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The Relation between Social Media Addiction Tendencies and Depression: The Mediating Effect of Objectified Body Consciousness Moderated by Self-Compassion

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Social networking website (SNS) addiction has led to a rise in research on its negative impacts, especially depression, due to a significant increase in SNS users over the past decade. According to social comparison theory, the use of SNS makes individuals vulnerable to depression through a comparison with others who are perceived to be superior to them, and via photos displaying an individual's appearance (which are the main upload target), as being likely to cause individuals to become excessively preoccupied with their own bodies. Hence, this study aimed to test whether objectified body consciousness (OBC) mediates the relationship between SNS addiction tendency and depression. Furthermore, we examined whether self-compassion moderates the consequences of OBC on depression. The participants (n = 271) completed questionnaires measuring SNS addiction tendency, OBC, self-compassion and depression. The results revealed that the indirect effect of SNS addiction tendency on depression through OBC was moderated by self-compassion, and that, specifically, this indirect effect was found to decrease as self-compassion increased. The results of this study suggest that an individual's SNS addiction tendency passes through OBC in the process of influencing depression, and that the effect of such a path may vary depending on the individual's level of self-compassion.

Keywords: depression, SNS addiction tendency, objectified body consciousness, self-compassion

Introduction

Depression is an affective disorder that is influenced by daily events affecting one's emotional states. One of the significant daily activities can be the use of social networking sites (SNS, henceforth), which is now considered a part of daily life for most people, given that more than 50% of the world's population are SNS users, with an estimated usage rate of 75% (Wichers et al., 2007; Lenhart et al., 2010; "Global Social Media Statistics – DataReportal – Global Digital Insights," n.d). Under the current climate, a phenomenon gained attention: individuals started exhibiting symptoms of depression after spending a considerable amount of time on SNS, which is referred to as 'Facebook depression' (Selfhout et al., 2009). Indeed, an experimental study indicated that individuals reported increased life satisfaction after abstaining from SNS for a week compared to the control group (Tromholt, 2016). Additionally, a meta-analysis (Yoon et al., 2019) showed that greater use of SNS predicted higher levels of depressive symptoms. These research results suggest that excessive use of SNS may lead to depression. However, no study has been conducted to examine the underlying factors that explain the relationship between SNS use and depression. Therefore, we aim to examine the cognitive changes resulting

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from excessive SNS use and its maladaptive consequences.

According to the Social Comparison Theory by Festinger (1954) and Smith (2000), since humans are indisputably social animals, they are oriented to socially compare themselves across various situations. Given that SNS allows individuals to form and cultivate social networks while selectively sharing their private information, it is considered an ideal platform for social comparisons. However, online social comparisons tested to have more detrimental effect on one's psychological well-being than offline ones due to upward comparison from viewing postings that are generated in one's favourable light (Feinstein et al., 2013; Haferkamp & Krämer, 2011; Vogel et al., 2014). Comparing oneself to others' unrealistic advantages led to feelings of inferiority, leading to decreased psychological well-being, depression, and lower subjective well-being (Feinstein et al., 2013; Smith, 2000).

Objectified body consciousness (OBC) is a cognitive process in which individuals internalize social norms, learn to see their bodies as objects to be looked at, and adopt a third-person perspective. Recent research has shown that individuals with a SNS addiction tendency are more likely to experience their bodies in an objectified way, as if evaluating them from a third-party perspective. In other words, frequent use of SNS increases the opportunity to compare one's body with that of others, thereby increasing the risk of repeating the experience of objectifying one's body. As these experiences accumulate, individuals may internalize the observer's perspective, solidifying unrealistic perceptions of body shape (Duan et al., 2022). In summary, the results of previous studies suggest that excessive use of SNS may contribute to the increase in OBC.

On the other hand, OBC may play as a risk factor in feeling depressed (Blashill & Wilhelm, 2014; Fredrickson & Roberts, 1997). When individuals internalise unattainable appearance standards, they may repeatedly experience feelings of shame and inadequacy when viewing themselves, as they try to meet these standards. Constantly failing to meet these idealised states can decrease one's motivation to decrease the discrepancy between the ideal and current states, potentially leading to a state of learned helplessness (Seligman, 1975). Furthermore, Additionally, Beck's cognitive theory of depression identified appearance-related shame as a cognitive factor that causes depression (Beck, 1973, 1979). These studies suggest that a higher level of OBC may lead to increased depressive symptoms.

Given that OBC is characterised by excessive self-criticism, self-compassion, which protects individuals from the negative emotional implications of perceived failure arising from self-criticism (Neff, 2003), may moderate the relationship between OBC and depression. In other words, it is likely that a psychological process will occur in which the non-judgmental nature or kind attitude toward oneself inherent in self-compassion interacts with the negative evaluative nature or shame inherent in OBC. And through such a process, it is expected that self-compassion will be able to somewhat alleviate the effect of OBC on depression. Indeed, previous studies tested that self-compassion moderated the effect of OBC on depression (Daye et al., 2014; Wollast et al., 2019).

Since SNS have become an integral part of life across generations (Lenhart et al., 2010), it is essential to thoroughly examine how SNS impacts individuals' psychological health. Previous research has shown that engaging in upward social comparison on SNS is significantly related to higher depressive symptoms (e.g., Vogel et al., 2014). However, social comparison can occur in various domains, making it challenging to specify in clinical interventions for individuals with SNS addiction tendencies. Given that the primary content of most SNS platforms revolves around photos and videos, we have narrowed our focus to appearance comparison among these domains. In addition, previous studies have revealed that OBC is a variable influenced by SNS addiction tendency (Duan et al., 2022) and has characteristics that cause depression (Blashill & Wilhelm, 2014). So, we tested whether OBC mediates the relationship between SNS addiction tendencies and depression. On the other hand, the negative self-judgment and shame involved in OBC are likely to be alleviated by the non-judgmental acceptance involved in self-compassion or a gentle and kind attitude toward the self. therefore, we examined self-compassion as a potential moderator in the aforementioned relationship.

Hence, we tested the following hypotheses: 1) Excessive SNS use leads to a higher level of OBC, which consequently results in higher depressive symptoms. 2) The mediation of OBC in the relationship between excessive SNS use and depression is moderated by self-compassion (Figure 1). This study aims to provide insights into intervening with individuals experiencing depression due to maladaptive SNS use.

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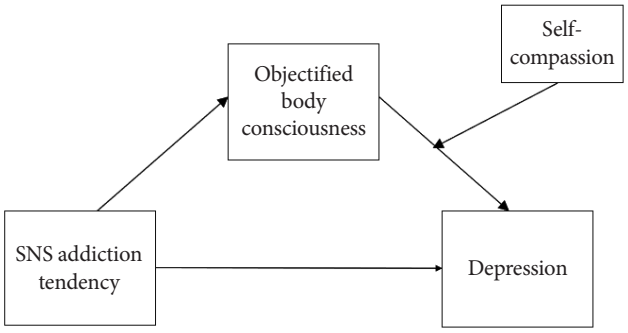

Figure 1. *Research model.*

Methods

Participants

271 Korean adults (81 males and 190 females) recruited by online advertisements with an age range from 18 to 64 years (mean [SD] = 30.05 [8.63]). The purpose of the study and informed consent was provided prior to participation and the researcher's contact information was provided. Participants completed a series of self-report questionnaires assessing SNS addiction tendency, the level of OBC, depressive symptoms and self-compassion. This study was conducted with the approval from the Institutional Review Board of ** University Medical Center (IRB No. C** 2023-01-001-001).

Measures

Objectified body consciousness (K–OBCS)

To measure levels of OBC in this study, the Korean version of the Objectified Body Consciousness scale (K-OBCS) was used. This modified version of the scale was developed by McKinley and Hyde (1996) to be applicable to Koreans across genders. Each item on the K-OBCS is rated on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of OBC. In the current study, the internal consistency of the K-OBCS was found to be high, with a Cronbach's α of .835 for Body surveillance and .836 for Body shame.

SNS addiction tendency

The Korean version of the Social Networking Sites Addiction Tendency Scale, developed by Cho and Suh (2013), was utilized to assess the level of SNS addiction tendency. The scale comprises 20 items in total, measuring the severity of SNS addiction tendency using a 4-point Likert scale ranging from 1 (not at all) to 4 (almost always). Higher scores indicate a greater degree of SNS addiction tendency. The internal consistency of the scale in the current study was Cronbach's α = .94 with the given population.

Depressive symptoms (CES–D)

The Korean version of Center for Epidemiological Student Depression Scale (Chon et al., 2001) was employed to measure the depressive symptoms of the community sample. It comprises 20 items that measure four aspects of depressive symptoms; depressive affect (4 items), somatic symptoms and bluntness (7 items), positive affect (4 items) and interpersonal difficulties (2 items). Scores range from 0 to 60 and higher scores indicates greater depressive symptoms. The internal consistency for this sample was Cronbach' α = .939.

Self–compassion (K–SCS)

The Korean version of Self-Compassion scale (K-SCS; Kim et al., 2008) was used to assess the level of self-compassion which was originally developed by Neff (2003). K-SCS is 26 items self-report questionnaire using a five-point Likert scale. The total scores range from 25 to 130 and a higher score indicates a higher level of self-compassion. The K-SCS consists of three sub-categories to assess the level of self-compassion; a) Self-kindness versus self-judgment, b) common humanity versus isolation, lastly c) mindfulness versus over-identification. In the original study, internal consistency was Cronbach' α = .92 (Neff, 2003) and the current study demonstrated Cronbach' α = .918.

Data analysis

In this study, the data collected using the SPSS 21.0 program and SPSS Macro PROCESS were analyzed. The analysis method for the data is as follows: First, Pearson's correlation analysis was conducted to confirm the relationship between SNS addiction tendency, OBC, self-compassion, and depression. Second, through analysis of PROCESS Macro model 14, we performed regression analysis included in the model and attempted to confirm whether the indirect effect of SNS addiction on depression through OBC is moderated by self-compassion. In addition, by using the 'boot' function and 'boot.ci' function included in the 'Boot' package of the R program (Davison & Hinkley, 1997), self-compassion scores are input

at 5-point intervals to determine the upper and lower limits of the indirect effect and confidence interval for each score. At this time, the number of bootstraps was set to 10,000, and the confidence interval was 'Bca' type. Afterwards, these scores were plotted using the 'loess' function included in the 'mgcv' package. Next, a hierarchical multiple regression analysis was conducted to examine whether self-compassion controls the effect of OBC on depression. To this end, the significance of the interaction term was verified by multiplying the average-centered two scores and putting them into the interaction term (Cohen et al., 2003). Finally, it was verified whether the mediating effect of OBC on the relationship between SNS addiction tendency and depression is controlled by self-compassion. To this end, the moderated mediating effect was analyzed through the PROCESS model 14, the number of bootstrap samples was 10,000, and the bias-corrected bootstrap confidence interval was used for the bootstrap confidence interval.

Results

First, the Pearson correlation coefficient between variables and the mean and standard deviation of each variable were calculated and presented in Table 1. Specifically, SNS addiction tendency showed a significant positive correlation with OBC and depression (r = 0.27, p < .001; r = 0.32, p < .001, respectively), and showed a significant negative correlation with self-compassion (r = 0.24, p < .001). In addition, OBC showed a significant positive correlation with depression (r = 0.38, p < .001), and a significant negative correlation with self-compassion (r = 0.38, p < .001). Finally, in the relationship between self-compassion and depression, the negative correlation was found to be significant (r = 0.67, p < .001). And the skewness and kurtosis of the variables included in this study satisfy the normality assumption.

Table 1. *Correlation between Variables (n = 271)*

	1	2	3	4
1. SNS addiction tendency	-			
2. Objectified body consciousness	0.27***	-		
3. Self-compassion	-0.24***	-0.38***	-	
4. Depression	0.32***	0.38***	-0.67***	-
Mean	35.87	47.93	80.30	17.04
SD	11.91	10.20	17.03	11.88
Kurtosis	-0.14	-0.42	-0.66	0.33
Skewness	0.58	-0.02	0.01	0.89

*Note.****p < .001.*

Second, PROCESS Macro model 14 analysis was performed and the results were presented in Table 2. First, as a result of a regression analysis using SNS addiction tendency as a predictor variable and objectified body consciousness as the reference variable, the regression coefficient was B = 0.23 (p < .001), showing that SNS addiction tendency has a significant influence on OBC. Second, in the results of a regression analysis using SNS addiction tendency, OBC, self-compassion, and the interaction term between OBC and self-compassion as the predictor variable on depression, SNS addiction tendency and OBC are self-compassion was found to have a significant effect on depression (in each order, B = 0.13, p < .01; B = 0.57, p < .01), but self-compassion did not significantly predict depression (B = -0.15, ns.). In addition, the effect of the interaction between OBC and self-compassion on depression was significant, B = -0.01, p < .05. This means that the effect of OBC on depression varies depending on the level of self-compassion.

Lastly, the significance of the moderating mediation effect was verified through the moderated mediation index provided in the PROCESS Model 14 model analysis (Table 3). The confidence interval for the moderated mediation index did not include 0, so the moderated mediation effect was found to be significant (Effect =

Table 2. *Regression Analysis Results Included in the Moderated Mediation Model (n = 271)*

Independent variable	Dependent variable	*B*	*SE*	*t*	*LLCI*	*ULCI*
SNS addiction tendency	Objectified body consciousness	0.23	0.05	4.62***	0.13	0.33
SNS addiction tendency	Depression	0.13	0.05	2.75**	0.04	0.22
Objectified body consciousness		0.57	0.22	2.56**	0.13	1.01
Self-compassion		-0.15	0.14	-1.10	-0.41	0.12
Objectified body consciousness × self-compassion		-0.01	0.00	-2.02*	-0.01	-0.00

*Note. *p < .05, **p < .01, ***p < .001.*

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Table 3. *Test of Significance of the Index of Moderated Mediation (n = 271)*

Variable			Effect	95% CI		
				Boot S.E.	*LLCI*	*ULCI*
Self-compassion			-0.001	0.001	-0.003	-0.000
Level	Low (*M-1SD*)	63.27	0.050	0.022	0.014	0.099
	Middle (*M*)	80.30	0.028	0.015	0.002	0.060
	High (*M+1SD*)	97.32	0.006	0.016	-0.027	0.038

Note. Bootstrap samples were extracted 10,000 times. Boot S.E. = Standard error calculated by the bootstrap method; LLCI, ULCI = the lower and upper limits within the 95% confidence interval.

-0.001, 95% CI = [-0.003, -0.000]). Figure 2 shows how the conditional indirect effect changes depending on the level of self-compassion. As self-compassion increases, the conditional indirect effect shows a decreasing trend. It can be seen that when self-compassion exceeds approximately 80 points, the effect is no longer significant.

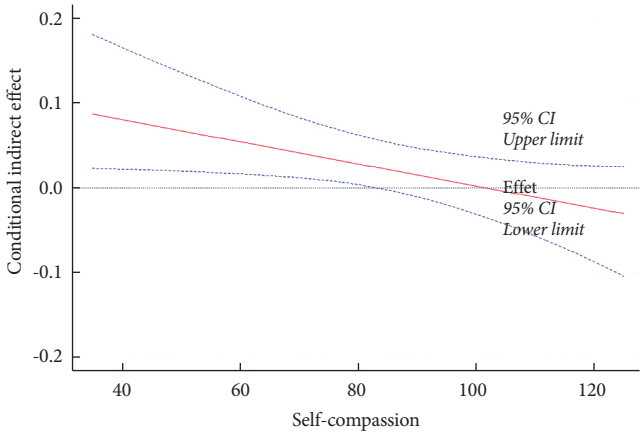

Figure 2. *Conditional indirect effect.*
Note. The red solid line is the point estimate, and the blue dotted line is the upper and lower limits of the confidence interval.

Discussion

This study examined the mediating effect of OBC on the relationship between SNS addiction tendency and depressive symptoms, as well as the moderating effect of self-compassion in this relationship. Our main findings are as follows: First, the results revealed that OBC significantly mediated the relationship between SNS addiction tendency and depression, indicating that excessive SNS use predicts individuals to experience OBC, which consequently leads to depressive symptoms.

Furthermore, we found that self-compassion was a significant moderator in the relationship between OBC and depression, indicating that self-compassion significantly moderated the effect of OBC and further prevented the manifestation of depressive symptoms. This finding aligns with previous literature that has demonstrated the beneficial impact of self-compassion on psychological well-being (e.g., Körner et al., 2015). Overall, it suggests that self-compassion may be a promising concept for preventing depression in individuals struggling with OBC.

More importantly, this study confirmed that the indirect relationship between SNS addiction tendency and depression through OBC was influenced by the level of self-compassion. The finding suggests that individuals with higher self-compassion are less likely to experience depressive symptoms, even in the presence of a higher level of OBC. Therefore, promoting self-kindness and non-judgmental attitudes towards oneself may be beneficial in intervening with individuals experiencing depressive symptoms resulting from patterns of excessive SNS use with high OBC.

Implications

This study has implications from the revealing that SNS addiction can trigger depressive symptoms, and this relationship is mediated by OBC. The results suggest that interventions targeting OBC could potentially prevent future depressive symptoms in individuals with SNS addiction tendencies. Practical interventions for individuals with depression who exhibit maladaptive SNS usage patterns may involve assessing and addressing distorted beliefs related to body objectification.

Furthermore, the results indicate that SNS addiction may lead to depression through OBC, and that self-compassion can moderate this effect, presenting an integrated perspective on SNS addiction, OBC, depression, and self-compassion. Clinicians may enhance treatment efficacy by facilitating the development of self-compassion in relevant populations. Additionally, the results may be beneficial in designing interventions for individuals with maladaptive SNS usage patterns by examining their attitudes toward themselves (i.e., OBC and self-compassion) to mitigate the risk of emotional difficulties. However, further research is necessary to establish the underlying mechanisms.

Limitations

While this study has important implications, it is not without limitations. This study examined various SNS uses among participants but did not differentiate between various platforms. It has been found that each SNS platform has its own characteristics due to differences in functionality and forms of content sharing (Saiphoo & Vahedi, 2019). Future studies should investigate the dysfunctional effects of specific SNS platforms.

Additionally, since this study relied on self-report questionnaires to measure the relevant variables, the findings may be subject to various forms of bias, such as recall bias, social desirability bias, or reporting only average levels. To address these limitations, future research should employ research designs that capture momentary experiences (i.e., Ecological Momentary Assessment) and assess individual differences to minimize bias and evaluate maladaptive cognitive beliefs.

Another potential limitation is the study's cross-sectional design, which may not capture the developmental trajectory of OBC and depression over time. Future studies should consider adopting a longitudinal design to better understand the directionality of these relationships.

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Author contributions statement

Sooyeon Kim conducted literature searches and wrote the first draft and contributed to and have approved the final manuscript. Changhyeon Lee contributed to statistical analysis and writing and to and have approved the final manuscript. There are no funding sources to report. All authors provided critical feedback, participated in revision of the manuscript, and approved the final submission.

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The Effects of Behavioral Activation System/Behavioral Inhibition System (BAS/BIS) and Peer Pressure on Smartphone Overdependence Among Korean Adolescents

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Adolescents' addictive use of smartphones has been the focus of clinical attention. Gray's neuropsychological systems, behavioral activation system (BAS) and behavioral inhibition system (BIS), consistently predict smartphone overdependence (SO) across various age groups. Additionally, peer pressure (PP)— as it relates to smartphone usage — is considered a notable factor and one which wields significant influence on adolescents. In this context, this study aimed to investigate the relative impact of intra-individual factors, BAS/BIS, and peer-related factor, PP, on adolescents' SO. Furthermore, the study sought to explore whether these two factors interact with each other in influencing adolescents' SO. We collected data from 489 Korean middle school students and analyzed the data separately by gender, considering potential gender differences in the interrelationships among variables based on prior research findings. The findings reveal a significant positive correlation among BAS/BIS, PP, and SO. Furthermore, BAS/BIS and PP were confirmed to significantly predict SO with no gender differences. However, the moderation effect was only significant in the male group. Based on these findings, we discussed preventive interventions concerning adolescents, limitations, and suggestions for further research.

Keywords: behavioral activation system (BAS), behavioral inhibition system (BIS), smartphone overdependence, smartphone addiction, peer pressure, adolescents

Introduction

The addictive use of smartphones among adolescents has long been a central topic in clinical discussions, with a notable increase in cases, particularly in South Korea. According to the 2022 survey conducted by the National Information Society Agency (NIA), 40.1% of adolescents were classified as smartphone overdependence groups, representing a 3.1% increase from the previous year. Today's adolescents have grown up in a technologically advanced environment, where smartphones are an integral part of their daily lives, evolving into indispensable tools for nearly every teenager. Haddon and Livingstone (2012) emphasize instilling online resilience in children, enabling them to effectively navigate and overcome the various issues that can arise in the digital environment, rather than pathologizing their smartphone use. From a sociocultural perspective, interventions should be culturally sensitive and accommodating to the unique adolescent culture, avoiding overly restrictive approaches that simply curtail smartphone usage. Therefore, investigating various factors influencing smartphone overdependence (SO) is crucial to effectively addressing adolescents' SO.

Prior research has classified SO as a form of behavioral addic-

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tion, akin to addiction to gaming or gambling (Goel et al., 2015; Lee & Yang, 2018). Within the domain of factors influencing behavioral addiction, the temperamental construct known as Behavioral Activation System/Behavioral Inhibition System (BAS/BIS) has consistently garnered attention as a pivotal variable explaining an individual's temperamental susceptibility to behavioral addiction (Breen & Zukerman, 1999; Kim et al., 2016; Kim & Hwang, 2019; Kim & Lee, 2011; Park et al., 2013). Furthermore, it is well-established that both BAS and BIS play pivotal roles in responding to environmental stimuli and regulating motivational aspects of behavior (Fowles, 1987, 1993). Therefore, to comprehend SO as a form of behavioral addiction, it is imperative to consider BAS and BIS within Gray's Reinforcement Sensitivity Theory (Gray, 1982). Gray identified these biological systems that influence individual behavior as the BAS and BIS. BAS is associated with reward sensitivity, a tendency to seek novelty and excitement, and an inclination toward impulsively pursuing one's desires. In contrast, BIS is linked to vigilance to cues of punishment or threat and the experience of anxiety (Carver & White, 1994). Essentially, if BAS can be likened to a psychological accelerator that promotes goal-directed behaviors, BIS can be likened to a psychological brake that inhibits responses when confronted with punitive or threatening cues (Kim & Kim, 2001).

In case of BAS, from a personality perspective, it is reported that BAS is closely associated with the dimension of impulsivity, which includes a tendency to seek stimulation and make hasty decisions (Moeller et al., 2001). This impulsivity is recognized as a risk factor for addictive behaviors (Thomsen et al., 2018). In this context, BAS is regarded as potential personality factor related to addiction (Jeong et al., 2020; Yi & Hwang, 2015). In the majority of studies assessing BAS, researchers employ a scale developed by Carver & White (1994) comprising three subdimensions: reward responsiveness, fun-seeking, and drive. According to findings from Lee et al. (2015), scores on the 'drive' and 'fun-seeking' subdimensions of BAS were significantly higher in groups of adolescents addicted to smartphones. Additionally, Kim et al. (2016) emphasized the importance of 'drive' and 'reward responsiveness' within these subdimensions for predicting the group at high risk of smartphone use. Anderson and Smith (2001) revealed that the 'reward-responsiveness' plays a role in facilitating reward-related learning. Positive expectations acquired through this learning process enhance the frequency of subsequent behaviors, ultimately leading to addiction. In summary, research outcomes vary depending on the subdimensions of BAS. However, Corr and McNaughton (2008) have suggested that for an effective measurement of the BAS, multidimensional subfactors should be comprehensively evaluated. Many previous studies have also treated these subdimensions as constituting a unified concept of BAS and consistently reported a positive correlation between a high BAS tendency and behavioral addiction (Cho & Cho, 2008; Park et al., 2013; Yang & Suh, 2017).

On the other hand, BIS is closely associated with negative emotions, and multiple studies consistently suggest an increased likelihood of experiencing anxiety or discomfort in social situations with the intensification of BIS inclination. Furthermore, there is evidence that individuals, when confronted with negative emotions, tend to engage in smartphone-mediated interactions as a means of avoidance (Jung et al., 2016; Amiel & Sargent, 2004; Kimbrel, 2008; Park et al., 2011). Additionally, there is an argument that individuals with prominent BIS characteristics may exhibit heightened sensitivity to cues of punishment compared to those with weaker BIS traits, leading to more pronounced experiences of anxiety and, consequently, an increased dependence on smartphones (Jo et al., 2017). Kruglanski and Orehek (2011) have reported that BIS exhibits increased sensitivity to social rejection. Moreover, individuals with heightened BIS sensitivity tend to be more vigilant towards negative aspects and show a propensity for a pessimistic outlook (Hirsh & Kang, 2016, as cited in McGarry & Shortland, 2023). Furthermore, based on studies showing that individuals with high levels of the fear of missing out (FOMO) tend to use social networking sites more often (Fox & Moerland, 2015; Przybylski et al., 2013), it can be inferred that individuals with pronounced BIS characteristics may turn to smartphones more frequently. Thus, it can be inferred that individuals with heightened BIS characteristics are likely to rely more on smartphones, in an effort to mitigate the fear of social exclusion.

Meanwhile, BIS represents a comprehensive concept of 'punishment sensitivity,' encompassing anxiety and fear. In line with these characteristics of BIS, Carver and White (1994) have made a questionnaire that differs from existing anxiety scales. This questionnaire does not inquire about the frequency of an individual's anxi-

ety experiences but rather whether they are likely to experience anxiety in certain situations (Jorm et al., 1998). However, McNaughton and Gray (2000) emphasize in the revised Reinforcement Sensitivity Theory that anxiety within the BIS should be clearly distinguished from the concepts of terror or fear. Thus, in order to explore the impact on SO more precisely, there is a need for research that distinguishes between the concepts of anxiety and fear within BIS and elucidates their relationship with SO. Meanwhile, Corr and McNaughton (2008) reported that fear operates when leaving a dangerous situation (active avoidance), anxiety when entering it (e.g., cautious 'risk assessment' approach behavior), or withholding entrance (passive avoidance). In light of these considerations, it can be inferred that the tendency to use smartphones more frequently out of fear of social exclusion or to rely on smartphones to alleviate anxiety experienced in social situations is closely related to the anxious facet of BIS. Therefore, this study attempts to investigate the connection between the anxiety concept within BIS and SO.

In sum, many studies report that BAS/BIS are ultimately associated with smartphone addiction. Therefore, when considering these findings collectively, it is predicted that individuals with high BAS traits may become deeply engrossed in smartphones, which provide immediate gratification because of their sensitivity to positive affect and rewards, such as the pursuit of new stimuli and pleasure, potentially leading to increased SO. On the other hand, individuals with high BIS characteristics may be expected to rely more on smartphones to alleviate negative emotions and avoid social exclusion. In simple terms, one can assume that BAS/BIS systems follow different pathways but ultimately converge on one outcome, SO. However, not all individuals with inherent vulnerabilities display maladaptive behaviors, such as behavioral addiction (Lee & Kwon, 2020). Therefore, it is important to explore the factors that may affect the relationship between these motivational systems and SO.

Adolescence is a period characterized by significant physical and emotional maturation, involving the reorganization of their self to meet emerging roles and social demands. Individuals' biological characteristics can lead to different outcomes even under similar environmental conditions (Yi, 2014). Additionally, as adolescence is the developmental period when individuals are most affected by peer relationships and peer culture, peer pressure appears to be another important factor influencing adolescents' SO. Early adolescents share more time with their peers than their parents (Palani & Mani, 2016) and tend to conform to peer values, group beliefs, and behaviors more easily than other age groups (Jeong, 2019). In typical development, from adolescence onward, it is common for children to develop greater emotional dependence and a sense of belonging through their peers than their parents (Buist et al., 2002).

Peer groups have long been a focal point of research as a substantial contributor to adolescent substance abuse and addiction (Bahr et al., 2005; Farrel & White, 1998; Steinberg et al., 1994). Oetting and Beauvais (1986) elucidated the psychological and social factors influencing adolescent substance abuse, using the Peer Cluster Theory (PCT). According to this theoretical framework, peer groups that encourage substance abuse introduce adolescents to drugs, instruct them on methods of use, and influence them to adopt beliefs and attitudes that perpetuate drug use. Likewise, during the trajectory leading to smartphone addiction, peer groups can exert a diverse range of influences. For instance, they can introduce adolescents to various smartphone features and usage methods, engage in collaborative gaming, share captivating content, and foster a sense of belonging among group members. Furthermore, Lee (2001) suggests that cultural elements are inherently embedded in the value of mobile phones as a medium. Individuals driven by motivation rooted in these cultural dimensions may be acutely aware of peer influence and are likely to conform within the group, driven by considerations related to their identity, social status, economic power, and communication style. In essence, due to the developmental characteristics of adolescents striving to establish their identity within peer groups, it is conceivable that unique cultural motivations specific to adolescent cohorts could influence smartphone usage.

Additionally, in the collectivist culture of Korean society, which tends to place more emphasis on the perceptions of other members within their groups, individuals are more likely to feel pressured into relationships based on collective values (Joo et al., 2018). Thus, it can be assumed that middle school students' smartphone use patterns will also be significantly influenced by their peer groups as their dependence on and sense of belonging to their peer

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groups increases during their development, especially in Korea. Therefore, it is crucial to investigate how adolescents experience peer norms and implicit pressures related to smartphone usage and how these factors influence their actual smartphone usage patterns. Nevertheless, prior research has overseen these aspects.

Numerous studies have revealed associations between smartphone addiction and peer-related factors such as peer pressure, peer attachment, and peer relationships (Chang et al., 2012; Jung, 2019; Kim & Kim, 2018; Kim & Byun, 2015; Park et al., 2012; Yoon, 2005). However, prior research predominantly treats peer variables and smartphone addiction as separate constructs, with a focus on understanding the influence of peer variables on smartphone (Kim et al., 2016). Additionally, while various scales related to peer pressure or conformity are available (Berndt, 1979; Brown et al., 1986; Santor et al., 2000; Cho & Chung, 2009), most of them primarily assess peer pressure or conformity concepts in general circumstances. In other words, studies exploring the peer norms or culture among adolescents that directly affect smartphone usage have been scarce thus far. Consequently, there exists a pressing need for research that delves into the distinctive traits of adolescents, particularly concerning the investigation of peer norms or culture that may directly impact smartphone usage. Hence, in this study, the term "peer pressure (PP)" refers to "peer pressure regarding smartphone use". This definition encapsulates the unique culture of adolescents and the unspoken norms related to smartphone usage. While the existing definition primarily addresses peer influence in general situations, the PP defined in this study focuses on the influence or pressure by peers that encourage smartphone use or heighten dependence on smartphones. Therefore, this study aimed to examine the more substantive peer influence related to adolescents' SO and complement the limitations of previous research, which has shown difficulties in directly explaining the relationship between variables related to peers and adolescents' SO.

Furthermore, it would be meaningful to investigate how PP, directly related to smartphone usage, interacts with the biological vulnerabilities studied as intrinsic factors (BAS/BIS) significantly associated with SO. We posited that individuals with high BAS sensitivity, as mentioned earlier, are more likely to engage in behaviors accessing positive reward cues, while those with high BIS sensitivity tend to exhibit more behaviors aimed at mitigating or avoiding negative cues. Within the same context, as peer groups hold significant importance for adolescents, it can be assumed that they may strongly sense the pressure to adhere to peer group guidelines regarding smartphone usage to maintain positive relationships and intimacy. Studies supporting our hypothesis emphasize the significance of smartphones in maintaining or enhancing smooth peer relationships as they facilitate communication with peers anytime and anywhere (Shin & Lee, 2013; Yi, 2014). Moreover, adolescents may experience anxiety about potential peer exclusion, leading to excessive smartphone use to avoid exclusion from their peers (Yoon & Kwon, 2011). In summary, it can be inferred that adolescents with a high BAS tendency are likely to exhibit higher levels of SO due to their inclination to seek positive emotions and rewards, such as joy and satisfaction, in intimate relationships. Lee and Kim (2020) confirmed that adolescents with high BAS/BIS levels also have higher levels of interaction and relationship motivation. Furthermore, adolescents with strong BIS traits may be more inclined to rely on smartphones as they may be more sensitive to cues such as exclusion from their peer groups. The findings of the study by Fox and Moerland (2015), supporting this assumption, suggest that individuals with higher anxiety about exclusion may use smartphones more frequently to maintain relationships.

In conclusion, this study aims to explore PP, which is expected to influence adolescents' SO, in conjunction with the well-established BAS/BIS factors closely related to SO. The primary objective is to investigate the impact of BAS/BIS, as well as the peer group norms directly linked to smartphone use among adolescents, on actual SO. Additionally, we examine the potential interactions among these key variables. Reflecting on similar studies, research has shown that peer conformity among adolescents has different associations with Internet addiction based on gender. For female students, higher peer conformity had a positive impact on internet addiction, while among male students, lower peer conformity was associated with higher levels of internet addiction (Ha & Jo, 2003). Moreover, in studies examining factors related to adolescent risk behaviors, it was observed that the influence of peer conformity is more prominent among female adolescents than male adolescents. These results suggest that the relationship between peer conformity

and peer pressure may vary by gender (Yoon & Nam, 2007). Furthermore, gender differences in BAS/BIS levels have also been reported (Choi & Yang, 2018; Jiang & Zhao, 2010; Oi et al., 2019). Considering these findings, we have investigated the influence of PP by gender in our research.

Methods

Participants and Procedure

The entire procedure received approval from the Institutional Review Board under Approval No. HYUIRB-202009-030-1 and adhered to the guidelines of the Declaration of Helsinki. Data was collected through a structured survey from middle school students. After providing a detailed study explanation and receiving consent, 495 student responses were collected. After excluding insincere responses, 489 responses were chosen for analysis. The average age of participants was 14.55 years (SD = 0.58), with males averaging 14.65 years (SD = 0.59) and females averaging 14.45 years (SD = 0.54). Out of the total participants (N = 489), 51.1% (n = 250) were male, and 48.9% (n = 239) were female. The average daily smartphone usage for all adolescents was 5.20 hours (SD = 1.97), with females averaging 5.86 hours (SD = 1.87) and males averaging 4.58 hours (SD = 1.87). Among the participants, 116 were classified as potential-risk groups for SO, and 14 individuals fell into the high-risk group for SO. The participant characteristics are presented in Table 1.

Table 1. *Characteristics of Participants (N = 489)*

	M (SD) or N (%)		
	Male	Female	Total
Gender	250 (51.1)	239 (48.9)	489 (100)
Age	14.55 (.587)	14.45 (.539)	14.55 (.578)
Grade			
2nd-Grade	97 (38.8)	115 (48.1)	212 (43.4)
3rd-Grade	153 (62.1)	124 (59.9)	277 (56.6)
Regions			
Seoul	43 (17.2)	45 (18.8)	88 (18.0)
Gyeonggi-do	78 (31.2)	77 (32.2)	155 (31.7)
Incheon	12 (4.8)	15 (6.3)	27 (5.5)
Daejoen	19 (7.6)	17 (7.1)	36 (7.4)
Chung-buk	18 (7.2)	17 (7.1)	35 (7.2)
Busan	18 (7.2)	7 (2.9)	25 (5.1)
Jeolla-do	26 (10.4)	24 (10.0)	50 (10.2)
Gyeongsang-do	36 (14.4)	37 (15.5)	73 (14.9)
Smartphone usage time (Average hours per day)	4.58 (1.87)	5.86 (1.87)	5.20 (1.97)
Age at first use of smartphone	10.68 (2.14)	9.98 (2.19)	10.34 (2.19)
Smartphone overdependency			
High-risk group	5 (1.0)	9 (1.8)	14 (2.9)
Potential-risk group	48 (9.8)	68 (13.9)	116 (23.7)
Non-risk group	197 (40.3)	162 (33.1)	359 (73.4)

Data Analysis

The collected data were analyzed using SPSS (v.21.0). An exploratory factor analysis was conducted to assess the reliability and validity of the PP scale. *T*-tests were carried out to investigate gender differences in key variables, and Pearson's correlational analysis was employed to examine the relationships among the primary constructs. Finally, using mean-centered data, hierarchical regression analysis was performed to examine the impact of BAS/BIS and PP on adolescents' SO, including any interaction effects.

Measure

BAS/BIS

To measure individual differences in BAS/BIS, we utilized the BAS/BIS Scales developed by Carver and White (1994) and standardized in Korean by Kim and Kim (2001). The scale was adapted for ease of comprehension by adolescents, with researchers making some modifications to the items and subjecting it to review by a clinical psychologist before use. This scale consists of 4 subfactors and 20 items: BAS-reward responsiveness (5 items), BAS-drive (4 items), BAS-fun seeking (4 items), and BIS (7 items). Cronbach's α for BAS was .88. Also, in this study, we aimed to measure the concept of 'anxiety,' which is distinct from the 'fear' aspect of BIS. Based on the study by Corr and McNaughton (2008), we measured BIS using the remaining 5 items, excluding the 2 items related to fear. The reliability coefficient for the 7 items was .70, while the reliability coefficient for the 5 items was .78.

Smartphone overdependence

The Smartphone overdependence Scale from the NIA (2017) was used. This scale consists of 3 subdimensions: Control Failure (3 items, diminished control over smartphone use), Salience (3 items, prioritizing smartphone use), and Problematic Results (4 items, continued smartphone uses despite negative consequences). Re-

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sponses are rated on a four-point Likert scale. In adolescents, a total score of 31 indicates high-risk group for SO, while 30 to 23 suggests potential-risk group for SO. Cronbach's α was .87.

Peer Pressure

In this study, we aimed to measure PP which is directly related to smartphone use. However, existing instruments capable of measuring these concepts were lacking, so the researchers created and used our own items. For example, an item measuring normal peer pressure might be "When I'm with my friends, I often feel the pressure to do things I wouldn't normally do." However, the scale developed by the researchers consists of items such as "Even when I want to take a break and relax, I have to keep going because my friends don't like it when I leave a messenger chat or a game in the middle."

Procedure for developing the measure of PP

Step 1: preliminary item construction

We conducted a literature review of previous studies on peer pressure (Oh, 1989; Yoon, 2005; Yoon & Kwon, 2011; Jo & Jung, 2009; Berndt, 1979; Palani & Mani, 2016) and found that peer pressure has both positive and negative impacts on adolescent behavior. Therefore, we designed the PP scale to encompass the positive and negative aspects of peer relationships in the context of smartphone use. On the negative aspect, we incorporated a tendency to use smartphones more to avoid feeling excluded by peers (Yoon & Kwon, 2011). To address this, we referred to the FOMO Scale (Przybylski et al., 2013) and adapted it to the Korean cultural context, following the version by Joo et al. (2018). For the positive aspect, we included a tendency to use smartphones more to maintain or enhance peer relationships. For this, we adopted the 'Measuring Online Communication Attitude (MOCA)' concept developed by Ledbetter (2009) reflecting relationship maintenance and dependency related to same-gender peers. Additionally, we acquired insights from the peer pressure vulnerability scale and peer popularity acceptance scale developed by Santor et al. (2000).

To incorporate the unique characteristics and culture aspects specific to adolescents' smartphone use behaviors, not covered in existing peer-related scales, we conducted Focus Group Interviews (FGIs). FGIs involved eight middle school students (4 boys and 4 girls), with interview lasting approximately 120 minutes. Prior to the interview, we prepared questions based on previous research that explored the relationships between adolescents, peers, and SO (Kim et al., 2016; Lee, 2015; Jo et al., 2020; Yi, 2014). Identical questions were presented to all participants, and the interview contents were recorded. After reviewing the interview contents repeatedly, we selected sentences that were consistently reported and considered to represent the thoughts, culture, and behaviors of adolescents related to smartphones. This process resulted in a total of 14 preliminary items for the scale.

Step 2: refinement of preliminary items and content validity check

To assess content validity, we employed Polit et al. (2007) method, which involved four experts rating each item on a 4-point Likert scale (1 point: not suitable at all to 4 points: highly suitable). Content validity was determined based on the proportion of experts finding each item suitable for measuring the intended concept. The experts, including a clinical psychologist, a child psychology professor, a youth counseling specialist, and a child psychology doctoral student, all with extensive experience in adolescent research and counseling, assessed the 14 preliminary items. Items with a score of 2 were revised based on expert opinions, while two items scored 1 were removed. After revisions and eliminations, a panel of three experts, including a scale development specialist, an addiction expert, and a clinical psychologist, reviewed the items. This process confirmed that all items in the final tool effectively measured the intended concept, resulting in a 12-item scale.

Step 3: reliability and validity verification

First, we collected responses from 489 participants and assessed data normality using various statistics such as mean, standard deviation, skewness, and kurtosis for each item. The validation results showed that the average scores for all 12 items ranged from 1.74 to 3.06, with standard deviations between 1.03 and 1.24. All items met the normality assumptions, as indicated by skewness (ranging from -.34 to 1.32) and kurtosis (ranging from -1.03 to 1.01) (West et al., 1995). When evaluating reliability coefficients for item removal, no item had a Cronbach's α below .85, indicating that no items needed to be eliminated. To assess the suitability of the collected data for factor analysis, we conducted the Kaiser-

Meyer-Olkin (KMO) and Bartlett's sphericity test. The KMO value of .880 confirmed the data's suitability, and Bartlett's sphericity test was significant ($\chi^2 = 2{,}172.3$, $p < .001$), validating its appropriateness for factor analysis. Due to substantial inter-factor correlations, we utilized an oblique rotation method for analysis (Seo et al., 2018). We performed common factor analysis using the maximum likelihood method (MLM) while considering the collected data as a sample rather than a population. This analysis yielded two factors with factor loadings exceeding .3 (.431-.793), demonstrating the quality of the items as good (Crocker & Algina, 1986). Eigenvalues, scree plots, and item content were assessed to determine the appropriate number of factors. The scree plot suggested that one to two factors were suitable (Hayton et al., 2004, as cited in Seo et al., 2018). However, following Gorsuch's (1983) guideline, if the eigenvalue of the first factor is at least three times the value of the second-highest eigenvalue, the scale can be considered unidimensional. In our study, the first factor had an eigenvalue of 5.00, and the second factor had an eigenvalue of 1.39, making it acceptable to merge them into a single dimension. Moreover, as this scale was designed to capture the overall characteristics of smartphone use patterns in adolescent peer groups, it was more appropriate to treat it as a unidimensional construct. Performing factor analysis with a fixed factor input of 1, the KMO value and Bartlett's sphericity remained at an acceptable level (KMO = 0.880, $\chi^2 = 2{,}172.3$, $p < .001$). The single factor had an eigenvalue of 5.003, explaining 41.69% of the total variance. Calculating the internal consistency (Cronbach's α) for the entire scale and individual subfactors, we found that item reliability generally exceeded .30. The overall scale reliability was .87, indicating good item-to-item consistency. This scale consists of 12 items, rated on a 5-point Likert scale (1 point: not at all true to 5 points: always true), with a total score of 60 points, where higher scores indicate a stronger influence of PP on smartphone use. The results of the factor analysis, including item content and factor loadings, are presented in Table 2.

Table 2. *Factor Analysis Results of the PP Scale (N = 489)*

Contents of items	Factor loadings	
9. If my friends contact me, I always keep my smartphone nearby and check immediately because I'm afraid my friends will get annoyed if I don't respond right away.	.693	
7. Even when I want to take a break and relax, I have to keep going because my friends don't like it when I leave a messenger chat or a game in the middle.	.695	
3. I feel like I have to participate in group chat rooms, even if I have to force myself, because my friends will criticize me if I'm not actively participating or if I leave.	.689	
4. I have to visit my friends' social media profiles frequently because my friends like it when I leave comments on their posts.	.684	
5. I feel that if I reduce my smartphone usage, I will have trouble communicating with my friends and our relationship will suffer.	.684	
8. To join in my friends' conversations, I must watch the contents (webtoons, videos, personal broadcasts, etc.) that my friends recommend as interesting.	.651	
6. To communicate well with my friends, I have to use my smartphone for at least 2 hours every day.	.630	
2. To communicate effectively with my friends, I have to check and respond to messenger messages as soon as they come.	.549	
1. Even if I don't like it, I have to accept invitations to group game rooms or group chat rooms when my friends invite me.	.490	
10. I think that SNS and messenger apps help maintain relationships with my friends because I can communicate with them at any time.	.474	
12. When I play games with my friends on my smartphone or watch the same video and chat, I feel a strong sense of closeness.	.459	
11. When I have something important to say, I feel that it's more natural to convey it through a messenger app rather than meeting in person and talking.	.458	
Eigenvalue	5.003	
KMO (Kaiser–Meyer–Olkin)	0.880	
Bartlett test of sphericity test	Chi-Square	2,172.300
	df (p)	*66 (.000)*

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Results

Descriptive Statistics and Correlations between the Variables

The status and correlations among the key variables in this study are presented in Table 3 below. Examination of gender-based differences in key variables revealed that females exhibited significantly higher BAS ($p < .05$) and BIS ($p < .001$) scores compared to males. Additionally, SO levels were significantly higher in females ($p < .001$), while smartphone use encouragement by peer groups showed similar levels for both genders. Correlational analysis showed that BAS had a significantly positive association with SO in both male and female groups (male $r = 0.27$, female $r = 0.27$, $p < .01$). Similarly, BIS showed a significantly positive association with SO in both male and female groups (male $r = 0.38$, female $r = 0.33$, $p < .01$). PP and SO were significantly positively correlated in both male and female groups (male $r = 0.54$, female $r = 0.51$, $p < .01$). Furthermore, after performing the Fisher transformation and z-test to examine differences in the magnitude of each correlation coefficient, it was found that the correlation between PP and SO was significantly stronger than the correlations between BAS/BIS and SO ($p < .05$) in both male and female.

Mediational Analysis

The results of hierarchical regression analysis on the influence of

Table 3. *Means, Standard Deviations, Correlations Among Variables (male n = 250, female n = 239)*

Variable	M (SD)		$t^{\dagger}$	1	2	3	4
	Male	Female					
1. BAS	31.74 (7.72)	33.25 (7.34)	-2.21*	1	0.31**	0.21**	0.27**
2. BIS	12.00 (3.58)	13.76 (3.40)	-5.56***	0.64**	1	0.32**	0.33**
3. PP	27.88 (9.10)	28.17 (8.62)	-0.36	0.32**	0.38**	1	0.51**
4. SO	17.91 (5.77)	19.91 (5.29)	-3.82***	0.27**	0.38**	0.54**	1

*Note. lower left triangle = male; upper right triangle = female; BAS = Behavioral Activation System; BIS = Behavioral Inhibition System; PP = Peer Pressure; SO = Smartphone Overdependence, **p < .01 (all two-tailed).*
*†t-test result; *p < .05, ***p < .001 (all two-tailed).*

Table 4. *Regressions Summary for BAS (male n = 250, female n = 239)*

Predictor		Male					Female				
		B (β)	*t*	R^2	ΔR^2	*F*	*B* (β)	*t*	R^2	ΔR^2	*F*
Step 1:	BAS	0.20 (0.27)	4.42***	0.07	0.07	19.57***	0.22 (0.27)	4.27***	0.07	0.07	18.22***
Step 2:	BAS (A)	0.08 (0.11)	1.93	0.31	0.23	82.92***	0.13 (0.17)	2.99**	0.29	0.22	71.56***
	PP (B)	0.32 (0.51)	9.11**				0.32 (0.48)	8.46***			
Step 3:	BAS (A)	0.12 (0.16)	2.11**	0.33	0.02	7.49**	0.13 (0.16)	2.86**	0.29	0.00	0.13
	PP (B)	0.32 (0.50)	9.11***				0.32 (0.48)	8.29***			
	A × B	0.01 (0.15)	2.74**				0.00 (-0.02)	-0.36			

Note. BAS = Behavioral Activation System; PP = Peer Pressure.
***p < .01, ***p < .001 (all two-tailed).*

Table 5. *Regressions Summary for BAS (male n = 250, female n = 239)*

Predictor		Male					Female				
		B (β)	*t*	R^2	ΔR^2	*F*	*B* (β)	*t*	R^2	ΔR^2	*F*
Step 1:	BIS	0.61 (0.38)	6.47***	0.14	0.14	41.83***	0.56 (0.33)	5.32***	0.11	0.10	28.28***
Step 2:	BIS (A)	0.33 (0.20)	3.63***	0.33	0.19	69.05***	0.31 (0.18)	3.10**	0.29	0.18	60.70***
	PP (B)	0.30 (0.47)	8.31***				0.30 (0.45)	7.80***			
Step 3:	BIS (A)	0.38 (0.24)	4.16***	0.35	0.02	5.94*	0.31 (0.18)	3.10**	0.29	0.00	0.42
	PP (B)	0.31 (0.49)	8.65***				0.30 (0.44)	7.30***			
	A × B	0.02 (0.13)	2.44*				0.01 (0.04)	0.65			

Note. BIS = Behavioral Inhibitiob System; PP = Peer Pressure.
**p < .05, **p < .01, ***p < .001 (all two-tailed)*

PP on the relationship between BAS and SO are presented in Table 4. First, in the male group, BAS explains 7% of the variance in SO in the first step. When examining the main effects, the BAS significantly predicted SO levels ($B = 0.20$, $\beta = 0.27$, $p < .001$). In the second step, with the introduction of PP, the main effect of BAS did not reach statistical significance. However, the PP accounted for 31% of the variance in SO and significantly predicted SO levels ($B = 0.32$, $\beta = 0.51$, $p < .01$). In the third step when the interaction term for BAS and PP is introduced, the explanatory power increases by 2%, and the interaction effect is significant. In the female group, the main effects were significant. BAS statically predicts SO levels ($B = 0.22$, $\beta = 0.27$, $p < .001$), while PP is also confirmed as a significant factor influencing SO ($B = 0.32$, $\beta = 0.48$, $p < .001$). However, the moderating effect was not significant.

The results of hierarchical regression analysis on the influence of PP on the relationship between BIS and SO are presented in Table 5. First, in the male group, BIS explains 14% of the variance in SO in the first step. When examining the main effects, the BIS significantly predicted SO levels ($B = 0.61$, $\beta = 0.38$, $p < .001$). In the second step, with the introduction of PP, the main effect of BIS and PP accounted for 33% of the variance in SO and significantly predicted SO levels (BIS: $B = 0.33$, $\beta = 0.20$, $p < .001$, PP: $B = 0.30$, $\beta = 0.47$, $p < .001$). In the third step when the interaction term for BIS and PP is introduced, the explanatory power increases by 2%, and the interaction effect is significant. In the female group, the main effects are significant. BIS statically predicts SO levels ($B = 0.56$, $\beta = .33$, $p < .001$), while PP is also confirmed as a significant factor influencing SO ($B = 0.30$, $\beta = 0.45$, $p < .001$). However, the moderating effect was not significant.

The interaction patterns in the male group were expressed as a regression line based on specific values of PP:1 *SD* above the mean, mean, 1 *SD* below the mean (Aiken & West, 1991). The results are shown in Figure 1. In the simple slope analysis, when PP was 'low (-1 *SD*),' the influence of BAS/BIS on SO was not significant (BAS: $B = 0.03$, $t = 0.55$, $p > .05$, BIS: $B = 0.19$, $t = 1.80$, $p > .05$). On the other hand, when PP levels were 'mid (M)' (BAS: $B = 0.12$, $t = 2.69$, $p < .01$, BIS: $B = 0.38$, $t = 4.14$, $p < .001$) and when PP levels were 'high (+1 *SD*),' the impact of BAS/BIS on SO was statistically significant (BAS: $B = 0.21$, $t = 3.34$, $p < .01$, BIS: $B = 0.57$, $t = 4.26$, $p < .01$). In other words, in the group less influenced by PP, the influence of BAS/BIS on SO is not substantial. However, in the group where PP has a moderate to high influence, an increase in BAS/BIS levels corresponds to a greater increase in SO levels.

Discussion

This study aimed to investigate peer group norms directly associated with smartphone usage and explore the influence of this environmental factor on SO. Simultaneously, it sought to examine the relationship of intrinsic individual factors closely linked to SO, such as BAS/BIS, and to determine whether these intrinsic and extrinsic variables functioned as predictive factors for adolescents' SO. The research findings are as follows: Firstly, the scale used in this study to measure PP related to smartphone usage exhibited

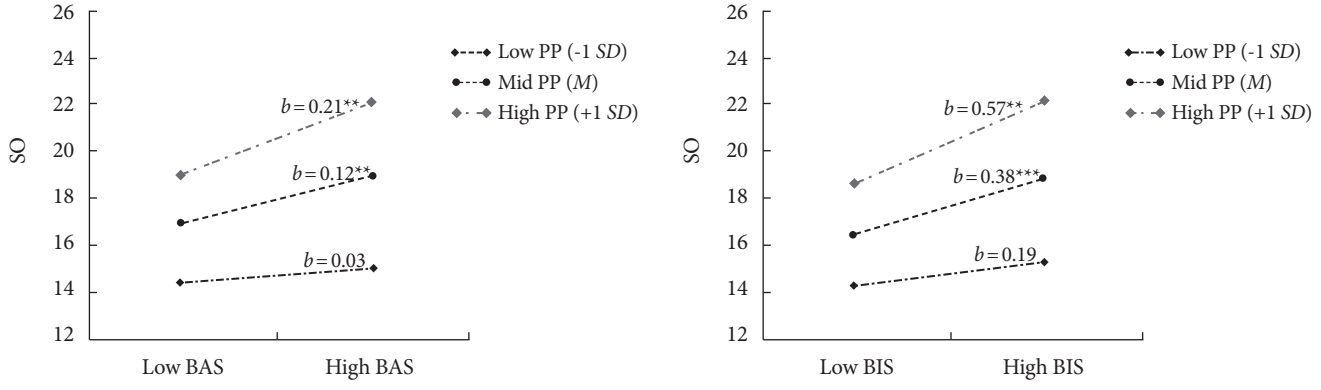

Figure 1. *Moderating effects of PP on the relationship between BAS/BIS and SO in the male group.*
*Note. SO = Smartphone Overdependence; BAS = Behavioral Activation System; BIS = Behavioral Inhibition System; PP = Peer Pressure; b = B (Unstandardized Coefficient). **p < .01, ***p < .001.*

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appropriate levels of reliability and validity. Consequently, this scale is considered useful for measuring the tendency of adolescents to use smartphones more to avoid isolation from or maintain close relationships with their peers. Kim et al. (2016) also emphasized the importance of recognizing the dependency on smartphones for maintaining peer relationships as a crucial factor for effective interventions related to SO. In the same context, it is anticipated that this scale can be utilized as a tool in clinical interventions to help adolescents recognize that PP related to smartphone usage can increase their risk of SO.

Secondly, an analysis of gender differences in key variables showed significant disparities in BAS/BIS and SO levels. Specifically, in terms of BAS/BIS levels, females exhibited significantly higher scores compared to males. This is consistent with previous research findings, which reported similar results indicating that BAS/BIS scores for females were higher than those for males (Choi & Yang, 2018; Jiang & Zhao, 2017; Oi et al., 2019). However, this presents a different pattern compared to research results indicating no significant differences in BAS/BIS levels between male and female adolescents (Lee & Kim, 2020). This highlights the potential for diverse patterns based on the age and gender of the study participants. Consequently, there is a need for additional research across various age groups to further explore gender differences in BAS/BIS levels. The level of SO was found to be higher in female students compared to male students, a result consistent with prior research findings and survey results (Kim, 2013; Jeon & Jang, 2014; NIA, 2020, 2021, 2022). However, the finding that female students have higher levels of SO compared to male students can be interpreted in various ways. Relevant studies report that female adolescents tend to actively engage in social networking services (SNS) due to their immersion in social relationships, and this is suggested to contribute to their higher levels of SO (Kim et al., 2016; Kim & Shin, 2015). Alternatively, some studies suggest that the mental health factor such as depression, may be more relevant to SO levels than peer relationships in female students (Kyoung & Kim, 2019). Furthermore, the portability and immediacy of smartphones are optimized for effective communication. This has led to reports suggesting that female students who use smartphones for communication and relationship-building purposes tend to have higher SO levels (Lee & Kim, 2020). In addition, many studies propose that female students may be more vulnerable to SO than male students and are influenced by a complex array of factors. Conversely, there were no significant gender differences observed in PP levels. This aligns with the findings of Kim and Lim (2019), who reported no significant gender differences in peer variables related to smartphone dependence, such as peer pressur susceptibility and peer popularity seeking tendencies. In other words, the norms and pressures related to smartphone use among peers may be concepts experienced similarly by adolescent groups regardless of gender. However, the PP measured in this study pertains to PP in specific situations directly related to smartphone use, and since there is a lack of previous research measuring a concept identical to this, further validation with adolescents is needed for a more accurate understanding of these results.

Thirdly, upon examining the correlations among the key variables, it was observed that BAS/BIS exhibited a significant positive association with SO, indicating that higher levels of BAS/BIS correspond to higher levels of SO. Furthermore, PP displayed significant positive correlations with SO within both male and female groups. Importantly, when comparing the correlation coefficients for statistical significance, it was confirmed that in both male and female adolescents, PP exhibited significantly stronger associations with SO compared to BAS/BIS. In other words, PP is strongly linked to adolescents' SO, possibly due to their strong desire for connection and relationships with their peers. A previous study reported that adolescents have conformity dispositions, and they are willing to accede to PP (Brown et al., 1986). Another study noted that adolescents high in the need for belonging will use the smartphone more than adolescents low in the need for belonging, putting them at a higher risk of smartphone addiction (Wang et al., 2017). This supports our finding that the PP inciting smartphone usage has a strong association with SO.

Fourthly, the results of examining the influence of BAS/BIS on SO depending on the level of PP are as follows. To begin with, regarding the main effects, BAS/BIS was identified as a statistically significant predictor of SO levels in both male and female groups, consistent with previous research findings. Similarly, PP also statistically influenced SO in both male and female groups. These findings align with Lee's (2016) research, which proposed that adolescents increase smartphone usage to build trust, facilitate effec-

tive communication, and alleviate feelings of social exclusion in their peer groups. Furthermore, the results of interaction tests revealed a significant moderating effect in the male adolescent group. Specifically, when PP levels were mid (*M*) or high (+1 *SD*), a positive relationship between BAS/BIS and SO was observed in the male adolescent group, indicating that higher levels of PP could enhance the impact of BAS/BIS characteristics on SO. The male group more influenced by PP showed SO levels approaching the range of potential-risk group for SO as their BAS/BIS levels increased. In other words, as our study targeted general adolescents rather than clinical groups experiencing smartphone addiction, the current average SO scores of the study participants may not reach potential or high-risk levels. Nevertheless, our findings indicate that, especially in the male adolescent group, through the interaction between BAS/BIS and PP, adolescents who are more influenced by peer norms are more likely to approach the potential-risk group level (23 points). This underscores the importance of preventive interventions, particularly for reducing peer influence in male adolescent groups. On the other hand, the male group less influenced by PP showed almost no difference in SO levels based on BAS/BIS levels. This suggests that the male group less affected by PP may potentially represent individuals with high self-regulation capabilities. In other words, despite BAS/BIS traits, individuals in this group seem capable of controlling their intrinsic tendencies. Therefore, it is expected that both PP and smartphone usage habits can be effectively regulated, it can be presumed that the level of SO is lower in this group. However, a precise understanding of these aspects would necessitate further exploration through relevant studies.

In the case of females, there were significant main effects of BAS/BIS and PP on SO, but the moderating effect of PP in the relationship between BAS/BIS and SO was not significant. The gender difference in this interaction effect may be attributed to the vulnerability of female adolescents to SO. Referring to the presented data, females exhibit significantly higher scores on the BAS/BIS scale, particularly on BIS related to anxiety about social exclusion. Additionally, the SO level of females was significantly higher, and the age at the first use of smartphones was earlier. Furthermore, Korean females prioritize relationships and a sense of belonging more than males and experience higher levels of FOMO (Joo et al., 2018). In other words, regulating anxiety related to social exclusion or controlling BAS/BIS tendency may be more challenging for females. Therefore, in the case of the female group, although the interaction effect was not significant in this study, there is a possibility that diverse interactions may exist among the vulnerabilities related to smartphone usage mentioned above.

Lastly, the most crucial finding of this study is the significant role of peer norms and pressures in predicting adolescents' SO level. Our results demonstrate that the explanatory power for SO significantly improves when considering both personal intrinsic factors, BAS/BIS, and external environmental factor, PP, in both male and female adolescent groups. Therefore, this study emphasizes the critical importance of peer norms and pressure, particularly in the context of smartphone use, as vital contributors to SO among adolescents. Furthermore, this research suggests that interventions focusing on promoting a peer culture that actively encourages wise smartphone use may be more effective than interventions solely emphasizing limitations on smartphone use. In other words, while individual therapy is crucial for adolescents with severe smartphone addiction, our results emphasize the need for preventive interventions aimed at fostering a culture where adolescents collectively engage with smartphones in a healthier manner. Previous studies on interventions for adolescents with smartphone addiction have often emphasized the significance of enhancing self-regulation skills. However, some studies have reported that this approach is effective in reducing resistance to addiction but does not significantly alleviate daily life impairment or withdrawal symptoms (Kim et al., 2015; Kim et al., 2013; Kim et al., 2020, as cited in Kim et al., 2020). Moreover, research investigating preventive programs for general users highlighted the effectiveness of activities that help individuals recognize negative emotions stemming from excessive smartphone use and explore alternative behaviors (Lee & Kim, 2019). Applying these insights to our findings, it appears beneficial to structure preventive intervention programs for adolescents by addressing peer pressure-related stress and exploring alternative activities to reduce involvement with such pressures. Additionally, a study by Shin and Jeong (2018) found that peer group discussions among friends about the potential risks associated with internet and smartphone content effectively reduced smartphone addiction levels, while parental interventions had minimal

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impact. Many studies have emphasized the importance of improving each other's smartphone usage habits and enhancing peer support to increase the effectiveness of adolescent smartphone addiction treatment programs (Avci et al., 2023; Jeon & Jeon, 2017). These findings support the proposal in our study that peer group interventions are crucial for establishing healthy media usage habits among adolescents. Therefore, expanding intervention programs in schools that enable adolescents to monitor each other and take on support roles within their peer groups can be a useful method for preventing SO among adolescents.

This study has several limitations. Firstly, our research sample consisted solely of second- and third-grade middle school students, necessitating further research that includes a broader age range to produce results more universally applicable to the entire adolescent population. Secondly, the measurement tool developed by the reseachers underwent validation and reliability analysis based solely on data collected within this study, without a preliminary investigation. Consequently, a supplementary phase involving extensive verification and confirmation of reliability and validity through follow-up studies is imperative. Thirdly, in our study, SO encompassed all smartphone content; however, it is crucial to recognize that issues related to smartphone use go beyond just overuse. Different usage patterns or intentions can lead to various other problems, independent of excessive use, as smartphones can enable activities such as online gambling, pornography consumption, social media engagement, gaming, etc. (Panova & Carbonell, 2018). Hence, future research should categorize usage based on patterns or intentions. Despite these limitations, the present study provides insight into and understanding of the strong effect of PP on smartphone use among adolescents. We expect that the results of this study can be applied as useful data for more effective prevention and educational intervention for adolescents in schools and clinical settings.

Author contributions statement

CJA, a graduate of Hanyang University and current clinical psychology intern at Gyeonggi Provincial Medical Center Uijeongbu Hospital, Department of Clinical Psychology, conceptualized and designed the research, collected and analyzed the data, and wrote the original draft of the manuscript. HSK, a professor at Hanyang University, supervised the research process, and reviewed the manuscript. All authors provided critical feedback, participated in the revision of the manuscript, and approved the final submission.

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Clinical Validity of Neuropsychological Assessment in Dementia: A Univariate and Multivariate Methodological Comparison

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Previous studies have documented validity evidence of neuropsychological measures in the assessment of dementia. However, known cognitive test measures were mostly validated as separate measurements rather than asconstituents of a whole battery. In this study, the neuropsychological battery (CERAD-K) and neuropsychiatric measures were acquired in older adults with Mild Cognitive Impairment, dementia of Alzheimer's Disease (AD), and Vascular dementia (VD). The assessment measures and demographic information were used to predict two validity criteria: dementia severity (CDR) and dementia type (AD or VD). A correlation between a single test measure and the target criteria indicated univariate validity, whereas relative importance among multiple regression models indicated the multivariate validity of a single measure as a constituent of the battery. We identified that test measures including the Boston Naming Test, Trail Making Test, and Word List Recall were predictive of the clinical outcome criteria as univariate validity; however, this strength of association did not remain consistent when evaluated in terms of multivariate validity. Regarding the multivariate validity, measures including Word List recognition, and neuropsychiatric impairment showed robust validity. This contrasting validity indices between univariate and multivariate frameworks may be owing to shared information between other measures, which can distort the conclusions of validity evidence. The findings suggest that the validity of a neuropsychological test differs as a function of the target criteria and whether administered as a whole battery. The findings suggest that the validity of a neuropsychological measure differs as a function of the criteria of clinical context and whether tested under a comprehensive battery.

Keywords: neuropsychological assessment, validity, multivariate, dementia

Introduction

Neuropsychological assessment aims to clarify neurological conditions and describe detailed characteristics of functional impairment (Fields et al., 2011). Typically, combined batteries of ratings and test scores are integrated during interpretation, which subsequently leads to clinical decisions (Vakil, 2012). Individuals with dementia due to specific types of neurological diseases are also administered with a known set of test batteries that were validated to have clinical utility in diagnosing and describing the severity and differential pathology types (Elahi & Miller, 2017).

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Ongoing examinations on the validity of neuropsychological tests have established cornerstones of how clinicians should select and construct a set of tests that can be applied to target illness (Garb & Schramke, 1996). The previous examinations on test validity, however, have shown how individual test evidences their validity as separate measurements. Here, the logical gap lies in the fact that test measures are not validated as a whole set as a battery even when practitioners integrate multiple measures acquired from a set of tests. Thus, the individual tests that constitute a neuropsychological battery should evince their validity under the context of battery composition, rather than as a single independent measure (Russell et al., 2005). Also, a test battery should cover a wide range of clinical purposes since potential clinical conditions are yet unnarrowed. It is likely that previously validated tests examined under a single measurement may not be generalized as valid tests within a whole battery.

The scope of the test validity also regards how the tests are quantified of their validity. One of the main approaches to evidence the test validity is to show the extent of concurrency and predictability to the clinical outcome of interest (Anastasi, 1950; Strauss & Smith, 2009). While the criterion validity of a single test measure can be examined as a univariate association between the test measure and clinical outcome, the validity of a whole set of tests can be examined as a multivariable association between test measures and clinical outcomes. In this case, the validity of a subtest can be evaluated in terms of its accountability of whole subtests (i.e., actuarial method), and this approach tends to provide more reliable and accurate diagnostic findings (Carlew et al., 2023; Fountain-Zaragoza et al., 2021). Specifically, there can be cases when a test is not useful among a whole comprehensive neuropsychological battery yet shows a sound univariate validity because the shared redundancy between the tests is not considered in the univariate examinations. If a test measure shares predictive value with other comprising measures, then the test validity can be undermined, whereas greater uniqueness of a test leads to larger validity as constituents among a battery. This multivariable nature of the test battery can directly be tested with quantifiable metrics and the resulting quantified validity index can aid as the rationale for selecting specific tests that have been determined by experienced clinicians.

Recent studies have utilized how combining multiple measures can aid findings in dementia assessment. For example, previous studies have shown that the reliability of diagnostic classification on mild cognitive impairment can be enhanced when conjointly using multiple measures rather than applying a single test cutoff (Bondi & Smith, 2014; Graves et al., 2020). Other multivariable approaches combined as a predictive model showed the potential to enhance the utility in the assessment of dementing outcomes (Chapman et al., 2010; Kwak et al., 2022; Nation et al., 2019; Stallard et al., 2022). Despite the evidence of the enhanced predictability of multivariate approaches, previous studies lacked detailed examinations of how individual measures contribute to the total criterion validity which would be referenced in the clinician's decision in test selection. In order for clinicians to aid battery construction, the subtests should be subject to validity evaluation (Garb & Schramke, 1996).

Another issue in quantifying the validity of neuropsychological battery is how the test validities can differ by the clinical context of the assessment and validity criterion. In the case of dementia assessment, for example, a particular test can claim its validity under differential diagnosis of dementia types, whereas some other tests may retain validity in predicting overall daily functioning (Bruun et al., 2018; Fields et al., 2010; Kwak et al., 2021; Nyenhuis et al., 2004). Neuropsychological test information may have differing utility in either identifying biological etiology in a medical context or assessing ecological functioning in a rehabilitation context. Indeed, a test with evidence of both aspects would be the most desirable case, the tests can also play a role under a specific validity context. A direct comparison of the two validity contexts has not been thoroughly examined in the studies of dementia assessment instruments.

Concurring knowledge of neuropsychological test validities is converged mostly based on the examination of each test as a single measure. This could lead to profoundly different conclusions. For example, a test that requires multiple processes (e.g., verbal fluency, trail making test) can exhibit strong utility in predicting clinical outcomes of interest. But the very conclusion may not coincide when tested under multiple sets of measures that are typically administered as a battery. To our knowledge, this discrepancy between univariate versus multivariate validity has not been exam-

ined previously.

Thus, the current study aimed to examine how measures of neuropsychological assessment are predictive of (1) overall functional impairment across the spectral population of cognitive impairment, and (2) differential diagnosis between Alzheimer's disease and vascular dementia. In this way, each assessment measure is evaluated for whether retains criterion validity under specific clinical contexts.

Methods

Participants

The older adults with cognitive impairment were retrospectively recruited from SMG-SNU Boramae Medical Center for Dementia from January 2012 to January 2021. The retrospective dataset was extracted from the in-house clinic database available. The participants underwent both neuropsychological assessment and structured clinical interview. This study was conducted under the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board of SMG-SNU Boramae Medical Center for Dementia (IRB No. 10-2020-295). The current study included older adults with Mild Cognitive Impairment (MCI), dementia of Alzheimer's Disease (AD), and Vascular dementia (VD). The clinical diagnosis of the probable or possible AD and MCI was based on the National Institute of Neurological and Communicative Disorders and Stroke and AD and Related Disorders Association (NINCDS-ADRDA) and the core clinical criteria of MCI (Albert et al., 2011; McKhann et al., 1984). The VD was diagnosed according to the National Institute of Neurological Disorders and Stroke/Association Internationale pour la Recherche et l'Enseignementen Neurosciences criteria (Román et al., 1993). The other dementia types were not considered as analyses of interest due to insufficient sample size. In cases of multiple follow-ups, the diagnosis and test measures of the first neuropsychological evaluation were analyzed.

Subjects suspected or diagnosed with dementia types other than AD or VD were not included in the analysis, including Lewy body dementia and frontotemporal lobe dementia. In addition, those identified or suspected of significant neurological or psychiatric conditions including traumatic brain injury, meningioma, subdural hemorrhage, normal pressure hydrocephalus, delirium, intellectual disabilities, and psychotic disorders were excluded. We confined our predictive analysis within the dementia staging of 'moderate' impairment (Clinical Dementia Rating sum of box score ≤ 15.5) (O'Bryant, 2008). The group size differed across diagnoses (MCI: $n=1,025$; AD: $n=1,262$; VD: $n=266$), and the validity evaluation set was comprised of two sets: (1) cognitive impairment severity (MCI, AD, and VD; $n=2,553$), (2) differential diagnosis (AD and VD; $n=1,528$). Descriptive statistics and histograms are shown in Table 1 and Figure 1.

Table 1. *Demographic Characteristics*

	Total	MCI[a]	AD[a, b]	VD[a, b]
Mean (SD)/Frequency				
n	2,553	1,025	1,262	266
Age	76.60 (7.80)	73.26 (7.26)	79.14 (7.15)	77.47 (7.96)
Education	7.37 (5.07)	8.31 (4.68)	6.66 (5.15)	7.17 (5.51)
Sex (M : F)	1618:935	593:432	873:389	152:114
Global CDR	0.80 (0.47)	0.50 (0.07)	0.97 (0.50)	1.14 (0.59)
CERAD-Total	44.35 (15.18)	55.87 (10.44)	36.77 (12.73)	35.95 (13.03)
NPI	6.72 (4.12)	4.43 (3.96)	7.16 (5.67)	7.90 (5.99)
GDS	6.14 (5.28)	6.23 (4.09)	6.93 (4.07)	7.62 (4.27)

Note. CDR = Clinical Dementia Rating; MCI = Mild Cognitive Impairment; AD = dementia of Alzheimer's disease; VD = Vascular dementia; NPI = Neuropsychiatric Inventory; GDS = Geriatric Depression Scale.
[a]*Included in analysis of Validity A (dementia severity),* [b]*Included in analysis of Validity B (dementia type).*

Neuropsychological assessment

All participants were administered the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease neuropsychological battery (CERAD-K) (Lee et al., 2002). The battery measures multiple domains of cognitive function and facilitates the diagnosis of MCI and dementia. The battery contains the following subtests: Semantic fluency (the number of correct animal words; four blocks of 15s interval), Boston Naming Test, Word List Recall (immediate, delayed), Word List Recognition (subtraction of the number of false positives from the number of true positives), and Constructional Praxis (copy, recall). The additional subtests included in CERAD-K was Trail Making Test A/B (TMT-A and B). The TMT measured the total time spent completing the tasks. The test administration had set the maximum time limit at 360 s (TMT-A) and 300 seconds (TMT-B) based on administration instruction in CERAD-K (Seo et al., 2006). The score was interpolat-

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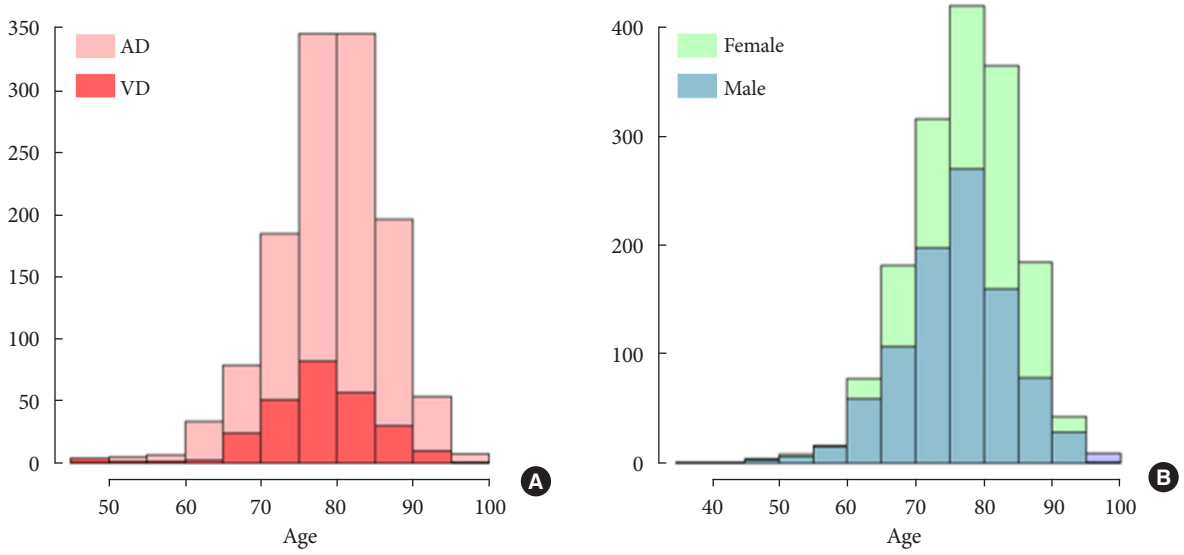

Figure 1. *Age distribution of subgroups.*
Note. (A) AD in light red and VD in dark red. (B) Female in green and male in blue.

ed as the maximum time limit (360s or 300s) in the cases when the TMT was aborted or not feasible due to the following reasons: exceeded the time limit, unable to understand the rule, or committed more than five errors. The scores (seconds) were inverted to have the same directional interpretation. The raw scores without demographic adjustment were used in the analyses. The battery was administered by trained clinical psychologists and trainees supervised by board-certified psychologists.

Neuropsychiatric Inventory (NPI) was used to characterize behavioral, social, and affective symptoms that are relevant to dementing illness (Choi et al., 2000; Cummings et al., 1994). The NPI was based on the semi-structured interview administered to the patients' informants or caregivers, if available, and rated by clinical psychologists. It consists of 12 separate items assessing neuropsychiatric disturbances, including delusion, hallucination, agitation/aggression, depression/dysphoria, anxiety, elation/euphoria, apathy/indifference, disinhibition, irritability/lability, aberrant motor behavior, sleep, and appetite. The symptom severity was rated based on observable behaviors that signify each symptom (e.g., expression of sadness and tears in depression/dysphoria item). Each item was rated from 0 to 3 scores across severity levels (0: No symptom, 1: Symptoms causes mild distress, 2: Symptoms are intractable and cause distress, 3: Symptoms are present with major distress). The summed score of 12 items was used to indicate overall behavioral abnormalities.

As a routinely assessed component of depressive symptoms, the self-reported depressive symptoms were assessed with the Korean version of the short-form Geriatric Depression Scale (GDS) (Bae & Cho, 2004). Questions from the original GDS which had the highest correlation with depressive symptoms in validation studies were selected for the short version with 15 items (Sheikh & Yesavage, 1986).

The validity criterion of overall functional impairment was assessed with the sum of box scores of Clinical Dementia Rating (CDR-SB). The CDR is a semi-structured interview developed to provide a global summary of dementia severity. The CDR is useful for staging and tracking the course of neurodegenerative progression (Fillenbaum et al., 1996; Morris et al., 1997; Morris, 1997). In addition, the sum of boxes score was calculated by summing impairment in six domains of daily cognitive categories (memory, orientation, judgment, community affairs, home and hobbies, and personal care), which provides a more fine-grained measure of functional disturbances within the same category of a global score or clinical diagnosis (Lynch et al., 2005; O'Bryant, 2008). The trained clinical psychologists administered the structured interview and the ratings. As noted in the administration standard, the decisions of CDR scoring were based on the information gathered in a structured interview but not on neuropsychological test per-

formance. The global CDR score ranged from 0 to 1 (MCI), 0.5 to 3 (AD and VD). The CDR-SB ranged from 0.5 to 9 (MCI), 0.5 to 15 (AD), and 1 to 15 (VD).

Statistical analysis

The individual measures that comprise the neuropsychological assessment (i.e., CERAD-K subscores, NPI, GDS) were each examined for clinical validity. Criterion validity was evaluated in how each test measure precisely tracks the target criteria. In the regression models, independent (explanatory) variables constitute test measures, and the dependent variable holds as a criterion to be predicted. The first validity criterion (Validity A) was overall impairment severity (i.e., CDR-SB), and was evaluated with total variance explained (R^2) in linear regression models. The second validity criterion (Validity B) was evaluated as the classification performance of the measures on differential diagnosis (i.e., AD-VD). The classification of the logistic regression models at varying cutoffs was summarized as the Area Under Curve (AUC).

The extent of the validity (i.e., validity index) was evaluated with both univariate and multivariate approaches. The univariate approach simply calculates the pairwise correspondence of the measure to the criterion variable. The multivariate approach fits the multiple regression model to the criterion variable as a whole while excluding a specified target test measure. The decreased amount of accuracy metrics (AUC or R^2) after excluding the target test represented indices of multivariate validity. Multivariate validity index aimed to indicate the unique proportion of information among the given set of the total battery.

The validity examination was conducted by two sets of predictors: (1) cognitive test subscores (CERAD-K), and (2) compiled subtest scores of CERAD-K, demographics, and neuropsychiatric measures. This is because several subtest scores in the CERAD-K result from the common source of test stimuli and procedures which thus produce autoregressive scores, leading to underestimated uniqueness of test scores. In Word List Recall, for example, Immediate Recall inherently has high auto-correlations with Delayed Recall and Recognition scores, which would lower the uniqueness of each subtest. Thus, the subsequent multivariate analysis was conducted after summing the scores under the same subtest unit (Word list: immediate recall, delayed recall, delayed recognition; Construction: copy and delayed reproduction; Fluency: 15 seconds interval scores; TMT: Type A and B) in addition to demographics and neuropsychiatric variables (NPI and GDS).

The correspondence with the two validity criteria was examined, which indicated the extent to which the test holds validity in either clinical context. The mismatching order of effect size between univariate and multivariable testing indicated a differing clinical value of the assessment measurements. Lastly, the full regression models examined total explanatory accuracy with the given measures.

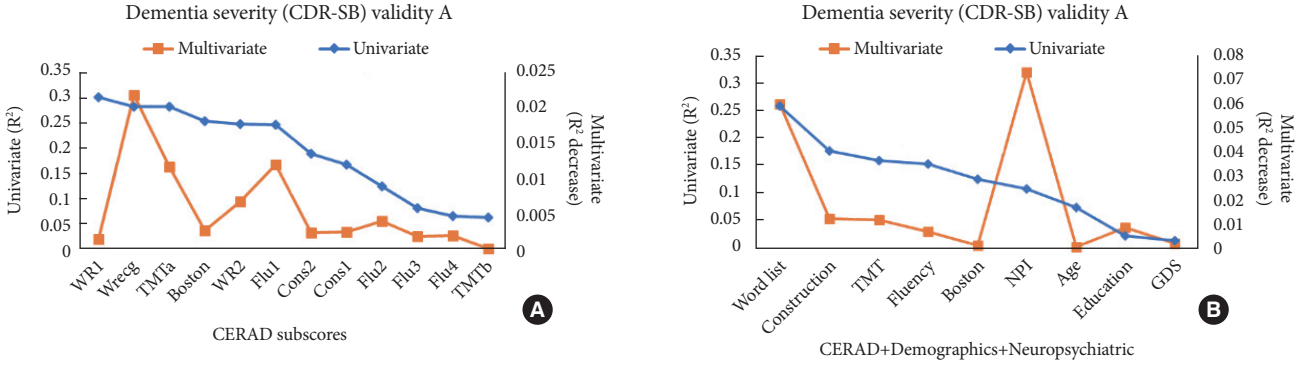

Figure 2. *Univariate and multivariate validity of neuropsychological tests on dementia severity (CDR-SB).*
Note. (A) Results with neuropsychological subtest set. (B) Results combined with demographics and neuropsychiatric measures. Y-axis (A-sided scale) and blue line indicate univariate associations (R^2) between the assessment variables and CDR-SB. Y-axis (B-sided scale) and orange line indicate multivariate contribution (decrease in R^2 when excluded) in the multiple regression model. The subtests are sorted in descending order of univariate validity. CDR-SB = Clinical rating scale-sum of boxes; WR1/2 = Word list immediate/delayed recall; Wrecg = Word list recognition; Cons1/2 = Constructional praxis copy/delayed; TMTa/b = Trail making test A and B; Flu1-4 = Animal fluency (four blocks of 15s interval); Boston = Boston naming test; NPI = Neuropsychiatric Inventory; GDS = Geriatric Depression Scale.

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Results

When examining the difference between univariate and multivariate correspondence with CDR-SB (Validity A), the overall tendency of consistency showed that the measures of high univariate association also showed higher multivariate importance (Figure 2). Specifically, however, Word Recall immediate (WR1) and Boston Naming Test showed a large discrepancy, showing generally low validity in the multivariate approach (Figure 2A). That is, the test scores were associated with CDR-SB individually, but the unique explanatory information was minimally provided. When examined while including demographics and neuropsychiatric variables with more summarized cognitive scores, NPI showed the most distinctive validity difference (Figure 2B). NPI was not the strongest predicting feature as a single univariate score but the multivariate index was superior to other cognitive test measures.

With the same analytic approach, the difference between univariate and multivariate classification accuracy on dementia types (AD vs. VD, Validity B) (Figure 3). Again, the overall tendency showed a general correspondence in that measures of high univariate validity also showed higher multivariate validity. However, specific patterns showed notable discrepancies. While TMT-A worked as a relatively superior univariate classifier of dementia types, it provided almost nonexistent information in the multivariate model (Figure 3A). Moreover, Word Recall delayed (WR2) was not uniquely informative in the multivariate model contrary

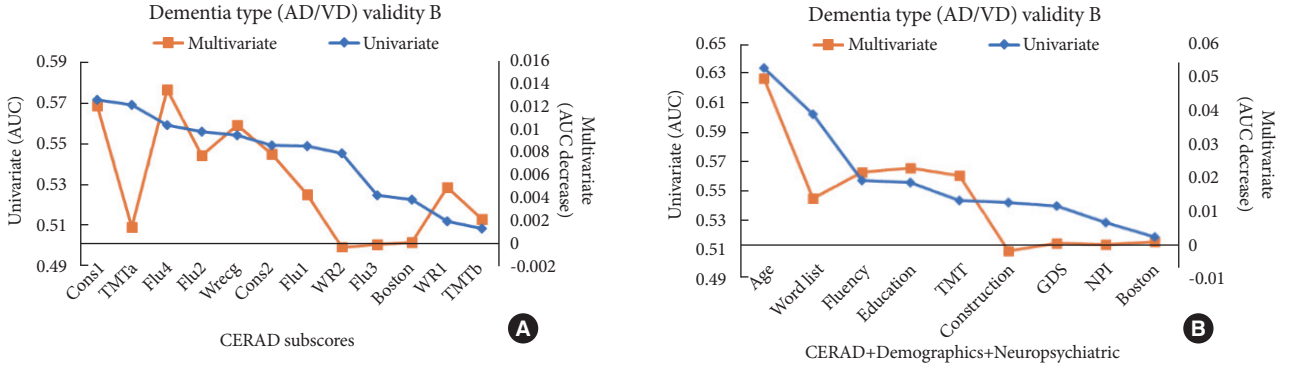

Figure 3. *Univariate and multivariate validity of neuropsychological tests on the differential diagnosis of dementia types (AD vs. VD).*
Note. (A) Results with neuropsychological subtest set. (B) Results combined with demographics (age) and neuropsychiatric measures (NPI). Y-axis (A-sided scale) and blue line indicate univariate classification accuracy (AUC) on dementia types. Y-axis (B-sided scale) and orange line indicate multivariate contribution (decrease in AUC when excluded) in the multiple regression model. The subtests are sorted in descending order of univariate validity.

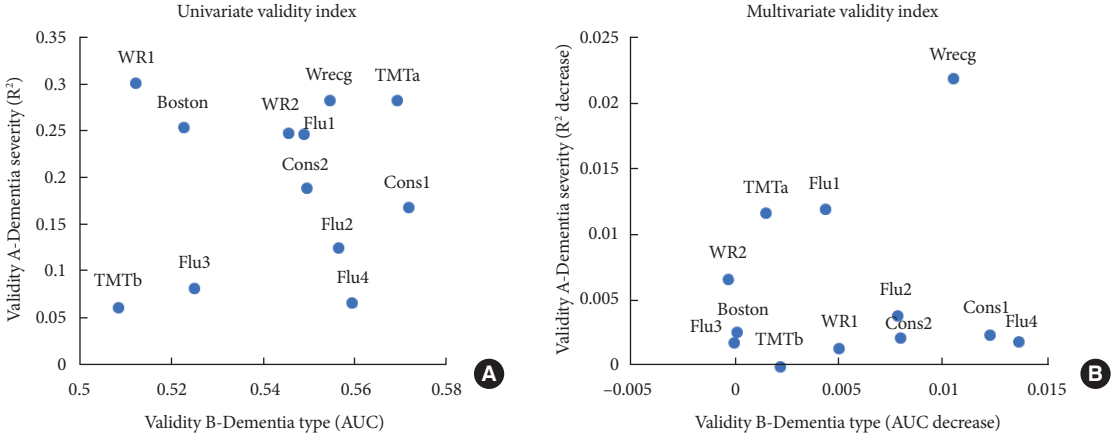

Figure 4. *Correspondence between two different types of validity indices.*
Note. Y-axis: Validity A indicates the amount of unique information of the measures in predicting dementia severity (CDR-SB). X-axis: Validity B indicates unique information in classifying Alzheimer's versus vascular dementia.

to its strong association in the univariate model. When examined by including demographics and neuropsychiatric variables, age showed the strongest validity on the classification in both univariate and multivariate models (Figure 3B).

When mapping the validity indices on the two dimensions of the validity criterion, measures were dispersed as having relatively higher and lower validity in each context (Figure 4). In the univariate approach, the measures did not represent specific validity, and multiple measures reflected both of the validity criteria. When examined as a multivariate approach, the Word List Recognition score showed the highest validity in both contexts of validity indices (Figure 4B). Furthermore, TMT-A and the initial performance of animal fluency (Flu1; performance in 1-15s) showed high contributions in predicting dementia severity, while constructional praxis and relatively later phases of animal fluency (Flu2, 4; performances in 16-30s, 46-60s) showed higher discriminating validity. Boston Naming Test, Trail Making B, Word List, and interim phase of animal fluency (Flu3; performance in 31-45s) showed minimal validity indices under both validity criteria. On the contrary, the univariate validity index shows that TMT-A has superior validity over other tests when examined as a univariate approach (Figure 4A). Similarly, the univariate approach was less dependent on the type of validity, showing that tests were high in both of the validity types.

Lastly, the full regression model that included all of the predictors showed moderate levels of correspondence (adjusted $R^2 = 0.588$, AUC = 0.680; Table 2).

Discussion

The current study examined the validity of individual measures that comprise neuropsychological assessment of dementia. The validity of assessment measures was evaluated in predicting dementia severity and differentiating dementia types (AD versus VD). The result generally showed that tests with high correspondence to the validity criterion as a single measure also showed high unique contributions among a whole assessment battery, indicating that univariate validity partly reflects multivariate validity. However, there were also notable discrepancies in the validity indices. Although the test has shown a strong association with the

Table 2. *Multivariate Models that Explain the Clinical Outcome of Dementia Severity (CDR-SB) and Dementia Type (AD vs. VD).*

Outcome (Dependent variable)	Dementia severity (CDR-SB)			Dementia type (AD < VD)		
	B	SE	*p*-value	B	SE	*p*-value
Age	0.013	0.006	.032	-0.028	0.010	.005
Education	0.089	0.010	$< 10^{-16}$	0.063	0.016	$< 8 \times 10^{-5}$
NPI	0.186	0.009	$< 10^{-16}$	0.013	0.013	.307
GDS	-0.032	0.011	.003	0.018	0.019	.336
WR 1	-0.042	0.013	.002	0.030	0.023	.185
WR 2	-0.156	0.030	2×10^{-7}	0.030	0.060	.614
Wrecg	-0.161	0.017	$< 10^{-16}$	0.074	0.027	.007
Cons 1	-0.142	0.024	3×10^{-9}	-0.124	0.038	.001
Cons 2	-0.071	0.020	3×10^{-4}	0.079	0.041	.053
TMT-A	0.005	0.001	$< 10^{-16}$	0.002	0.001	.007
TMT-B	0.000	0.001	.831	-0.001	0.002	.593
Fluency 1	-0.164	0.022	3×10^{-13}	-0.061	0.040	.128
Fluency 2	-0.101	0.028	4×10^{-4}	-0.113	0.058	.052
Fluency 3	-0.071	0.033	.031	-0.009	0.063	.884
Fluency 4	-0.099	0.033	.003	-0.231	0.077	.003
Boston	-0.073	0.017	2×10^{-5}	0.013	0.029	.652
N		2,553			1,528	
Full model		Adjusted $R^2 = 0.588$			AUC = 0.680	

Note. CDR-SB = Clinical rating scale-sum of boxes; AD = dementia of Alzheimer's disease; VD = Vascular dementia; WR1/2 = Word list immediate/delayed recall; Wrecg = Word list recognition; Cons1/2 = Constructional praxis copy/delayed; TMT-A/B = Trail making test A and B; Flu1-4 = Animal fluency (four blocks of 15s interval); Boston = Boston naming test; NPI = Neuropsychiatric Inventory; GDS = Geriatric Depression Scale.

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criterion as a single score, fewer test scores remained valid in the multivariate model. Specifically, Word List Recognition showed the highest multivariate validity in both of the clinical criteria, whereas other subtest measures including TMT, construction, and fluency tests showed validity under either specific validity criteria (i.e., dementia severity or differential diagnosis of AD and VD).

One of the main purposes of the study was to examine whether the validity metric of assessment measures depends on the framework of univariate or multivariate testing. When comparing the validity index between univariate and multivariate approaches, there was a tendency for a corresponding pattern. In other words, the test measures with high accountability as a single test tend to contain larger unique information among the multiple regression model that accounts for the validity criterion. For example, the Word List memory test showed favorable validity in both univariate and multivariable validity, and the subsequent measures tend to follow the ranks correspondingly. Based on the high proportional weight of AD, verbal memory measures were also indicative of functional impairment due to neurological disease (Belleville et al., 2017).

However, there are several notable discrepancies that the ordering of univariate importance does not map into multivariate importance. In the criterion of dementia severity (Validity A), Word Recall (Immediate) and Boston Naming Test scores showed a moderate level of bivariate association with the CDR-SB, whereas their accountability became nullified among the total battery set. In the criterion of dementia type (Validity B), the discrepancy was profound in TMT-A and Word Recall delayed scores. This indicates that the Word Recall (Immediate) and BNT measures contained redundant information that was mostly shared by other test measures in predicting AD spectrum severity.

Another notable finding was the unique contribution of NPI in predicting dementia severity. NPI qualitatively differs from other cognitive test performances in that the measured domain of socio-affective function is distinct from classical neurocognitive domains and that the source of information comes from the behavioral disturbances observed by clinicians, caregivers, and informants (Delgado et al., 2019; Sachdev et al., 2014). Such uniqueness of the information may have led to relatively higher multivariate validity compared to the univariate index. Our findings support an indispensable role of acquiring neuropsychiatric symptoms in characterizing the progression of dementia that are not replaced with classical cognitive tests (Ismail et al., 2016, 2017). Although the significance of NPI in the assessment of dementia severity is not a novel finding itself, the conspicuous discrepancy between the univariate and multivariate indices indicates an irreplaceable value the NPI measure can provide.

It was also examined whether the test measures can effectively distinguish prevalent types of dementia. Previous findings have shown that VD is more sensitively detected by tests of frontal lobe function or executive/speed domain under the time-limited protocol, whereas AD is more subject to specific memory processing which in turn leads to noticeable differences in subtest validity indices (Jang et al., 2017; Mathias & Burke, 2009; Oosterman & Scherder, 2006; Vasquez & Zakzanis, 2015). In the current evaluation of diagnostic validity, well-documented measures of episodic memory and executive/speed function also showed favorable multivariate validity. For example, the low score in Word List recognition was specific to the deficit in AD, and the low fluency test score was specific to VD, which was indicated by indices of high multivariate validity.

Despite the general alignment with the previous findings, however, some of the inconsistent findings need detailed discussion. The notable finding was shown in BNT score and TMT-A. In the previous meta-analysis of the neurocognitive difference between AD and VD, the picture naming test showed a moderated effect size ($d = -0.4$) (Mathias & Burke, 2009) but our findings showed that the picture naming test (BNT) included in the CERAD-K battery was moderately valid only as a single test score but not as a combined element among the battery. This rather discordant finding may be due to the way a test contributes to the prediction as a common or specific variance. The components of expressive language function reflected in the picture naming test may be more abundantly measured from the fluency test, leaving the test utility redundant (Greenaway et al., 2009). It is also possible that the subtest included in the BNT was more reflective of content-based semantic knowledge rather than process-based efficiency (Ackerman, 2022), and this tendency may be especially so in the population of a wide range of education levels (Kim et al., 2017).

Another notable measure in AD-VD differing measure was

TMT-A, which showed minimalized multivariate validity contrary to univariate validity in distinguishing AD from VD. This result contrast with the previous literatures that notes TMT as useful measure in detecting presence of subcortical or frontal lesions (Bagnoli et al., 2012; Ghafar et al., 2019). Since the previously summarized meta-analysis has examined the test measure as a single predictor, the finding may not generalize to the validity under the constituent of the whole neuropsychological battery. These contrasting results indicate that test measures with similar univariate utility may show disagreeing multivariate utility when composed as a total battery set.

Overall, the current study is suggestive of the cautious perspective in interpreting the validity evidence of neuropsychological measures. Most of the widespread research design reports the group comparison result between AD versus MCI, AD versus healthy controls, or AD versus other dementia types which in turn aggregated as univariate meta-analytic analyses. Though the univariate validity evidence is intuitive in determining the utility of a test, we have suggested that some of the instruments do not retain their validity as a comprehensive set. In practice, clinicians acknowledge the inter-mixture of the information provided by each measure but the decisions regarding the selection and construction of neuropsychological battery heavily rely on the qualitative aptness of the clinician. Our framework suggests that such clinical decision-making of battery construction can be aided by more direct quantification of test validity. This actuarial approach may not always coincide with clinical intuition but can buttress the possible human bias made under univariate research findings.

There are several limitations that require future investigation. First, there are varying sets of neuropsychological batteries used for the assessment of dementia, and the current study lacked some of the popular instruments that have shown robust validity (e.g., Digit Symbol Substitution, vegetable/fruit fluency, logical memory). The indices of multivariate indices can be easily affected by the presence of homologous tests with high collinearity, and adding these tests can alter the main conclusions. Since the CERAD battery was initially developed for diagnosing AD with additional extensions of executive/speed subtests (Seo et al., 2006, 2008), more flexible utilization of the battery may be required in identifying other dementia types.

Another critical limitation of the study was the scope of validity criterion that targets dementia types. There are other varying types of dementia that require differential diagnosis in practice other than AD and VD, and current examinations suggest little information regarding the validity criterion in other contexts of differential diagnosis. Since the current study only compared the two types of dementia, the index of Validity B may or may not reflect the pathology of certain dementia pathology. This issue is also relevant in that the index of Validity A more likely to reflect the severity of the AD spectrum rather than the severity of general dementing pathology. The populational characteristics and proportions of dementia types that the current dataset covers can affect the relative weight of the validity criterion toward specific diagnoses. Moreover, the resulting Validity B may only reflect the prototypic correspondence to the single category side of AD (i.e., presence or absence of AD-specific pattern) rather than reflecting the effect of VD. Further data on other dementia types should be integrated in order to develop the validity index that differentiates 'unspecified non-AD' or 'specific non-AD.'

Lastly, another remaining issue of test selection regards that the validity index does not fully represent the cost-efficiency of neuropsychological measures. Indeed, the number of administered tests is proportional to the time and effort required for the total assessment, and a test can be excluded from the battery if it does not provide incremental information regarding clinical criteria (Donders, 2020; Hunsley & Meyer, 2003). There are, however, there are more complex issues, in that not every measure requires the same amount of time and effort to administer. Some test produces a score with minimal time while some test measures require anteceding procedures (e.g., delayed recall and recognition). In the case of NPI, the single sum score may require a huge amount of cost including the semi-structured interview with an informant while the Boston Naming Test requires a shorter time to administer, which suggests that the measures should not be compared on an equal starting line. Thus, a test can be justified as valid if it requires minimal cost, whereas a costly test should prove its expensive utility accordingly.

Author contributions statement

SK, Formal analysis, writing-original draft; KYK, SMP, and DYO,

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Data curation, supervision; HK and DL, Data curation; JL, Supervision, funding acquisition, investigation.

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