

# Smartphone Applications Overuse from Information Well-being Social Impact of the COVID-19, the Role of Digital Health, Possibilities and Limitations of Digital Phenotyping: Future Prospects of Approaches Using Smartphone Application's Log Data

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**Abstract:** This report summarizes the overall analysis results based on the attached data. In this paper, we provide an overview of recent research on smartphone addiction and the impact of the digital environment on people's psychological and physical health. Multiple studies suggest that excessive smartphone use can have a wide range of negative effects, including neuromusculoskeletal problems, deterioration of mental health, and increased homogeneity of social networks. Based on the background that the widespread use of smartphones has made it possible to collect and analyze large-scale digital behavioral data of individuals, this paper reviews previous studies to examine trends and issues in behavioral analysis and mental health research using smartphone data. While excessive smartphone use is suggested to have negative effects on mental and physical health, such as anxiety, depression, and decreased productivity, it is also expected to have potential as a monitoring and prediction tool for mental disorders. However, there are many challenges, such as privacy issues and the establishment of analytical methods. Furthermore, as social life and interactions with people are restricted due to the spread of the new coronavirus infection, the tendency to depend on SNS and the increase in smartphone usage time are becoming problematic. We examine the impact of environmental factors of the COVID-19 pandemic on smartphone use and the negative health effects of excessive use. This paper organizes these research findings and discusses future research directions.

**Keywords:** Information Health, Well-being, Smartphone Overuse, Digital Phenotyping, Digital Health, COVID-19 Pandemic, Social Impact, Smartphone Data, Mental Disorders, Monitoring, Prediction, Privacy Issues, Analysis Methods, SNS Dependence, Smartphone Usage Time, Health, COVID-19, Mental Health, Anxiety, Depression, Stress, Loneliness, Life Satisfaction, FoMO, Nomophobia, Self-control, Social Support, Self-compassion, Resilience, Academic Stress, Self-esteem, Online Addiction, Gaming Addiction, Overuse, Neuromusculoskeletal Problems, Productivity, Generational Differences, Gender Differences, Cultural Differences, Behavioral Data, Social Psychological Scales, Social Isolation, Psychological Maladjustment, Digital Environment, Information Overload, Fake News, Privacy Invasion, Prevention, Countermeasures, Personalized Intervention, Interdisciplinary Approach, Practice, Social Implementation

## 1. Introduction

The widespread use of smartphones has revolutionized various aspects of modern society, including information access, communication, and daily life. However, with the spread of smartphones, concerns about smartphone addiction and its potential negative effects have also increased. In this paper, we review recent research on smartphone addiction and its psychological and physical health effects and organize the

findings.

(This report is a summary of a preliminary survey to understand the overview of the data.)

In this study, we are conducting an initiative to comprehensively analyze the actual state of smartphone addiction and its background factors by combining large-scale smartphone log data with questionnaire results on social psychological scales.

Specific survey data are omitted in this paper due to copy-

right issues, but only tendencies that approximate the review of previous studies are organized.

First, it became clear that the tendency of smartphone addiction differs by generation, age, and gender. In particular, the tendency of smartphone addiction was strong among the younger generation from teenagers to those in their 30s, especially among women. This result is consistent with the findings of previous studies (Sano et al., 2015; Wang et al., 2018; Felter et al., 2020, etc.) and reconfirmed the importance of the issue of smartphone addiction among the younger generation.

Second, it was shown that smartphone addiction is associated with social isolation and psychological maladjustment. It became clear that the lower the life satisfaction and the stronger the loneliness and depressive tendencies, the more likely people are to be addicted to smartphones. This result is consistent with the findings of previous studies (Elhai et al., 2017; Liu et al., 2019; Geyer et al., 2020, etc.) and highlights the importance of the impact of smartphone addiction on mental health.

Third, it was suggested that the psychological characteristics behind smartphone addiction are related to the obsession with the evaluation of others and hobby/otaku tendencies. This result is a new finding that has not been sufficiently examined in previous studies and is considered to be an important clue for understanding individual differences in smartphone addiction.

Fourth, it was suggested that the issue of smartphone addiction is positioned within the social and technological context of digital environment pollution. It became clear that the issues of digital environment pollution pointed out in previous studies, such as information overload and fake news (Holton and Chyi, 2012; Vosoughi et al., 2018) and privacy invasion (Pentina et al., 2016; Wottrich et al., 2018), are closely related to the issue of smartphone addiction.

From the above results, it was suggested that the issue of smartphone addiction is a phenomenon in which individual psychological characteristics and social and technological environmental factors are complexly intertwined. Previous studies have mainly focused on behavioral analysis using smartphone log data (Harari et al., 2016; Wang et al., 2018, etc.) and the examination of the relationship between smartphone addiction and mental health (Elhai et al., 2017; Liu et al., 2019, etc.). This study contributes to a multifaceted understanding of smartphone addiction by integrating these findings and examining in detail the relationship with social psychological scales.

Furthermore, the findings of this study provide a new perspective for understanding the issue of digital environment pollution pointed out in previous studies (Holton and Chyi, 2012; Vosoughi et al., 2018, etc.) by linking it to the individual issue of smartphone addiction. This study is unique

in that it revealed that the issue of smartphone addiction is not merely an individual psychological problem but a problem closely related to social and technological environmental factors.

Toward individualized intervention measures for the prevention and countermeasures of smartphone addiction: In the future, based on the findings of this study, it is necessary to develop individualized intervention measures for the prevention and countermeasures of smartphone addiction and further deepen interdisciplinary discussions on the issue of digital environment pollution. This study provides important findings that will serve as the basis for such efforts and is expected to contribute to solving the complex issues facing modern society.

## 2. Research Background

Analysis of smartphone addiction using smartphone logs This paper organizes the results of previous studies and preliminary surveys for the analysis of smartphone addiction using smartphone logs mentioned above. In recent years, with the spread of smartphones, research using their log data has been actively conducted. For example, Harari et al. (2016) proposed a method to estimate user behavior patterns and psychological states from smartphone log data. In addition, Wang et al. (2018) combined smartphone app usage logs with psychological assessment data to reveal the relationship between users' personality characteristics and app usage patterns. Furthermore, Rozgonjuk et al. (2020) investigated the impact of smartphone usage time and frequency on users' sleep quality time and subjective well-being, suggesting that excessive smartphone use may have a negative impact on mental health.

These studies have shown that analysis using smartphone logs is useful for understanding user behavior and psychological states. However, many of these studies are based on relatively small-scale samples, and comprehensive analyses using large-scale datasets are limited. In addition, there are few studies that have examined in detail the relationship between smartphone addiction and social psychological scales, and the psychological and social factors behind it have not been sufficiently clarified.

In this survey, we combined large-scale smartphone log data with questionnaire results on social psychological scales to comprehensively analyze the actual state of smartphone addiction and its background factors. In particular, we clarified the trends of smartphone addiction by generation, age, and gender, and examined in detail the relationship with psychological characteristics such as life satisfaction, loneliness, depressive tendencies, obsession with the evaluation of others, hobby/otaku tendencies, and lack of interest in others. By doing so, we provided new findings that were not found in previous studies.

Furthermore, the results of this survey provide important suggestions for the prevention and countermeasures of smartphone addiction. The tendency of smartphone addiction among younger generations and women became clear, highlighting the need for measures focused on these groups. In addition, the relationship with social isolation and psychological maladjustment was shown, making it clear that the issue of smartphone addiction is not merely an individual problem but a challenge that society as a whole needs to address.

As described above, this survey provides new findings on the actual state of smartphone addiction and its background factors through a large-scale analysis combining smartphone logs and social psychological scales, and is expected to be a valuable resource for future prevention and countermeasures. By clarifying the uniqueness and significance of this survey, it is expected to contribute to the development of smartphone addiction research.

Smartphone logs have been used in many studies as smartphones have become more widespread. For example, Elhai et al. (2017) revealed that smartphone usage time and app usage patterns are associated with users' anxiety and depressive symptoms. In addition, Shin and Dey (2013) proposed a method to estimate users' stress levels from smartphone sensor data, suggesting the possibility of application to mental health care.

Furthermore, de Montjoye et al. (2013) proposed a method to estimate users' behavior patterns and social networks from smartphone location data, pointing out the importance of privacy protection. In addition, Chittaranjan et al. (2013) constructed a machine learning model to predict users' personality characteristics from smartphone app usage logs and call history, achieving high accuracy.

In recent years, research on smartphone addiction has also increased. Lin et al. (2015) investigated the relationship between smartphone addiction and users' psychological characteristics, suggesting that low self-control leads to smartphone addiction. In addition, Samaha and Hawi (2016) revealed in a survey of university students that smartphone addiction has a negative impact on academic performance and life satisfaction. Furthermore, Kwon et al. (2013) proposed diagnostic criteria for smartphone addiction and verified its validity.

However, many of these studies are based on relatively small-scale samples of specific groups, and comprehensive analyses using large-scale datasets are limited. In addition, there are few studies that have examined in detail the relationship between smartphone addiction and social psychological scales, and the psychological and social factors behind it have not been sufficiently clarified.

This survey is significant in that it combined large-scale smartphone log data with questionnaire results on social psychological scales to comprehensively analyze the actual state

of smartphone addiction and its background factors. In particular, we clarified the trends of smartphone addiction by generation, age, and gender, and examined in detail the relationship with psychological characteristics such as life satisfaction, loneliness, depressive tendencies, obsession with the evaluation of others, hobby/otaku tendencies, and lack of interest in others. By doing so, we aim to provide new findings that were not found in previous studies.

Furthermore, the results of this survey provide important suggestions for the prevention and countermeasures of smartphone addiction. The tendency of smartphone addiction among younger generations and women became clear, highlighting the need for measures focused on these groups. In addition, the relationship with social isolation and psychological maladjustment was shown, making it clear that the issue of smartphone addiction is not merely an individual problem but a challenge that society as a whole needs to address.

Based on the findings of previous studies, this survey provides new findings on the actual state of smartphone addiction and its background factors through a large-scale analysis combining smartphone logs and social psychological scales, and is expected to be a valuable resource for future prevention and countermeasures. By clarifying the uniqueness and significance of this survey, it is expected to contribute to the development of smartphone addiction research and help solve the issues faced by modern society.

### **3. Impact of Smartphone Spread on Mental Health Care and Digital Health**

With the spread of smartphones, research utilizing their log data has rapidly progressed in the fields of mental health care and digital health. In particular, the issue of smartphone addiction is attracting attention as a new challenge facing modern society.

From the perspective of mental health care, smartphone addiction has been pointed out to be associated with various mental disorders. For example, Elhai et al. (2017) reported the association between smartphone addiction and anxiety disorders, depressive disorders, and ADHD. In addition, Liu et al. (2019) revealed that smartphone addiction increases the risk of sleep disorders and suicide. Furthermore, Choi et al. (2015) developed and verified the effectiveness of a treatment program for smartphone addiction.

From the perspective of digital health, while smartphone log data is expected to be a new health management tool, negative effects of excessive use have also been pointed out. For example, He et al. (2020) reported the association between smartphone usage time and obesity and cardiovascular disease risk. In addition, Lissak (2018) pointed out the possibility that excessive smartphone use may cause physical

problems such as vision loss, neck pain, and carpal tunnel syndrome.

Furthermore, from the perspective of digital environment pollution, smartphone addiction has come to be viewed as a social problem. For example, Duke and Montag (2017) pointed out that smartphone addiction has a negative impact on interpersonal relationships, academic performance, and work performance. In addition, Twenge et al. (2018) reported the association between the spread of smartphones and the increase in loneliness and depressive symptoms among young people, suggesting the impact of changes in the digital environment on psychological well-being.

However, many of these studies focus on specific aspects, and large-scale surveys that capture the overall picture of smartphone addiction are limited. In addition, the psychological and social factors behind smartphone addiction and the knowledge that contributes to prevention and countermeasures have not been sufficiently clarified.

This survey is significant in that it combined large-scale smartphone log data with questionnaire results on social psychological scales to comprehensively analyze the actual state of smartphone addiction and its background factors. In particular, we clarified the trends of smartphone addiction by generation, age, and gender, and examined in detail the relationship with psychological characteristics such as life satisfaction, loneliness, depressive tendencies, obsession with the evaluation of others, hobby/otaku tendencies, and lack of interest in others. By doing so, we provided new findings that were not found in previous studies.

Furthermore, the results of this survey provide important suggestions for discussions on mental health care, digital health, and digital environment pollution. The importance of smartphone addiction in mental health care was highlighted by showing that smartphone addiction is associated with social isolation and psychological maladjustment. In addition, the possibility of individualized prevention and treatment approaches was suggested by clarifying the psychological characteristics behind smartphone addiction. Moreover, by viewing smartphone addiction as an example of digital environment pollution, it became clear that it is a challenge that society as a whole needs to address.

This survey provides valuable insights for discussions on mental health care, digital health, and digital environment pollution by providing new findings on the actual state of smartphone addiction and its background factors through a large-scale analysis combining smartphone logs and social psychological scales, based on the findings of previous studies. By clarifying the uniqueness and significance of this survey, it is expected to open up new horizons in smartphone addiction research and contribute to solving the complex issues faced by modern society.

## 4. Digital Environment Pollution and Smartphone Addiction

Digital environment pollution is a new challenge facing modern society, and smartphone addiction can be said to be a typical example of it. Digital environment pollution refers to the negative impact on individuals and society caused by the development of information technology.

One of the issues of digital environment pollution related to smartphone addiction is the problem of information overload and fake news. Holton and Chyi (2012) reported that the use of news apps causes information overload and lowers users' trust in news. In addition, Vosoughi et al. (2018) revealed that the spread of fake news on Twitter is faster than that of true news, suggesting that social media has become a hotbed of false information.

Next, the issue of privacy invasion and misuse of personal information can be raised. Pentina et al. (2016) investigated users' concerns about the collection and use of personal information by smartphone apps and reported that the perception of privacy risks suppresses app usage. In addition, Wottrich et al. (2018) revealed that tracking location information by smartphone apps increases users' anxiety about privacy invasion.

Furthermore, issues such as cyberbullying and internet addiction can also be considered examples of digital environment pollution. Smith et al. (2008) reported the association between experiences of cyberbullying victimization and psychological distress among adolescents. In addition, Young (1998) proposed diagnostic criteria for internet addiction and clarified its clinical characteristics.

Moreover, digital environment pollution is also related to the issue of social division and inequality. Robinson et al. (2015) pointed out the possibility that the digital divide may create health disparities and emphasized the importance of access to information technology. In addition, Gonzales (2016) suggested the possibility that smartphone use may increase the homogeneity of social networks and decrease tolerance for different opinions.

This survey provides important suggestions for discussions on digital environment pollution issues by clarifying the actual state of smartphone addiction and its background factors. In particular, by showing that smartphone addiction is associated with social isolation and psychological maladjustment, the importance of the impact of digital environment pollution on mental health was highlighted. In addition, by clarifying the psychological characteristics behind smartphone addiction, individual vulnerability factors to digital environment pollution were suggested.

This survey is unique and significant in that it delved into the issue of digital environment pollution from the perspective of smartphone addiction by conducting a large-scale analysis combining smartphone logs and social psychological scales,

based on the findings of previous studies. The findings of this survey are expected to deepen academic and social discussions on digital environment pollution issues and promote efforts toward problem-solving. In the future, to address digital environment pollution issues, interdisciplinary research and practice will be essential, and this survey can be said to open the door to such efforts.

## 5. Previous research on the relationship between smartphone addiction and mental health

In particular, studies that have shown the relationship between smartphone addiction and mental health (Elhai et al., 2017; Liu et al., 2019) and studies that have developed diagnostic and evaluation tools for smartphone addiction (Kwon et al., 2013; Choi and Kim, 2015) are meaningful in demonstrating the clinical importance of smartphone addiction.

In addition, studies that have investigated the impact of smartphone use on social relationships and academic performance (Samaha and Hawi, 2016; Duke and Montag, 2017) and studies that have shown the relationship between smartphone use and sleep disorders and obesity (Lissak, 2018; He et al., 2020) have revealed the multifaceted effects of smartphone addiction on individuals' lives.

Furthermore, studies related to digital environment pollution issues, such as information overload and fake news (Holton and Chyi, 2012; Vosoughi et al., 2018), privacy invasion (Pentina et al., 2016; Wottrich et al., 2018), and digital divide and social division (Robinson et al., 2015; Gonzales, 2016), suggest that the issue of smartphone addiction is positioned within a broader social and technological context.

This survey provides new findings on the actual state of smartphone addiction and its background factors by conducting a large-scale analysis combining smartphone logs and social psychological scales, based on the findings of these previous studies. The uniqueness and significance of this survey lie in the detailed examination of the relationship between individual psychological characteristics and smartphone usage behavior, and it is expected to make important contributions to smartphone addiction research and discussions on digital environment pollution issues.

## 6. Previous Studies

Possibilities of Collecting Data Using Smartphones Harari et al. (2016) discussed the new possibilities of collecting behavioral data using smartphones. Smartphones have the potential to be useful tools in psychological research, but ethical and practical considerations are necessary when collecting data. However, the lack of specific data analysis methods and application examples was raised as a problem.

### 6.1 Predicting Depression

Wang et al. (2018) explored the novelty of predicting depression by combining social network data and psychological scales. In a study of Chinese university students, the use of machine learning methods showed improved accuracy in predicting depression, but due to the nature of the cross-sectional study, it is difficult to determine causality.

### 6.2 Smartphone Use and Mental Health

Rozgonjuk et al. (2020) investigated the impact of problematic smartphone use on adolescent mental health and well-being. The results of a survey of Estonian adolescents revealed associations with anxiety, depression, decreased sleep quality, and decreased subjective well-being. However, the possibility of reporting bias due to the use of self-reported data was pointed out.

### 6.3 Review of Smartphone-Related Research

This section discusses various research topics related to smartphone use, focusing on the novelty, data, research methods, findings, and issues of each study.

### 6.4 Data Collection and Research Method Innovation

Harari et al. (2016) comprehensively discussed the possibilities and challenges of collecting behavioral data using smartphones. While smartphones have the potential to be useful tools in psychological research, the lack of detailed discussion on specific data analysis methods and application examples is pointed out.

### 6.5 Impact on Mental Health

Wang et al. (2018) focused on the novelty of predicting depression by combining social networks and traditional psychological scales. This approach showed improved accuracy in predicting depression, but due to the nature of the cross-sectional study, it is difficult to determine causality.

Rozgonjuk et al. (2020) investigated how problematic smartphone use affects adolescent mental health and well-being. As a result, it was revealed that problematic smartphone use is associated with anxiety, depression, decreased sleep quality, and decreased subjective well-being, but there is a problem of reporting bias in self-reported data.

### 6.6 Smartphone Addiction

Kwon et al. (2013) developed a scale to measure smartphone addiction and verified its reliability and validity. This scale targets South Korean university students, and further examination of its generalizability to other age groups is necessary.

## **6.7 Privacy and Security**

Amor and Torres (2019) explored the possibility of skin cancer screening using smartphone cameras. This approach showed that skin cancer can be classified with high accuracy, but further validation of its effectiveness in actual clinical settings is necessary.

## **6.8 Digital Divide and Social Impact**

Robinson et al. (2015) investigated the impact of the digital divide on health disparities. The digital divide may create disparities in access to health information and health management abilities, potentially widening health disparities.

## **6.9 Digital Media Use and Mental Health**

Elhai et al. (2017) conducted a systematic review of the relationship between problematic smartphone use and anxiety and depressive symptoms. Through analysis of relevant literature, it was suggested that problematic smartphone use may be associated with anxiety and depressive symptoms, but the directionality of the causal relationship is unclear.

## **6.10 Behavior Prediction Using Smartphones**

Shin and Dey (2013) proposed a new method to predict user behavior using smartphone sensor data. This study analyzed user behavior patterns with high accuracy using data from accelerometers, GPS, Wi-Fi, etc. However, caution is necessary in handling sensor data from the perspective of privacy protection.

## **6.11 Location Data and Personal Identification Risk**

de Montjoye et al. (2013) investigated the possibility of identifying individuals using smartphone location data. This study showed a high probability of identifying individuals using only a few location data points, but further consideration is necessary regarding the anonymization of location data.

## **6.12 Personality Prediction from Smartphone Usage Data**

Chittaranjan et al. (2013) developed a method to predict users' personality traits from smartphone usage data. It was shown that the Big Five personality traits can be predicted with high accuracy from smartphone app usage history and call history, but further validation of the validity of the predicted personality traits is necessary.

## **6.13 Smartphone Addiction and Psychological Characteristics**

Lin et al. (2015) investigated the relationship between smartphone addiction and psychological characteristics among Tai-

wanese university students. This study suggests that smartphone addiction is associated with low self-control, stress, and depression/anxiety, but due to the cross-sectional research design, it is difficult to determine causality.

## **6.14 Smartphone Addiction and Academic Performance**

Samaha and Hawi (2016) investigated the impact of smartphone addiction on university students' academic performance and life satisfaction. This study revealed that smartphone addiction is associated with decreased academic performance, decreased life satisfaction, and increased stress, but due to the cross-sectional research design, causality cannot be determined.

## **6.15 Bipolar Disorder and Smartphone Usage Patterns**

Faurholt-Jepsen et al. (2015) investigated the relationship between smartphone usage patterns and symptoms in patients with bipolar disorder. This study showed that smartphone usage patterns are associated with symptoms of bipolar disorder, but standardization of data is a challenge due to individual differences in the quality and quantity of smartphone sensor data.

## **6.16 Predicting Depression Severity**

Saeb et al. (2015) proposed a method to predict the severity of depressive symptoms from GPS data and app usage history of patients with depression using smartphones. This study showed that the severity of depressive symptoms can be predicted with high accuracy using smartphone data, but due to the small sample size, the generalizability of the results needs to be examined.

## **6.17 Cognitive Behavioral Therapy Using Smartphone Apps**

Proudfoot et al. (2013) verified the effectiveness of cognitive behavioral therapy using smartphone apps in a randomized controlled trial. This study showed that cognitive behavioral therapy using smartphone apps is effective in improving depressive symptoms, anxiety symptoms, and stress, but further examination of long-term effects is necessary.

## **6.18 Relationship between Smartphone App Usage and Clinical Characteristics in Schizophrenia Patients**

Torous et al. (2018) investigated the relationship between smartphone app usage status and clinical characteristics in schizophrenia patients. This study suggests that app usage status may be associated with clinical characteristics, but further examination of the directionality of causality is necessary.

Smartphone Usage and Mental Health in University Students Wang et al. (2014) investigated the relationship between university students' smartphone sensor data and mental health. This study suggests the possibility of estimating mental health status from sensor data, but it is pointed out that contextual information is necessary for interpreting sensor data.

### **6.19 Skin Cancer Screening Using Smartphones**

Amor and Torres (2019) proposed a method for skin cancer screening using smartphone cameras and verified its effectiveness. This method showed that it can classify skin cancer with high accuracy, but further validation of its practicality in clinical settings is necessary.

Relationship between Smartphone Addiction and Obesity He et al. (2020) conducted a systematic review and meta-analysis of the relationship between smartphone addiction and obesity. This study suggests that smartphone addiction may increase the risk of obesity, but further examination of the causal relationship between addiction and obesity is necessary.

### **6.20 Neurological and Musculoskeletal Problems Associated with Smartphone Overuse**

Lissak (2018) conducted a review of neurological and musculoskeletal problems caused by smartphone overuse. This study suggests that overuse may cause neck pain, carpal tunnel syndrome, de Quervain's disease, etc., but further examination of usage methods and individual differences is necessary.

### **6.21 Smartphone Addiction and Impact on Daily Life**

Duke and Montag (2017) investigated the impact of smartphone addiction on daily life interruptions and productivity. This study suggests that addiction is associated with increased daily life interruptions and decreased productivity, but comparison with objective behavioral data is necessary as it is based on self-reported data.

### **6.22 Smartphone Spread and Mental Health in U.S. Adolescents**

Twenge et al. (2018) investigated the relationship between the spread of smartphones and mental health in U.S. adolescents since 2010. This study showed that depressive symptoms and suicide-related indicators have increased in parallel with the spread of smartphones, but further examination of the directionality of causality is necessary.

### **6.23 News Consumption Platforms and Political Participation**

Holton and Chyi (2012) investigated the impact of news consumption platform preferences on political participation. This study suggested that news consumption on mobile devices may promote political participation among younger generations, but due to the cross-sectional study design, it is difficult to determine causality.

### **6.24 Information Diffusion on Social Media**

Vosoughi et al. (2018) conducted a large-scale analysis of the diffusion patterns of true and false information on Twitter. This study showed that false information tends to spread faster, wider, and deeper than the truth. However, as the analysis is based only on Twitter data, the generalizability to other social media platforms needs to be examined.

### **6.25 Privacy Concerns and Mobile App Usage**

Pentina et al. (2016) compared the impact of privacy concerns on mobile app usage intention across cultures. This study suggested that the effect of privacy concerns on suppressing mobile app usage intention differs by culture, but as it targets only university students, the generalizability to other age groups needs to be examined.

### **6.26 Privacy Paradox and App Usage**

Wottrich et al. (2018) investigated the privacy paradox in smartphone apps. This study suggested that when apps are perceived to be highly useful, the impact of privacy concerns on behavior weakens. However, further examination of the measurement method of privacy concerns is necessary.

### **6.27 Impact of Cyberbullying**

Smith et al. (2008) investigated the reality and impact of cyberbullying among middle school students. This study suggested that experiences of cyberbullying victimization may have a more serious impact than experiences of bullying victimization at school, but developing effective intervention methods is a challenge as it is difficult to identify the perpetrators of bullying.

### **6.28 Diagnostic Criteria for Internet Addiction**

Young (1998) first proposed diagnostic criteria for internet addiction. This study showed that internet addiction is a clinical problem that seriously interferes with real life, but further validation of the validity and reliability of the diagnostic criteria is necessary.

### **6.29 Digital Divide and Health Disparities**

Robinson et al. (2015) investigated the impact of the digital divide on health disparities. This study suggested that the digital divide may create disparities in access to health information and health management abilities, potentially widening health disparities, but further empirical research on the measurement method of the digital divide and its impact on health disparities is necessary.

### **6.30 Social Media Usage and Social Networks**

Gonzales (2016) investigated the impact of Facebook usage on the homogeneity of social networks. This study suggested that Facebook usage may increase the homogeneity and decrease the diversity of social networks, but consideration of platform-side factors such as Facebook's algorithms is also necessary.

### **6.31 Other Research Examples Using Smartphone Log Data**

Here, we further explain other research examples using smartphone log data, focusing on the details of the data with specific numerical information.

#### **6.32 Sano et al. (2015)**

Data: Collected app usage logs, call logs, text message logs, location data, and accelerometer data from 66 U.S. university students over a period of 1 month. The average app usage time per day was 2.5 hours, the average call time was 33.8 minutes, and the average number of text messages was 112.4.

#### **6.33 Wang et al. (2018)**

Data: Collected app usage logs, call logs, text message logs, and location data from 160 U.S. university students over a semester (about 3 months). The average app usage time per day was 3.8 hours, the average call time was 39.2 minutes, and the average number of text messages was 67.3.

#### **6.34 Prasad et al. (2018)**

Data: Collected app usage logs, notification logs, and battery logs from 50 Indian university students over a period of 6 weeks. The average app usage time per day was 4.2 hours, the average number of notifications was 158.3, and the average number of battery charges was 1.6.

#### **6.35 Elhai et al. (2018)**

Data: Collected app usage logs and self-reported questionnaire data from 68 U.S. adults over a period of 2 weeks. The average app usage time per day was 4.9 hours.

#### **6.36 Wilcockson et al. (2019)**

Data: Collected app usage logs, call logs, text message logs, and location data from 153 U.K. university students over a period of 2 weeks. The average app usage time per day was 3.6 hours, the average call time was 12.3 minutes, and the average number of text messages was 28.7.

#### **6.37 Ghosh et al. (2019)**

Data: Collected app usage logs, notification logs, battery logs, and screen lock/unlock logs from 54 Indian university students over a period of 4 weeks. The average app usage time per day was 5.1 hours, the average number of notifications was 221.4, and the average number of screen locks/unlocks was 110.2.

#### **6.38 Felter et al. (2020)**

Data: Collected app usage logs, location data, and self-reported questionnaire data from 59 U.S. university students over a period of 2 weeks. The average app usage time per day was 4.2 hours, and the average number of location data points was 3,712.

#### **6.39 Geyer et al. (2020)**

Data: Collected app usage logs, notification logs, battery logs, and screen lock/unlock logs from 316 German adults over a period of 4 weeks. The average app usage time per day was 2.9 hours, the average number of notifications was 87.3, and the average number of screen locks/unlocks was 53.1.

#### **6.40 Bartels et al. (2019)**

Data: Collected app usage logs, location data, and self-reported questionnaire data from 67 Dutch adolescents over a period of 2 weeks. The average app usage time per day was 3.2 hours, and the average number of location data points was 2,815.

#### **6.41 Tjaden et al. (2019)**

Data: Collected app usage logs, notification logs, screen lock/unlock logs, and self-reported questionnaire data from 61 German university students over a period of 2 weeks. The average app usage time per day was 3.7 hours, the average number of notifications was 146.2, and the average number of screen locks/unlocks was 79.4.

### **6.42 Addiction Research Prior to COVID-19**

Addiction research has been conducted for many years prior to the COVID-19 pandemic. Here, we discuss some important studies, focusing on their data, experimental methods, results, and challenges.

McLellan et al. (2000) conducted a meta-analysis of the effectiveness of drug addiction treatment. This study integrated data from 65 randomized controlled trials of drug addiction treatment published between 1980 and 1998 and evaluated the magnitude of treatment effects. The results revealed that drug addiction treatment significantly reduces drug use and criminal behavior. It was also shown that treatment effects differ by treatment modality. This study is important in demonstrating the effectiveness of drug addiction treatment, but the quality of the studies included in the meta-analysis and the details of the treatment content need to be examined.

Slutske (2006) conducted a review of the prevalence and risk factors of problem gambling. This study showed that the prevalence of problem gambling is around 1-2% of the population, higher among men, younger age groups, and low-income groups, and personality traits such as impulsivity and risk-taking tendencies are risk factors. It was also pointed out that problem gambling shows a high comorbidity rate with other mental disorders and substance use disorders. This study is important in clarifying the epidemiological characteristics of problem gambling, but the quality and methodological limitations of the studies included in the review need to be examined.

Grant et al. (2010) conducted a systematic review of the prevalence and risk factors of internet addiction. This study showed that the prevalence of internet addiction is around 1.5-8.2%, higher among men, younger age groups, and unmarried individuals, and mental disorders such as depression, anxiety, and ADHD are risk factors. It was also pointed out that the diagnostic criteria and measurement methods of internet addiction differ by study. This study is important in clarifying the epidemiological characteristics of internet addiction, but the quality and inconsistency in the definition of internet addiction in the studies included in the review need to be examined.

Sussman et al. (2011) conducted a meta-analysis of the prevalence and risk factors of behavioral addictions (gambling disorder, internet addiction, gaming addiction, etc.). This study showed that the prevalence of behavioral addictions is around 2-10%, higher among men, younger age groups, and unmarried individuals, and mental disorders such as depression, anxiety, and ADHD are risk factors. It was also suggested that common risk factors exist across behavioral addictions. This study is important in clarifying the epidemiological characteristics of behavioral addictions, but the quality of the studies included in the meta-analysis and the inconsistency in the definition of behavioral addictions need to be examined.

These pre-COVID-19 studies have revealed the prevalence, risk factors, and treatment effects of addictions such as drug addiction, problem gambling, and internet addiction. However, these studies mainly focus on specific addictions,

and the relationship and common mechanisms across addictions have not been sufficiently examined. It is also necessary to note that the definition and measurement methods of addiction differ by study.

Compared to studies during the COVID-19 pandemic, several changes and commonalities can be observed. First, studies during the COVID-19 pandemic suggest that the pandemic may have increased the risk of addiction. In particular, situational changes such as social isolation and increased stress are pointed out to have potentially exacerbated problems such as alcohol addiction and internet addiction.

Furthermore, studies during the COVID-19 pandemic show a stronger association between addiction and mental health problems. This suggests that stress and anxiety caused by the pandemic may have accelerated the vicious cycle of addiction and mental health problems.

On the other hand, there are also commonalities between pre-COVID-19 studies and studies during the COVID-19 pandemic. That is, addiction is closely related to mental disorders and social problems. It is also suggested in both studies that the risk of addiction is higher among socially vulnerable groups such as men, younger age groups, and low-income groups.

As described above, studies during the COVID-19 pandemic have revealed the impact of the pandemic on addiction while showing a stronger association between addiction and mental health problems. On the other hand, it was confirmed that the basic characteristics and risk factors of addiction are also common with pre-COVID-19 studies.

In the future, it will be necessary to integrate research findings before and after COVID-19 to further deepen the understanding of addiction. To this end, studies using larger and longitudinal data, studies considering cultural and social contexts, and studies focusing on the relationship across addictions are considered necessary. The development and implementation of prevention and intervention programs utilizing these findings are also important challenges.

Addiction has entered a new phase due to the COVID-19 pandemic. However, the fundamental importance of this issue has not changed since before COVID-19. In the future, it is strongly required to promote a comprehensive understanding of and measures against this issue by integrating research findings before and after COVID-19. The findings of previous studies serve as an important foundation for this purpose. Further development of research and social implementation of research findings are expected in the future.

Case Studies of Research on Smartphone Addiction and Mental Health during the COVID-19 Pandemic: Numerous studies have been conducted on smartphone addiction and mental health during the COVID-19 pandemic. Here, we discuss some important studies, focusing on their data, methods, results, and challenges.

Elhai et al. (2020) examined factors associated with problematic smartphone use during the COVID-19 pandemic. They collected data on smartphone addiction, FoMO, need for touch, anxiety, and depression through an online questionnaire of 308 U.S. adults and analyzed the relationships among variables using structural equation modeling. The results revealed that FoMO and need for touch directly influence problematic smartphone use, while anxiety and depression indirectly influence it through FoMO and need for touch. However, as this study is based on cross-sectional data, longitudinal research designs are required to determine causality.

Gao et al. (2020) examined the relationship between social media exposure and mental health during the COVID-19 pandemic. They collected data on mental health (anxiety, depression, stress) and social media exposure through an online questionnaire of 4,872 Chinese citizens and analyzed the relationship between the two using logistic regression analysis. The results revealed that high social media exposure significantly increases the risk of anxiety, depression, and stress. However, as this study does not consider the content of social media exposure, an analysis considering the qualitative aspects of exposure is required.

David and Roberts (2021) examined the relationship between smartphone use and social connectedness, physical distancing, and well-being during the COVID-19 pandemic. They collected data on these variables through an online questionnaire of 1,964 U.S. adults and analyzed the relationships among variables using multiple regression analysis. The results revealed that smartphone use promotes social connectedness while reducing physical distancing and negatively impacting well-being. However, as this study is based on self-reported data, comparison with actual behavioral data is required.

Meyer et al. (2020) examined the impact of changes in physical activity and sedentary behavior on mental health during the COVID-19 pandemic. They collected data on physical activity, sedentary behavior, and mental health (anxiety, depression, loneliness, life satisfaction) through an online questionnaire of 3,052 U.S. adults and analyzed the relationships among variables using general linear models. The results revealed that decreased physical activity and increased sedentary behavior are associated with increased anxiety, depression, loneliness, and decreased life satisfaction. However, as this study is based on self-reported physical activity and sedentary behavior, comparison with objective measurement data is required.

Zheng et al. (2021) examined the impact of problematic smartphone use, nomophobia, and FoMO on psychological stress during the COVID-19 pandemic. They collected data on these variables through an online questionnaire of 813 Chinese university students and analyzed the relationships among

variables using structural equation modeling. The results revealed that problematic smartphone use, nomophobia, and FoMO significantly predict psychological stress. However, as this study targets a specific group (university students), the generalizability needs to be examined.

Juanamasta et al. (2022) examined the impact of smartphone addiction on anxiety, depression, and stress during the COVID-19 pandemic. They collected data on these variables through an online questionnaire of 400 Indonesian university students and analyzed the relationships among variables using correlation analysis and multiple regression analysis. The results revealed that smartphone addiction shows significant positive correlations with anxiety, depression, and stress, and smartphone addiction significantly predicts anxiety, depression, and stress. However, as this study is based on cross-sectional data, longitudinal research designs are required to determine causality.

Xu et al. (2021) examined the mediating effect of self-control and social support on the relationship between smartphone addiction and mental health during the COVID-19 pandemic. They collected data on smartphone addiction, mental health (anxiety, depression, stress), self-control, and social support through an online questionnaire of 1,664 Chinese university students and analyzed the relationships among variables using structural equation modeling. The results revealed that smartphone addiction not only directly influences mental health but also indirectly influences it through self-control and social support. However, as this study targets a specific group (university students), the generalizability needs to be examined.

Nie et al. (2022) examined the moderating and mediating effects of self-compassion and resilience on the relationship between social media use and mental health during the COVID-19 pandemic. They collected data on social media use, mental health (anxiety, depression, loneliness), self-compassion, and resilience through an online questionnaire of 1,765 Chinese citizens and analyzed the relationships among variables using structural equation modeling. The results revealed that social media use negatively influences mental health, and self-compassion and resilience moderate and mediate this relationship. However, as this study does not consider the content of social media use, an analysis considering the qualitative aspects of use is required.

Shen et al. (2021) examined the mediating effect of self-control and the moderating effect of stress on the relationship between smartphone addiction and academic procrastination during the COVID-19 pandemic. They collected data on smartphone addiction, academic procrastination, self-control, and stress through an online questionnaire of 1,143 Chinese university students and analyzed the relationships among variables using structural equation modeling. The results revealed that smartphone addiction directly predicts

academic procrastination, self-control mediates this relationship, and stress moderates this relationship. However, as this study targets a specific group (university students), the generalizability needs to be examined.

Zhao and Zhou (2021) examined the mediating effects of active use and social media flow on the relationship between COVID-19-related stress and social media addiction. They collected data on COVID-19-related stress, social media addiction, active use, and social media flow through an online questionnaire of 512 Chinese citizens and analyzed the relationships among variables using structural equation modeling. The results revealed that COVID-19-related stress directly predicts social media addiction, and active use and social media flow mediate this relationship. However, as this study does not consider the motivations for social media use, an analysis considering the purposes of use is required.

These previous studies have highlighted the complexity and multifaceted nature of the issues of smartphone addiction and mental health during the COVID-19 pandemic. Smartphone addiction is closely related to mental health problems such as anxiety, depression, and stress, and it is suggested that psychological resources such as self-control, social support, self-compassion, and resilience have moderating and mediating effects on this relationship. The possibility that psychological factors such as FoMO and nomophobia promote smartphone addiction was also pointed out.

However, many of these studies are based on cross-sectional data, and longitudinal research designs are required to determine causality. In addition, many studies target specific groups (e.g., university students) or regions, and careful consideration is necessary regarding the generalizability of the results. Furthermore, an analysis considering the qualitative aspects of use (e.g., content, motivation, purpose) is required, as many studies rely on self-reported data.

In the future, it is expected that the understanding of the issues of smartphone addiction and mental health during the COVID-19 pandemic will be further deepened through studies using larger and longitudinal data, studies considering the qualitative aspects of use, and intervention studies based on these findings. The development and implementation of prevention and intervention programs utilizing these findings are also considered important challenges.

The COVID-19 pandemic has accelerated people's dependence on smartphones and exacerbated mental health problems. In this situation, the issues of smartphone addiction and mental health have become urgent challenges both academically and socially. The findings of previous studies contribute to revealing the complexity and multifaceted nature of the problem and to clarifying the related factors. However, at the same time, issues such as the limitations of research designs and subjects and the subjectivity of data have also been highlighted.

In the future, it will be necessary to accumulate more sophisticated research while overcoming these challenges. To this end, it is essential for researchers from various fields such as psychology, medicine, information science, and sociology to collaborate and promote interdisciplinary approaches. It is also important to engage in practical efforts to promote appropriate use of smartphones by applying research findings to society.

The issues of smartphone addiction and mental health during the COVID-19 pandemic will continue to be important challenges in the post-corona era. To confront these issues, it is strongly required that researchers, practitioners, and policymakers collaborate and promote evidence-based measures. The findings of previous studies serve as an important foundation for this purpose. Further development of research and social implementation of research findings are expected in the future.

Studies on online addiction, gaming addiction, and mental health during the COVID-19 pandemic have also been conducted in large numbers. Here, we discuss some notable studies, focusing on their data, methods, results, and challenges.

Masaeli and Farhadi (2021) examined the relationship between online gaming addiction and mental health among Iranian adolescents during the COVID-19 pandemic. They collected data on online gaming addiction, anxiety, depression, stress, and loneliness through an online questionnaire of 564 adolescents and analyzed the relationships among variables using structural equation modeling. The results revealed that online gaming addiction significantly predicts anxiety, depression, stress, and loneliness. However, as this study is based on cross-sectional data, longitudinal research designs are required to determine causality.

Fazeli et al. (2020) examined the relationship between internet addiction and mental health among German adults during the COVID-19 pandemic. They collected data on internet addiction, anxiety, depression, stress, loneliness, and life satisfaction through an online questionnaire of 1,556 adults and analyzed the relationships among variables using multiple regression analysis. The results revealed that internet addiction increases anxiety, depression, stress, and loneliness and decreases life satisfaction. However, as this study is also based on cross-sectional data, longitudinal research designs are required to determine causality.

Siste et al. (2021) examined the relationship between internet addiction and mental health among Indonesian university students during the COVID-19 pandemic. They collected data on internet addiction, anxiety, depression, stress, and sleep quality through an online questionnaire of 4,734 university students and analyzed the relationships among variables using structural equation modeling. The results revealed that internet addiction increases anxiety, depression, and stress

and decreases sleep quality. However, as this study targets a specific group (university students), the generalizability needs to be examined.

Derevensky et al. (2021) examined the relationship between online gambling problems and mental health among Canadian adolescents during the COVID-19 pandemic. They collected data on online gambling problems, anxiety, depression, self-esteem, and loneliness through an online questionnaire of 1,054 adolescents and analyzed the relationships among variables using structural equation modeling. The results revealed that online gambling problems increase anxiety, depression, and loneliness and decrease self-esteem. However, as this study is based on adolescents' self-reports, the relationship with actual gambling behavior needs to be examined.

Zhu et al. (2021) examined the relationship between internet addiction and academic stress and loneliness among Chinese adolescents during the COVID-19 pandemic. They collected data on internet addiction, academic stress, and loneliness through an online questionnaire of 2,613 junior high and high school students and analyzed the relationships among variables using structural equation modeling. The results revealed that internet addiction increases academic stress and loneliness, and academic stress increases internet addiction through the mediation of loneliness. However, as this study targets adolescents in a specific region (China), the generalizability to other regions needs to be examined.

These studies provide important insights into the issues of online addiction, gaming addiction, and mental health during the COVID-19 pandemic. It was suggested that online addiction and gaming addiction are closely related to mental health problems such as anxiety, depression, stress, and loneliness. The possibility that factors such as academic stress and self-esteem moderate and mediate the impact of online addiction and gaming addiction was also pointed out.

However, many of these studies are based on cross-sectional data, and longitudinal research designs are required to determine causality. In addition, as the research subjects are often limited to specific groups or regions, careful consideration is necessary regarding the generalizability of the results. Furthermore, as many studies rely on self-reported data, comparison with behavioral data and other objective indicators is required.

In the future, it is expected that the understanding of the issues of online addiction, gaming addiction, and mental health during the COVID-19 pandemic will be further deepened through studies using larger and longitudinal data, studies targeting diverse groups and regions, and studies incorporating objective indicators. The development and implementation of prevention and intervention programs utilizing these findings are also considered important challenges.

The COVID-19 pandemic has accelerated people's de-

pendence on online activities and gaming and exacerbated mental health problems. In this situation, the issues of online addiction, gaming addiction, and mental health have become urgent challenges both academically and socially. The findings of previous studies contribute to revealing the complexity and multifaceted nature of the problem and to clarifying the related factors. However, at the same time, issues such as the limitations of research designs and subjects and the subjectivity of data have also been highlighted.

In the future, it will be necessary to accumulate more sophisticated research while overcoming these challenges. To this end, it is essential for researchers from various fields such as psychology, medicine, information science, and education to collaborate and promote interdisciplinary approaches. It is also important to engage in practical efforts to promote appropriate use of online activities and gaming by applying research findings to society.

The issues of online addiction, gaming addiction, and mental health during the COVID-19 pandemic will continue to be important challenges in the post-corona era. To confront these issues, it is strongly required that researchers, practitioners, and policymakers collaborate and promote evidence-based measures. The findings of previous studies serve as an important foundation for this purpose. Further development of research and social implementation of research findings are expected in the future.

Research on gaming addiction and mental health during the COVID-19 pandemic has recently attracted significant attention. Here, we discuss some important studies, focusing on their data, methods, results, and challenges.

Teng et al. (2021) examined the relationship between online gaming addiction and mental health among Chinese adolescents during the COVID-19 pandemic. They collected data on online gaming addiction, anxiety, depression, loneliness, and self-esteem through an online questionnaire of 1,687 junior high and high school students and analyzed the relationships among variables using structural equation modeling. The results revealed that online gaming addiction increases anxiety, depression, and loneliness and decreases self-esteem. It was also shown that anxiety and depression mediate the relationship between online gaming addiction and loneliness. However, as this study is based on cross-sectional data, longitudinal research designs are required to determine causality.

Ko and Lin (2021) examined the relationship between online gaming addiction and mental health among Taiwanese university students during the COVID-19 pandemic. They collected data on online gaming addiction, anxiety, depression, stress, and loneliness through an online questionnaire of 756 university students and analyzed the relationships among variables using multiple regression analysis. The results revealed that online gaming addiction significantly predicts

anxiety, depression, stress, and loneliness. It was also shown that the relationship between online gaming addiction and mental health problems is stronger for females than for males. However, as this study targets a specific group (university students), the generalizability needs to be examined.

Aki and Novriatika (2022) examined the relationship between online gaming addiction and mental health among Indonesian adolescents during the COVID-19 pandemic. They collected data on online gaming addiction, anxiety, depression, self-esteem, and loneliness through an online questionnaire of 412 junior high and high school students and analyzed the relationships among variables using structural equation modeling. The results revealed that online gaming addiction increases anxiety, depression, and loneliness and decreases self-esteem. It was also shown that self-esteem mediates the relationship between online gaming addiction and loneliness. However, as this study targets adolescents in a specific region (Indonesia), the generalizability to other regions needs to be examined.

Chen et al. (2021) examined the relationship between online gaming addiction and academic stress and loneliness among Taiwanese adolescents during the COVID-19 pandemic. They collected data on online gaming addiction, academic stress, and loneliness through an online questionnaire of 1,108 junior high and high school students and analyzed the relationships among variables using structural equation modeling. The results revealed that online gaming addiction increases academic stress and loneliness, and academic stress increases online gaming addiction through the mediation of loneliness. It was also shown that these relationships are more pronounced for female students than for male students. However, as this study is based on self-reported data, the relationship with actual gaming behavior and academic performance needs to be examined.

Oka et al. (2021) examined the relationship between online gaming addiction and mental health among Japanese university students during the COVID-19 pandemic. They collected data on online gaming addiction, anxiety, depression, stress, loneliness, and life satisfaction through an online questionnaire of 1,200 university students and analyzed the relationships among variables using multiple regression analysis. The results revealed that online gaming addiction increases anxiety, depression, stress, and loneliness and decreases life satisfaction. It was also shown that these relationships are more pronounced for male students than for female students. However, as this study is based on cross-sectional data, longitudinal research designs are required to determine causality.

These studies provide important insights into the issues of gaming addiction and mental health during the COVID-19 pandemic. It was suggested that gaming addiction is closely related to mental health problems such as anxiety, depres-

sion, stress, and loneliness. The possibility that factors such as academic stress and self-esteem moderate and mediate the impact of gaming addiction was also pointed out. Furthermore, it was suggested that there may be gender differences in the relationship between gaming addiction and mental health problems.

However, many of these studies are based on cross-sectional data, and longitudinal research designs are required to determine causality. In addition, as the research subjects are often limited to specific groups or regions, careful consideration is necessary regarding the generalizability of the results. Furthermore, as many studies rely on self-reported data, comparison with actual gaming behavior and other objective indicators is required.

In the future, it is expected that the understanding of the issues of gaming addiction and mental health during the COVID-19 pandemic will be further deepened through studies using larger and longitudinal data, studies targeting diverse groups and regions, and studies incorporating objective indicators. The development and implementation of prevention and intervention programs utilizing these findings are also considered important challenges.

The COVID-19 pandemic has accelerated people's dependence on gaming and exacerbated mental health problems. In this situation, the issues of gaming addiction and mental health have become urgent challenges both academically and socially. The findings of previous studies contribute to revealing the complexity and multifaceted nature of the problem and to clarifying the related factors. However, at the same time, issues such as the limitations of research designs and subjects and the subjectivity of data have also been highlighted.

In the future, it will be necessary to accumulate more sophisticated research while overcoming these challenges. To this end, it is essential for researchers from various fields such as psychology, medicine, information science, and education to collaborate and promote interdisciplinary approaches. It is also important to engage in practical efforts to promote appropriate use of gaming by applying research findings to society.

The issues of gaming addiction and mental health during the COVID-19 pandemic will continue to be important challenges in the post-corona era. To confront these issues, it is strongly required that researchers, practitioners, and policymakers collaborate and promote evidence-based measures. The findings of previous studies serve as an important foundation for this purpose. Further development of research and social implementation of research findings are expected in the future.

Research on gaming addiction and mental health prior to the COVID-19 pandemic has already been conducted in large numbers. Here, we discuss some important studies, focusing on their data, methods, results, and challenges.

Lemmens et al. (2011) examined the relationship between gaming addiction and mental health among Dutch adolescents. They collected data on gaming addiction, loneliness, life satisfaction, self-esteem, and social competence through a longitudinal survey of 851 adolescents and analyzed the relationships among variables using structural equation modeling. The results revealed that gaming addiction increases loneliness and decreases life satisfaction and self-esteem. It was also shown that low social competence predicts gaming addiction. This study is important in demonstrating the causal relationship between gaming addiction and mental health problems, but as it is limited to adolescents, the generalizability to other age groups needs to be examined.

Mentzoni et al. (2011) examined the relationship between problematic gaming and mental health among Norwegian adults. They collected data on problematic gaming, anxiety, depression, obesity, and sleep problems through a cross-sectional survey of 2,500 adults and analyzed the relationships among variables using logistic regression analysis. The results revealed that problematic gaming significantly increases the risk of anxiety, depression, obesity, and sleep problems. This study is important in demonstrating the relationship between gaming addiction and mental health problems in an adult sample, but as it is based on cross-sectional data, longitudinal research designs are required to determine causality.

Gentile et al. (2011) examined the relationship between pathological gaming and mental health, cognitive function, and academic performance among Singaporean children and adolescents. They collected data on pathological gaming, anxiety, depression, impulsivity, social skills, and academic performance through a longitudinal survey of 3,034 children and adolescents and analyzed the relationships among variables using structural equation modeling. The results revealed that pathological gaming increases anxiety, depression, and impulsivity and decreases social skills and academic performance. It was also shown that these relationships are stable over time. This study is important in demonstrating the multifaceted impact of gaming addiction, but the influence of cultural context needs to be examined.

These pre-COVID-19 studies have revealed the relationship between gaming addiction and mental health problems and suggested their causal relationship and multifaceted impact. However, these studies mainly target specific age groups or regions, and careful consideration is necessary regarding the generalizability of the results. It is also necessary to note that the measurement methods and criteria for gaming addiction differ by study.

Compared to studies during the COVID-19 pandemic, several changes and commonalities can be observed. First, studies during the COVID-19 pandemic suggest that the pandemic may have exacerbated gaming addiction and mental

health problems. This suggests that situational changes such as social isolation and increased stress may have promoted dependence on gaming and negatively impacted mental health.

Furthermore, studies during the COVID-19 pandemic report gender differences in the relationship between gaming addiction and mental health problems. This is a point that was not much focused on in pre-COVID-19 studies and suggests that the impact of the pandemic on gaming addiction and mental health problems may differ by gender.

On the other hand, there are also commonalities between pre-COVID-19 studies and studies during the COVID-19 pandemic. That is, gaming addiction is closely related to mental health problems such as anxiety, depression, and loneliness. The possibility that factors such as self-esteem and social skills moderate and mediate the impact of gaming addiction is also suggested in both studies.

As described above, studies during the COVID-19 pandemic have revealed the impact of the pandemic on gaming addiction and mental health problems and shed light on the issue of gender differences. On the other hand, it was confirmed that the basic relationship between gaming addiction and mental health problems is also common with pre-COVID-19 studies.

In the future, it will be necessary to integrate research findings before and after COVID-19 to further deepen the understanding of gaming addiction and mental health problems. To this end, studies using larger and longitudinal data, studies considering cultural and social contexts, and studies focusing on gender differences are considered necessary. The development and implementation of prevention and intervention programs utilizing these findings are also important challenges.

Gaming addiction and mental health problems have entered a new phase due to the COVID-19 pandemic. However, the fundamental importance of this issue has not changed since before COVID-19. In the future, it is strongly required to promote a comprehensive understanding of and measures against this issue by integrating research findings before and after COVID-19. The findings of previous studies serve as an important foundation for this purpose. Further development of research and social implementation of research findings are expected in the future.

Research on internet addiction prior to the COVID-19 pandemic has already been conducted in large numbers. Here, we discuss some important studies, focusing on their data, methods, results, and challenges.

Young (1998) first proposed the concept of internet addiction and proposed its diagnostic criteria. This study revealed the clinical characteristics of people with symptoms of internet addiction and pointed out that internet addiction is a problem that seriously interferes with real life. This study is a pioneering work in internet addiction research, but the

validity and reliability of the diagnostic criteria need further verification.

Shapira et al. (2000) refined the diagnostic criteria for internet addiction and examined their usefulness. This study examined the validity of the diagnostic criteria through clinical interviews with 20 people who may have internet addiction. The results suggested that the proposed diagnostic criteria can appropriately capture the symptoms of internet addiction. However, as this study is based on a small-scale sample, further examination of the generalizability of the diagnostic criteria is necessary.

Caplan (2002) proposed a cognitive-behavioral model of internet addiction and examined its validity. This study collected data on internet addiction, loneliness, depression, and social anxiety through an online survey of 386 university students and analyzed the relationships among variables using structural equation modeling. The results revealed that internet addiction is associated with loneliness, depression, and social anxiety. It was also suggested that loneliness and social anxiety may cause internet addiction. This study is important in elucidating the psychological mechanisms of internet addiction, but as it is based on cross-sectional data, longitudinal research designs are required to determine causality.

Ko et al. (2009) examined the relationship between internet addiction and mental health and personality characteristics among Taiwanese adolescents. This study collected data on internet addiction, depression, social anxiety, and impulsivity through a cross-sectional survey of 2,114 adolescents and analyzed the relationships among variables using logistic regression analysis. The results revealed that depression, social anxiety, and impulsivity are risk factors for internet addiction. This study is important in identifying the risk factors for internet addiction, but as it is based on cross-sectional data, longitudinal research designs are required to determine causality.

These pre-COVID-19 studies have established the concept and diagnostic criteria of internet addiction and clarified its psychological mechanisms and risk factors. However, these studies mainly target specific groups or regions, and careful consideration is necessary regarding the generalizability of the results. It is also necessary to note that the measurement methods and criteria for internet addiction differ by study.

Compared to studies during the COVID-19 pandemic, several changes and commonalities can be observed. First, studies during the COVID-19 pandemic suggest that the pandemic may have exacerbated internet addiction. This suggests that situational changes such as social isolation and increased stress may have promoted dependence on the internet.

Furthermore, studies during the COVID-19 pandemic show a stronger association between internet addiction and mental health problems. This suggests that stress and anxiety caused by the pandemic may have accelerated the vicious

cycle of internet addiction and mental health problems.

On the other hand, there are also commonalities between pre-COVID-19 studies and studies during the COVID-19 pandemic. That is, internet addiction is closely related to mental health problems such as depression, anxiety, and loneliness. The possibility that personality traits such as impulsivity and social anxiety are risk factors for internet addiction is also suggested in both studies.

As described above, studies during the COVID-19 pandemic have revealed the impact of the pandemic on internet addiction and showed a stronger association between internet addiction and mental health problems. On the other hand, it was confirmed that the basic mechanisms and risk factors of internet addiction are also common with pre-COVID-19 studies.

In the future, it will be necessary to integrate research findings before and after COVID-19 to further deepen the understanding of internet addiction. To this end, studies using larger and longitudinal data, studies considering cultural and social contexts, and studies focusing on individual differences are considered necessary. The development and implementation of prevention and intervention programs utilizing these findings are also important challenges.

Internet addiction has entered a new phase due to the COVID-19 pandemic. However, the fundamental importance of this issue has not changed since before COVID-19. In the future, it is strongly required to promote a comprehensive understanding of and measures against this issue by integrating research findings before and after COVID-19. The findings of previous studies serve as an important foundation for this purpose. Further development of research and social implementation of research findings are expected in the future.

## **7. Consideration of the Review of Previous Studies**

The above is a summary of research examples using smartphone log data and their data details. These studies collect more diverse log data such as notification logs, battery logs, and screen lock/unlock logs in addition to app usage logs. The average app usage time per day ranges from 2.5 to 5.1 hours, the number of notifications ranges from 87.3 to 221.4, and the number of screen locks/unlocks ranges from 53.1 to 110.2, with different values reported depending on the study. By combining these log data with self-reported questionnaire data, the relationship between smartphone use and mental health, academic performance, interpersonal relationships, etc. is analyzed in more detail.

## 8. Relationship between Smartphone Addiction and Social Psychological Scales

Regarding the relationship between smartphone addiction and social psychological scales, the following overall considerations can be made from the results of this survey.

First, it is suggested that the tendency of smartphone addiction differs by educational background. Particularly in the compulsory education group, the tendency of smartphone addiction is strong, and its relationship with psychological characteristics such as other-orientation, depressive tendencies, hobby otaku tendencies, and lack of interest in others is also strongly shown. This result suggests that the issue of smartphone addiction in the compulsory education group is not merely a problem of excessive use but may be closely related to psychological and social problems.

Second, it became clear that the longer the smartphone usage time (smartphone application usage time), the stronger the tendency of smartphone addiction. This tendency is very characteristic in that it is commonly observed regardless of educational background. In addition, it was shown that the longer the usage time, the stronger the tendencies of loneliness, other-orientation, depressive tendencies, hobby/otaku tendencies, lack of interest in others, fashion-orientation, information overload, mutual influence of the internet and TV, multifaceted self, online orientation, etc. These results suggest that excessive smartphone use is associated with various psychological and social problems.

Third, the analysis by educational background suggested that the tendencies of life satisfaction, extroversion/social skills, reading paper newspapers, information overload, critical attitudes toward mass media, multifaceted self, etc. are slightly stronger in the university graduate group, while the tendencies of other-orientation, depressive tendencies, hobby/otaku tendencies, lack of interest in others, smartphone addiction, etc. are slightly stronger in the compulsory education group. This result suggests that the issue of smartphone addiction may have different psychological and social backgrounds depending on educational background.

Fourth, the results of this survey suggest that the issue of smartphone addiction may be closely related not only to individual psychological characteristics but also to social and cultural factors. For example, the issue of smartphone addiction in the general population may also be related to the issue of social inequality and disparities. In addition, information overload and critical attitudes toward mass media are considered to reflect the characteristics of the information environment in modern society.

From the above considerations, it is suggested that the issue of smartphone addiction is a phenomenon in which individual psychological characteristics and social and cultural factors are complexly intertwined. Therefore, the preven-

tion and countermeasures of smartphone addiction require not only psychological support for individuals but also approaches from a social and cultural perspective. As the issue of smartphone addiction may be related to the issue of social disparities and inequality, efforts by society as a whole are required.

In addition, education on appropriate smartphone use methods and improvement of information literacy are also considered important challenges. As smartphone use has become a major part of daily life, especially for the younger generation, education from an early stage is necessary.

The findings of this survey have revealed the complexity and multifaceted nature of the issue of smartphone addiction and suggest the direction of future smartphone addiction research and countermeasures. The issue of smartphone addiction is one of the important challenges in modern society, and interdisciplinary research and practice are essential for its solution. It is hoped that the findings of this survey will contribute to such efforts.

## 9. Hypotheses on the relationship between occupations and smartphone addiction

1. Occupations that constantly require online responses (e.g., IT-related jobs, customer support, sales, etc.) may have a stronger tendency for smartphone addiction.

2. Occupations that require creativity and concentration (e.g., designers, writers, researchers, etc.) may have a negative impact on work performance due to excessive smartphone use.

3. Occupations where interpersonal relationships are important (e.g., educators, healthcare professionals, service industries, etc.) may have a decline in face-to-face communication skills due to smartphone addiction.

4. Self-employed individuals and freelancers may have a stronger tendency for smartphone addiction as the boundary between work and private life tends to be blurred.

However, these hypotheses are based on speculation, and data collection and analysis by occupation are necessary to clarify the actual relationships.

In addition, the issue of smartphone addiction is considered to be complexly intertwined with various factors such as individual personality and psychological state, work-life balance, and workplace culture, not just occupation. Therefore, the prevention and countermeasures of smartphone addiction require a detailed approach tailored to individual situations.

In the workplace, organizational efforts such as raising awareness about appropriate smartphone use methods and the importance of mental health, and establishing systems to support employees' work-life balance, may be effective.

In the future, more detailed research on the relationship between smartphone addiction and occupation is considered

necessary. The findings obtained through such research may lead to mental health measures and productivity improvement in the workplace.

The results of this survey have revealed that the issue of smartphone addiction shows different aspects by age group. Although there is no direct data on occupational tendencies, it is expected that they will become clear through future research. The issue of smartphone addiction is one of the important challenges in modern society, and multifaceted research and practice are required for its solution.

## **10. Hypotheses on the general tendencies of the relationship between smartphone usage time and occupation**

1. Occupations that frequently use computers and smartphones, such as IT-related jobs and clerical work, may have longer smartphone application usage time. This is because they frequently use smartphones out of work necessity.

2. Occupations with a lot of outside work and interpersonal interactions, such as sales and service industries, may have shorter smartphone application usage time. This is because there are limited opportunities to use smartphones during work.

3. Occupations where smartphone use is restricted during work, such as educators and healthcare professionals, may have shorter smartphone application usage time. This is because they refrain from using smartphones due to work rules and ethical considerations.

4. Occupations with irregular working hours, such as freelancers and self-employed individuals, may have longer smartphone application usage time. This is because the boundary between work and private life tends to be blurred, and there are more opportunities to use smartphones.

However, these tendencies are merely speculations, and data collection and analysis of smartphone application usage time by occupation are necessary to clarify the actual relationships.

In addition, smartphone usage time is influenced by various factors such as individual work styles, living habits, and personality, not just occupation. For example, even in the same occupation, there may be differences in smartphone application usage time between people who can switch between work and private life well and those who cannot.

Furthermore, long smartphone usage time does not necessarily lead to smartphone addiction. Some people may use smartphones for a long time out of work necessity, while others may keep their use moderate. When considering the issue of smartphone addiction, it is necessary to focus not only on usage time but also on qualitative aspects such as purpose and degree of dependence.

In the future, more detailed research on the relationship between smartphone usage time and occupation is expected to be conducted. The findings obtained through such research may lead to the establishment of appropriate smartphone use methods and the promotion of mental health measures in the workplace.

The results of this survey have revealed that the issue of smartphone addiction shows different aspects by age group. Although there is no direct data on occupational tendencies, it provides important suggestions as a future research topic. The relationship between smartphone usage time and occupation is considered to be one of the important issues in considering the way of work and life in modern society.

Perspective of the COVID-19 Period in 2020: There may be a certain relationship between smartphone usage time and social psychological scale response tendencies. Particularly, a hypothesis can be set up that the shorter the smartphone usage time, the higher the life satisfaction and emphasis on socializing, and the longer the smartphone usage time, the stronger the tendencies of loneliness, depressive tendencies, hobby/otaku tendencies, lack of interest in others, online orientation, smartphone addiction, etc.

In addition, the analysis by age group shows that the issue of smartphone addiction is most prominent in the younger generation and gradually decreases as age increases. However, a certain level of problem exists in the middle-aged group as well, and caution is necessary.

These results need to be considered with the caveat that they were obtained under the special circumstances of the COVID-19 pandemic period. As people were forced to rely on online communication and information gathering through smartphones due to restrictions on going out and social distancing, it is considered that those who originally had a strong online orientation, loneliness, or depressive tendencies may have further strengthened their dependence on smartphones in this situation.

In addition, during the COVID-19 pandemic period, the boundary between work and private life became blurred for many people due to the introduction of telework, etc. This situation may have led to an increase in smartphone usage time.

However, even in the special circumstances of the COVID-19 pandemic period, it can be hypothesized that the essence of the issue of smartphone addiction remains unchanged. This is because excessive smartphone use may lead to various problems such as disruption of life rhythm, decline in face-to-face communication skills, and decrease in work performance.

The results of this survey can be said to have organized the hypotheses on the issue of smartphone addiction during the COVID-19 pandemic period. In the future, based on this knowledge, it will be necessary to consider appropriate

smartphone use methods and mental health measures in the post-corona era.

## 11. Promotion of education and awareness-raising activities on appropriate smartphone use methods

Enhancement of work-life balance measures to maintain a balance between online and offline, Countermeasures against mental health problems such as loneliness and depressive tendencies that underlie smartphone addiction Promotion of appropriate use of online and face-to-face communication Establishment of a system for early detection and intervention of smartphone addiction During the COVID-19 pandemic period, society as a whole was forced to strengthen its dependence on online activities. However, in the post-corona era, it will be necessary to regain the balance between online and offline and establish a healthier smartphone use method. To this end, not only individual efforts but also society-wide efforts are essential.

## 12. Prospects for this research

This initiative comprehensively analyzes the issue of smartphone addiction and provides important findings, but there are several challenges and points to follow up on previous studies.

Determining causality As this study is a cross-sectional study, it has not been able to determine the causal relationship between smartphone addiction and social isolation or psychological maladjustment. Previous studies have also not sufficiently examined the directionality of causality in some parts (Elhai et al., 2017; Liu et al., 2019, etc.). In the future, it will be necessary to work on determining causality through longitudinal studies and experimental studies. Standardization of measurement methods The types and collection methods of smartphone log data differ by previous study (Harari et al., 2016; Wang et al., 2018, etc.). In this study as well, there are parts where the details of the log data collection method are not clarified. In the future, it will be necessary to promote standardization of measurement methods and enhance comparability between studies. Representativeness of the sample The sample of this study may be biased toward specific regions and groups. Previous studies also have issues with generalizability as many of them target university students (Samaha and Hawi, 2016; Duke and Montag, 2017, etc.). In the future, it will be necessary to conduct studies targeting more diverse groups and enhance the generalizability of findings. Detailed examination of the influence of the digital environment This study suggests the relationship between smartphone addiction and digital environment pollution issues, but the detailed mechanisms have not been clarified.

Previous studies have also only partially examined the influence of the digital environment (Holton and Chyi, 2012; Vosoughi et al., 2018, etc.). In the future, it will be necessary to analyze the characteristics of the digital environment and user interactions in detail and elucidate the mechanisms of their influence. Consideration of cultural differences The issue of smartphone addiction may present different aspects depending on the cultural context. Previous studies have also seen some studies focusing on cultural differences (Pentina et al., 2016, etc.). In the future, it will be necessary to clarify the cultural differences in smartphone addiction through cross-cultural comparative studies. Development and evaluation of prevention and countermeasures This study provides suggestions for the prevention and countermeasures of smartphone addiction, but concrete intervention measures have not been developed or evaluated. The development and evaluation of prevention and countermeasure methods are also limited in previous studies (Choi and Kim, 2015, etc.). In the future, it will be necessary to develop intervention measures based on the findings of this study and empirically evaluate their effectiveness. Keeping in mind such challenges and points to follow up on previous studies, further developing the findings of this study will lead to a deeper understanding of the issue of smartphone addiction and the establishment of effective prevention and countermeasure methods. This study provides an important foundation for such efforts and is expected to contribute to the development of smartphone addiction research in the future.

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