, which are common mobile phone functions (Jun, 2014; Salehan & Negahban, 2013). In addition, aggressive treatment of depressive symptoms is needed even for adolescents who feel mild symptoms of depression because mild depressive symptoms might to lead to severe depressive symptoms over time.

We also found that the causal relationships between mobile phone addiction and depressive symptoms were bidirectional across time. Mobile phone addiction had a harmful impact on depressive symptoms, as suggested in previous studies (Bickhan et al., 2015; Ko, 2012; Kumar, 2014). Depressive symptoms also increased the level of mobile phone addiction, which also supports prior studies (Babadi-Akashe et al., 2014; Koo, 2012; Toda & Ezoe, 2013; Yen et al., 2009). Although a number of previous studies only examined unidirectional relationships or correlations without controlling for autoregressive effects based on cross-sectional data, in the present study, we used longitudinal data to discover that the reciprocal relationships between mobile phone addiction and depressive symptoms might occur in vicious circles.

A few studies have suggested that depressed people use mobile phones excessively to alleviate their low mood based on data gathered through in-depth interviews and focus group discussions (James & Drennan, 2005) and through a path model (Kim et al., 2015). However, our results show that mobile phone addiction does not relieve depressive symptoms; rather, it might worsen them. According to our results, mobile phone addiction, a growing problem in adolescents' daily lives, might be compounded by symptoms of depression—which is the most serious psychological problem among adolescents—and vice versa. Mobile phone addiction is a health risk. A few studies have indicated that mobile phone addiction might cause a variety of brain tumors such as glioma and acoustic neuroma (Hardell, Carlberg, & Mild, 2013; Khurana, Teo, Kundi, Hardell, & Carlberg, 2009). The risk of serious brain pathology is higher in adolescents because their brains, with thinner skull bones and higher brain tissue conductivity, are more sensitive to toxins and absorb higher levels of radiation from mobile phones than do adults (Hardell & Carlberg, 2009; Hardell, Carlberg, & Gee, 2012). Further, mobile phone addiction may lead to difficulties relaxing, headaches, tension, stress, and sleep disturbances (Bianchi & Phillips, 2005; Thomée et al., 2011; Zhao et al., 2007). Thus, schools, families, and communities should act to simultaneously reduce depressive symptoms and mobile phone addiction among adolescents. For example, a mobile phone addiction counseling process in schools and communities should include treatment of depressive symptoms for adolescents. In addition, face-to-face interactions with family members and friends can help adolescents break out of the vicious cycle between mobile phone addiction and depressive symptoms (Kim et al., 2015; Kumar, 2014). Because adolescents who suffer from stress related to academics and poor peer relationships are likely to become addicted to mobile phone use (Lee, 2009; Park & Baik, 2004), schools should play a key role in depressive symptom treatment programs by enacting new programs considering mobile phone addiction and provide lectures on the proper use of mobile phones. Various promotion programs to increase awareness of the risks of the mutually damaging relationship between mobile phone addiction and depressive symptoms are also needed for adolescents. Above all, it is important that mobile phone addiction and depressive symptoms be controlled in early adolescence to prevent the worsening of these problems over time.

This study has several limitations. First, this study did not distinguish between the use of smartphones and feature phones. We speculated that most adolescents were using smartphones because the survey was conducted from 2011 to 2013; however, this was not confirmed. The type of mobile phone might influence the level of mobile phone addiction because only smartphone users can enjoy the benefits of wireless Internet services. Second, we set the relations between mobile addiction and depressive symptoms based on the PM (Billieux, 2012). However, other variables—such as family conflicts and academic stress—may affect both mobile phone addiction and depressive symptoms. Therefore, future research can extend the research frame by adding significant mediators using longitudinal analysis. Finally, all estimations of the study consisted of self-reported items, which might reduce the reliability and validity of the data.

Despite these limitations, the present study contributes to the understanding of the reciprocal relationships between mobile phone addiction and depressive symptoms among adolescents as expressed through longitudinal analysis. In this pioneer study, we have demonstrated the bidirectional relations between mobile phone addiction and depressive symptoms across time. Additionally, this study found that both mobile phone addiction and depressive symptoms worsened consistently over time. Therefore, early and continuous treatment and education should be provided for adolescents to prevent mobile phone addiction and depressive symptoms. Adolescents themselves should also be aware of the risk of falling into a vicious cycle of mobile phone addiction and depressive symptoms.

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