Exploratory Cluster Analysis of Adolescent Technology Use and Activities during COVID-19 in Relation to their Mental Health Conditions: An Empirical Study

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Exploratory Cluster Analysis of Adolescent Technology Use and Activities during COVID-19 in Relation to their Mental Health Conditions: An Empirical Study

Abstract (232 words)

Purpose: The impact of the COVID-19 pandemic on adolescents has been significant due to disruptions to their education, social interactions, and mental health. The aim of this study is (a) to conduct an exploratory cluster analysis using three different clustering algorithms to identify the profiles of adolescent technology use and activities during COVID-19 and (b) compare the resulting clusters on their demographic composition, social support received, and various dimensions of adolescent mental health conditions.

Method: The first wave of longitudinal Oxford Achieving Resilience during COVID-19 (ARC) study of adolescents (aged 13-18) and their parents was used (n=1,196). The profiles of adolescent technology use and other activities during COVID-19 were identified using three clustering analysis algorithms: k-means partitioning, k-medoids partitioning, and agglomerative hierarchical clustering. The final, optimal clustering solution was validated statistically (comparing the Average Silhouette Widths across the clustering model results based on three clustering methods) and empirically (comparing the original mean values for each clustering feature across the clusters). Follow-up descriptive and inferential statistics (e.g., Chi-Square tests & ANOVA) were then computed to examine the possible significant differences in demographic, social, and psychological aspects among the adolescents as a function of their cluster membership.

Results: The three clusters were characterized as follows: Cluster 1 (n = 380) = low media use & moderate activity, Cluster 2 (n = 153) = high media use & low activity, and Cluster 3 (n = 23) =

moderate media use & high activity. Cluster 2 (*high media use/low activity*) adolescents identified more as male, heterosexual, and non-white with increased reported alcohol consumption. Furthermore, this cluster experienced higher depression and scored lower on conscientiousness.

Conclusion: This study analyzed adolescent support strategies recommended to parents during the COVID-19 pandemic, along with an initial exploration into adolescents' experiences related to mental health impacts. The increased rate of depressive symptoms within Cluster 2 (*high media use/low activity*) supported expert recommendations to limit alcohol use, avoid excessive media use, and exercise regularly (activities). In addition, the adolescents' COVID-related experiences impact their behavioral patterns in various types of media technology use and non-technology activities.

Keywords: cluster analysis, COVID-19, adolescent technology use, mental health

Implications and Contribution

Three contributions were noted for this study: (a) deepened understanding of heterogenous adolescents' COVID-related experiences by providing distinct group files; (b) furthered investigation of the relationship between adolescent media use/other activities during COVID and their psychosocial/mental well-being; and (c) uncovered critical contextual and personal factors mediating the relationship in (b).

Introduction

COVID-19 was declared a global pandemic by the World Health Organization (WHO) on March 11, 2020, leading to self-isolation factors such as stay-at-home orders. The pandemic has had a significant, systematic impact on society and individuals, with adolescents being a particularly vulnerable population. While research has begun to explore the effects of the pandemic on this demographic, much remains to be discovered (Zhou et al., 2020).

Adolescents have been affected by the pandemic in many ways, including disruptions to their education, social interactions, and mental health (WHO, 2020). For example, the closure of schools and universities, as well as the shift to remote learning, has significantly impacted the education of adolescents (Zhou et al., 2020). In addition, restricting social gatherings and increased isolation have led to decreased social support and increased feelings of loneliness among adolescents (WHO, 2020).

The pandemic has also significantly impacted adolescents' mental health, with increased stress, anxiety, and depression reported (Zhou et al., 2020). A study by the World Health Organization (WHO) found that adolescents reported higher levels of stress, anxiety, and depression compared to adults (WHO, 2020). The disruption of daily routines, increased

isolation, and uncertainty about the future have all contributed to the adverse mental health effects experienced by adolescents (WHO, 2020).

From March 2020 to August 2021, the Oxford Achieving Resiliency during COVID-19 Study collected data from parents and adolescents to evaluate the mental health detriments of adolescents during the pandemic (Parsons et al., 2022). From mental health aspects to resiliency, surveys were collected over a year during the pandemic to determine the impact on juveniles. This study focused on the adolescent (13-18 years old) population to explore how their various activities and technology use related to pandemic-associated mental health issues, controlling for the adolescents' demographic backgrounds, personality types, social support received during the pandemic, self-perceived positive/negative influences from COVID-19 on their lives, and personal resiliency.

Literature Review

The COVID-19 pandemic has heavily impacted adolescents' technology use and daily activities. A brief literature review shows that adolescents have increased their use of technology for both educational and leisure purposes during the pandemic. Additionally, it has been found that parental support plays a crucial role in managing adolescent technology use and other activities during the pandemic.

For instance, Salzano and colleagues (2021) found that among adolescents (aged 13-17), technology had been predominantly used for both recreational and educational purposes since the pandemic began, which played a crucial role in helping adolescents stay connected with the outside world and maintain certain levels of resilience against the pandemic impacts.

The shift to virtual learning has also greatly impacted adolescent technology use. For example, Kotrla Topić and colleagues (2021) found that most students reported using

technology more often for educational purposes during the pandemic. The study also found that parental support, including providing students with the necessary technology and helping with their online coursework, was positively associated with their technology use and academic performance.

Despite the increased use of technology among adolescents during the pandemic, more research has yet to explore the potential variation of its adverse impacts on different subgroups of the adolescent population. Furthermore, while the studies above focus on the use of technology, there needs to be more research on the impact of the pandemic on adolescents' daily activities outside of technology use. For example, how has the pandemic impacted adolescents' social, learning, and emotional routines, especially physical activities, concerning their mental health conditions?

Loades et al. (2020) systematically reviewed 83 empirical studies on the impact of social isolation and loneliness on children's mental health. They found that COVID-19 has forced the public to practice social distancing and stay-at-home isolation, increasing teens' feelings of loneliness and isolation. One-third of parents reported that their child needed treatment for mental health issues, such as acute stress disorder, adjustment disorder, and post-traumatic stress disorder (Loades et al., 2020, p.1234). To combat the effects of isolation and loneliness, it is recommended that adolescents identify values and alternative activities in addition to building structure and purpose into isolation periods (Loades et al., 2020).

Jester and Kang (2021) further evaluated the effects of COVID-19 among teenagers. A cohort of teenagers provided self-reported perceptions of physical and mental health during COVID-induced isolation. Fifty-five volunteers aged 15-18 were selected through the opportunity sampling method and were studied over eight weeks. The study showed a

decrease in the participant's overall health and creativity, in contrast to increased screen time and conflicts. Interestingly, social media use did not change substantially over the eight weeks (Merikangas et al., 2010; Wagner, 2020).

Based on similar empirical findings, researchers advised adolescents to abstain from social media and pandemic-related news bombards for maintaining mental health, regular exercise, healthy eating, adequate and proper sleeping, and avoidance of alcohol or drugs. It is also crucial that parents provide enough support to their children to mitigate their anxiety or fear (Galderisi et al., 2020; Lyubomirsky et al., 2013; Shah et al., 2020; Zhang et al., 2020).

However, only some existing empirical studies have tested the effects of the above-listed recommendations with large-scale, longitudinal behavioral data collected from adolescents. Consequently, the heterogeneity and complexity in the adolescent population regarding their COVID-related experiences and mental health conditions still need to be investigated.

Purpose of Study

This cluster analysis study aims to identify and compare the profiles of adolescent technology use and other activities during the first year of COVID-19 and to investigate the potential cross-cluster differences in terms of the cluster member demographic composition, social support received, personality types, and seven mental health dimensions.

Method

The profiles of adolescent technology use and other activities during COVID-19 were explored and identified using three clustering analysis algorithms: k-means partitioning, k-medoids partitioning, and agglomerative hierarchical clustering. The final, optimal clustering solution was validated statistically (comparing the Average Silhouette Widths across the

clustering model results based on three clustering methods) and empirically (comparing the original mean values for each clustering feature across the clusters). Follow-up descriptive and inferential statistics (e.g., Chi-Square tests & ANOVA) were then computed to examine the possible differences in demographic, social, and psychological aspects among the adolescents as a function of their cluster membership.

All data analyses were conducted using R packages (e.g., *cluster*, *factoextra*, etc.) in R 4.0.2 (R Core Team, 2022).

Study Sample

The original data for the Oxford Achieving Resilience during COVID-19 (ARC) study were collected from adolescents around the world aged 13 to 18 and their parents from March 2020 to August 2021. Among the participants, 1,274 completed a baseline survey, and they were further invited to take 11 follow-up weekly surveys, then nine monthly follow-up surveys, and finally, an optional cognitive task. The surveys were designed to gather participant responses on mental health, resilience, and well-being, COVID-19-related experiences, and pandemic anxiety (Parsons et al., 2022).

Due to the complexity and scale of the original dataset as well as the large proportion of missing values in the longitudinal data (missing rate > 75%), this exploratory study focused ONLY on the adolescent baseline survey responses (N =1,196). Furthermore, before performing cluster analysis, any missing values on any of the selected variables needed to be removed, resulting in a final study sample of 556 cases. As shown in Table 3, the demographic composition of this sample of adolescents is as follows: 100% UK citizens, 79.1% female, 63.1% heterosexual, 72.7% white, 81.7% single, 68.4% urban dwellers, 77.8% below high-school level, and 93.3% still at school.

Study Variables

Clustering Features. Nine variables on *media use* and *activities* were selected and included in the cluster analysis models. For *media use*, participants responded to a survey item such as "*How many hours per day have you typically been Watching TV shows, movies or videos (e.g., YouTube)?*" for each of the six items that include *TV*, *playing*, *social media*, *messaging*, *video*, and *playing* Voice. While for *activities*, participants were asked how many hours they typically spent on *exercise inside* (this can include gentle activity like dancing), *exercise outside* (this can include gentle activity like a walk), *exercise outside2* (going outside for something other than exercise or work, such as shopping, meeting people).

Social Support. Four aggregate variables were computed and analyzed across the technology use and activities clusters concerning four types of social support that adolescents received during COVID-19: *parents' support* (4 items), *friends' support* (4 items), *employment support* (3 items), and *school support* (5 items).

Personality Typology. The 15-item Big Five Inventory (BFI; Lang et al., 2011) was used to measure personality. The questionnaire includes three items for each big-5 personality taxonomy: *Openness*, *Conscientiousness*, *Extraversion*, *Agreeableness*, and *Neuroticism*. In addition, five aggregate variables corresponding to the big-5 dimensions were compared to ascertain possible cross-cluster significant differences.

Mental Health. Seven aggregate variables for the respective aspects of adolescent mental health conditions were measured by selected standardized psychometric instruments and analyzed for any cross-cluster differences: *Depression* (9 items), *Resilience* (6 items), *Mental Well-being* (7 items), *Pandemic Anxiety* (9 items), *Generalized Anxiety* (7 items), *Isolation* (4 items), *Perceived Stress* (4 items).

Data Analysis Plan

Prior cluster analysis assumption testing. Two assumptions were tested before cluster analysis. First, to examine whether the sample is sufficiently representative of the population for cluster analysis, the Kaiser-Mayer Olkin (KMO) test is performed to measure the adequacy of the sample for each indicator. The Kaiser-Mayer Olkin (KMO) test has a value of 0 to 1. If the KMO value ranges from 0.5 to 1, the sample can represent the population or a representative sample. Second, to test the multicollinearity assumption, the correlational matrix among the nine clustering features to examine if the magnitude of any pair-wise correlation exceeds 0.9, or more strictly, 0.4.

Validation of *k* optimal clusters. Three statistical validation methods were adopted and compared to determine the optimal *k* clusters, including the elbow method, silhouette analysis, and gap statistics. The elbow method plotted and compared the values of WSS (Within Sum Square) for $k = 1{:}10$ and identified the highest WSS for a specific *k* number. Likewise, the silhouette analysis plot specified the highest average silhouette width at a certain *k* number. Finally, the gap statistics method compared the change in within-cluster dispersion with that expected under an appropriate reference null distribution for a range of *k* numbers and identified the optimal *k* at the most significant jump in within-cluster distance.

Clustering algorithm. Cluster analysis is a family of multivariate, unsupervised machine learning methods that search for patterns in a data set by grouping similar observations into distinct clusters. This method aims to find an optimal grouping for which the observations or objects within each cluster are similar (homogeneous). Three different clustering algorithms were performed on the ARC data. The model results were compared to find the optimal

clustering solution: K-means algorithm, K-medoids algorithm, and agglomerative hierarchical clustering.

Chi-square tests and ANOVA. Chi-square tests were performed to investigate the cross-cluster statistical differences for the categorical variables, such as gender, race, education, etc. In contrast, ANOVA tests were conducted to compare the continuous variables (e.g., depression, pandemic anxiety, isolation, etc.) across the clusters.

Results

Test of assumptions. The Kaiser-Mayer Olkin (KMO) test was performed on the nine clustering features regarding adolescent technology use and activities, which yielded an overall KMO value of o.58, falling within the acceptable range from 0.5 to 1. It suggested that the sample was sufficiently representative of the population. Further, to test the multicollinearity assumption, the correlational matrix among the nine clustering features was computed, and only one pair slightly exceeded 0.4, which implied multicollinearity was not an issue (See Table 1).

Validation of *k* optimal clusters. Three statistical validation methods (the elbow method, silhouette analysis, and gap statistics) were performed and compared to determine the *k* optimal clusters before conducting each of the three clustering algorithms. As shown in Figures 1.1 – 1.2, the results were broadly consistent, supporting that the optimal *k* number was 3.

Clustering algorithm. Three different clustering algorithms (i.e., K-means algorithm, K-medoids algorithm, and agglomerative hierarchical clustering) were performed at k =3. The ARC data and the model results were compared to find the optimal clustering solution. As shown in Table 2, the hierarchical clustering model was chosen because of the relatively lower average silhouette width and better empirical interpretability. Figure 2 illustrates the visualization of the three clustering solutions. The three clusters could be characterized as follows: Cluster 1 (n =

380) = low media use & moderate activity, Cluster 2 (n = 153) = high media use & low activity, and Cluster 3 (n = 23) = moderate media use & high activity. It seemed that Cluster 1 was the most prominent, more typical of the target population; In contrast, Cluster 2 and Cluster 3 were more atypical, indicated by their small cluster sizes, and more extreme in either media use or non-technology activities.

Cross-cluster comparison. As shown in Table 3, although chi-square tests across the three clusters failed to yield any significant statistical differences in the demographic factors, some interesting cross-cluster differences could be noted in gender, sexual orientation, race, and relationship status, especially for Cluster 2. Figure 3 illustrates the cross-cluster comparisons regarding *social support*, *personality dimensions*, and *mental health conditions*. ANOVA tests yielded significant cross-cluster differences on the *big5 Conscientiousness Dimension* (F = 17.528, $p < .001$), where Cluster 2 scored significantly lower than both Cluster 1 and Cluster 3; significant cross-cluster differences were also found on *Depression* (F = 6.084, p = .002), where Cluster 2 members seemed significantly more depressed than the adolescents in other clusters.

Discussions

Adolescent Media Use/Activities during Early COVID Experiences

This study explored the profiles of adolescent technology use and other activities during the first year of COVID-19 and how that might relate to the potential differences in demographic, social, and psychological aspects among adolescents. The cluster analyses yielded three distinct clusters: cluster 1 (*low media & high activities*), clusters 2 (*high media & low activities*), and 3 (*high media & high activities*). This exploratory cluster analysis study effectively addressed the heterogeneity and complexity of adolescents' early COVID-19 experiences instead of overgeneralizing or oversimplifying the phenomenon as a standard,

overall concept. In other words, different adolescents coped with the pandemic in their distinct ways, for which this study showed solid empirical support.

The COVID-19 pandemic potentially changed how researchers view adolescent behavioral patterns, mental health, and their interrelations. For example, did adolescents change their social media usage habits and other activities primarily due to pandemic-induced lockdowns and isolation, or just following/reinforcing their pre-COVID patterns? Morrissey and Engel (2023) noted that the time spent with friends significantly decreased during the first year of the pandemic, while time spent sleeping was like pre-pandemic time. Likewise, much empirical research revealed that even before the pandemic, individuals scoring lower on *conscientiousness* appeared to be less diligent, less orderly, more easy-going, and less willing to conform or follow the rules, finding rules as overly restrictive (Gordon, 2022; Roberts, Lejuez, Krueger, Richards, & Hill, 2014). Arguably, this opens many potential research strings. Did these adolescents, with a notable disdain for rules, choose not to follow lockdown rules, thus catching COVID? This could, at some level, explain lower activity levels and more social media use. Alternatively, did Cluster 2 respondents, typically enjoying an easy-going lifestyle, feel stifled and limited, thus inviting depressive symptoms? These individuals, with lower self-discipline and goal orientation, possibly struggled to adapt and find a path to growth and success when such qualities became exponentially more critical to staying on course to accomplish personal, professional, or academic goals.

Adolescent Support System and Media Use/Activities during Early COVID Experiences

To explore possible links between adolescents' support system and their media use and other activities during the first year of the COVID-19 outbreak, this study compared the three identified clusters of adolescents in terms of four dimensions of their support system, including

parents' support, *friends' support*, *parents' employment support*, and *adolescents' school support*. Although no statistically significant differences were found across the three clusters, Cluster 2 (*high media & low activities*) showed that they received notably lower *friends' support* than Cluster 1 (*low media & high activities*) and Cluster 3 (*high media & high activities*). At the same time, adolescents across the board reported receiving roughly equal support from their parents, employers, and schools. This finding aligns with the empirical literature highlighting that contrary to common expectations, only a small percentage of adolescents reported significantly decreased social support during the pandemic. In contrast, about 20% and 40% of the adolescents claimed they received more support from their friends and family members, an essential protective factor against the negative pandemic impacts (Simon et al., 2021; Zhu et al., 2021).

Furthermore, numerous empirical research has emphasized the essential role of parental support and supervision in mitigating the adverse effects of the COVID-19 lockdown on adolescents' psychosocial well-being (Kroshus et al., 2022; Panchal et al., 2021). However, this study deepened our understanding in that compared to other forms of social support (including parental support), the perceived level of peer support tended to vary more greatly across different sub-groups of the adolescent population, especially for Cluster 2 (*high media & low activities*) members who were identified typically as male, heterosexual, and non-white with increased reported alcohol consumption. This profile differed from many other empirical studies, which concluded that compared to others, female and gender non-binary/LGBQ-identifying adolescents were more susceptible to social isolation and reported higher media use due to the pandemic (Aarah-Bapuah et al., 2021; Wray-Lake et al., 2022).

Adolescent Personality Traits and Media Use/Activities during Early COVID Experiences

Research has shown that tapping into adolescents' pre-COVID psychological resources, such as their character strengths, proved an influential protective factor against the pandemic-induced harms (e.g., stress, anxiety, and depression) on adolescents' mental well-being (Liu & Wang, 2021; Yan et al., 2021). Following this line of research, this study also explored the possible relationships between adolescents' personality traits (as measured by the Five Factor Model personality dimensions) and the patterns of their media use and other activities during the initial COVID-19 outbreak. The findings highlighted significant cross-cluster differences in the *conscientiousness* dimension, with Cluster 2 (*high media & low activities*) members demonstrating significantly *lower conscientiousness* than clusters 1 & 3. Congruent with this finding, López-Fernández and colleagues' (2021) empirical study with 364 adolescent videogame players also revealed that disordered gaming behaviors among adolescents were directly and indirectly (i.e., via the mediation of gaming motives and social interaction) predicted by *conscientiousness* and *low agreeableness*.

Thus, this study strengthened the empirical foundation for investigating risky personality pathways observed in adolescents' problematic media use behaviors before, during, and after the COVID-19 pandemic.

Adolescent Mental Health and Media Use/Activities during Early COVID Experiences

Although the cross-cluster comparisons did not yield statistically significant differences in some of the adolescent mental health conditions (e.g., resilience, anxiety, stress, and overall mental well-being), the differences noted in Cluster 2 (*high media & low activities*) in terms of significantly *higher depression* and *lower conscientiousness* present avenues for future research while confirming previous findings. Regarding past research, many studies indicate that increased social media use directly correlates to self-reported depression symptoms (Aalbers et

al., 2019; Primack et al., 2017; Woods & Scott, 2016; Zhong et al., 2021). Additional studies indicate that people scoring high on the personality trait *conscientiousness* tend to report fewer depressive symptoms (Boudouda & Gana, 2020; Liu et al., 2022), and alcohol, as a depressant, tends to be associated with depressive symptoms whether as a cause or result of alcohol (Schick et al., 2022).

In conclusion, reflecting the originally identified literature gaps, this study initially explored heterogenous adolescents' experiences related to mental health impacts. Consequently, the initial cluster analyses successfully provided three distinct group profiles: Cluster 1, *low media use & moderate activity;* Cluster 2 *high media use & low activity; and* Cluster 3, *moderate media use & high activity*. Among these, Cluster 2 (*high media use & low activity*) adolescents were identified more as male, heterosexual, and non-white, with increased reported alcohol consumption. The follow-up cross-cluster comparisons revealed that this cluster experienced higher *depression* and scored lower on the personality trait *conscientiousness*. The increased rate of depressive symptoms within this cluster supports expert recommendations to limit alcohol use, avoid excessive media use, and exercise regularly (activity).

Overall, using multiple clustering methods and validation techniques adds to the robustness of the findings and effectively addresses the heterogeneity and complexity of adolescents' unique early COVID experiences that are often underexplored in the existing empirical literature.

References

Aalbers, G., McNally, R. J., Heeren, A., De Wit, S., & Fried, E. I. (2019). Social media and depression symptoms: A network perspective. *Journal of Experimental Psychology: General*, 148(8), 1454–1462. https://doi.org/10.1037/xge0000528.

Aarah-Bapuah, M., Sarpomaa Oppong, S., Ohenewaa Yawson, A., Dzansi, G., & Adjorlolo, S. (2022). Covid-19 and mental health of children and adolescents: A systematic review. *Cogent Psychology*, *9*(1), 2111849. https://doi.org/10.1080/23311908.2022.2111849.

Boudouda, N. E., & Gana. K. (2020). Neuroticism, conscientiousness and extraversion interact to predict depression: A confirmation in a non-Western culture. *Personality and Individual Differences*, 167, 110219. https://doi.org/10.1016/j.paid.2020.110219.

Galderisi, S., Heinz, A., Kastrup, M., Beezhold, J., & Sartorius, N. (2015). Toward a new definition of mental health. *World Psychiatry*,14(2), 231-233. https://doi.org/10.1002/wps.20231.

Jester, N., & Kang, P. (2021). COVID-19 pandemic: Is teenagers' health in crisis? An investigation into the effects of COVID-19 on self-reported mental and physical health of teenagers in secondary education. *Public Health in Practice*, *2*, 100099. https://doi.org/10.1016/j.puhip.2021.100099.

Kotrla Topić, M., Varga, V., & Jelovčić, S. (2021). Digital technology use during the COVID-19 pandemic and its relations to sleep quality and life satisfaction in children and parents. *Društvena istraživanja: časopis za opća društvena pitanja*, *30*(2), 249-269.

Kroshus, Emily, Pooja S. Tandon, Chuan Zhou, Ashleigh M. Johnson, Mary Kathleen Steiner, and Dimitri A. Christakis. "Problematic Child Media Use During the COVID-19 Pandemic." *Pediatrics* 150, no. 3 (2022). https://doi.org/10.1542/peds.2021-055190.

Liu, Q., & Wang, Z. (2021). Perceived stress of the COVID-19 pandemic and adolescents' depression symptoms: The moderating role of character strengths. *Personality and individual differences*, *182*, 111062. https://doi.org/10.1016/j.paid.2021.111062.

Liu, T., Liu, Z., Zhang, L., & Mu, S. (2022). Dispositional mindfulness mediates the relationship between conscientiousness and mental health-related issues in adolescents during the COVID-19 pandemic. *Personality and Individual Differences*, 184. 111223. https://doi.org/10.1016/j.paid.2021.111223.

López-Fernández, F. J., Mezquita, L., Ortet, G., & Ibáñez, M. I. (2021). Mediational role of gaming motives in the associations of the Five Factor Model of personality with weekly and disordered gaming in adolescents. *Personality and Individual Differences*, *182*, 111063. https://doi.org/10.1016/j.paid.2021.111063.

Lyubomirsky, S., & Layous, K. (2013). How do simple positive activities increase well-being? *Current Directions in Psychological Science,* 22(1), 57-62. https://doi.org/10.1177/0963721412469809.

Merikangas, K.R., He, J., Burstein, M., Swanson, S.A., Avenevoli, S., Cui, L., Benjet, C., Georgiades, K., & Swendsen, J. (2010). Lifetime prevalence of mental disorders in u.s. adolescents: Results from the National Comorbidity Survey Replication-Adolescent Supplement (NCS-A). *Journal of the American Academy of Child & Adolescent*

Psychiatry, 49(10), 980-989. https://doi.org/10.1016/j.jaac.2010.05.017

Morrissey, T. W., & Engel, K. (2023). Adolescents' Time During the First Year of the COVID-19 Pandemic: Evidence From the American Time Use Survey. *Journal of Adolescent Health, 72*(2), 295-299. https://doi.org/https://doi.org/10.1016/j.jadohealth.2022.08.018

Panchal, U., Salazar de Pablo, G., Franco, M., Moreno, C., Parellada, M., Arango, C., & Fusar-Poli, P. (2021). The impact of COVID-19 lockdown on child and adolescent mental health: systematic review. *European child & adolescent psychiatry*, 1-27. https://doi.org/10.1007/s00787-021-01856-w.

Parsons, S., Todorovic, A., Lim, M. C., Songco, A., & Fox, E. (2022). Data and protocol for the Oxford Achieving Resilience During COVID-19 (ARC) Study. *Journal of Open Psychology Data*, 10(1). https://doi.org/10.5334/jopd.56.

Primack, B. A., Shensa, A., Escobar-Viera, C. G., Barrett, E. L., Sidani, J. E., Colditz, J. B., & James, A. E. (2017). Use of multiple social media platforms and symptoms of depression and anxiety: A nationally-representative study among U.S. young adults. *Computers in Human Behavior*, 69, 1-9. https://doi.org/10.1016/j.chb.2016.11.013.

Radhamani, K. & Kalaivani, D. (2021). Academic resilience among students: A review of literature. *International Journal of Research and Review*, 8(6), 360-369. https://doi.org/10.52403/ijrr.20210646.

Raghunathan, S., Singh, A. K., & Sharma, B. (2022). Study of resilience in learning environments during the COVID-19 pandemic. *Frontiers in Education*, 6, 552. https://doi.org/10.3389/feduc.2021.677625.

Roberts, B. W., Lejuez, C., Krueger, R. F., Richards, J. M., & Hill, P. L. (2014). What is conscientiousness and how can it be assessed? *Developmental Psychology*, 50(5), 1315. https://doi.org/10.1037/a0031109.

Salzano, G., Passanisi, S., Pira, F., Sorrenti, L., La Monica, G., Pajno, G. B., ... & Lombardo, F. (2021). Quarantine due to the COVID-19 pandemic from the perspective of adolescents: the crucial role of technology. *Italian Journal of Pediatrics*, *47*(1), 1-5.

Schick, M. R., Nalven, T., Thomas, E. D., Weiss, N. H., & Spillane, N. S. (2022). Depression and alcohol use in American Indian adolescents: The influence of family factors. *Alcoholism: Clinical and Experimental Research*, 46(*1*), 141-151. https://doi.org/10.1111/acer.14748.

Shah, Kaushal, Shivraj Mann, Romil Singh, Rahul Bangar, and Ritu Kulkarni. "Impact of COVID-19 on the Mental Health of Children and Adolescents." *Cureus* 12, no. 8 (2020). doi:10.7759/cureus.10051.

Simon, J., Helter, T. M., White, R. G., van der Boor, C., & Łaszewska, A. (2021). Impacts of the Covid-19 lockdown and relevant vulnerabilities on capability well-being, mental health and social support: an Austrian survey study. *BMC public health*, *21*(1), 1-12. doi: 10.1186/s12889-021-10351-5.

Wagner, K. D. (2020). Addressing the experience of children and adolescents during the covid-19 pandemic. *The Journal of Clinical Psychiatry*, 81(*3*), 421. https://doi.org/10.4088/JCP.20ed13394.

WHO. (2020). Mental health and psychosocial considerations during the COVID-19 outbreak. Retrieved from https://www.who.int/publications/i/item/mental-health-and-psychosocial-considerations-during-the-covid-19-outbreak

Woods, H. C., & Scott, H. (2016). #Sleepyteens: Social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. *Journal of Adolescence*, 51, 41-49. https://doi.org/10.1016/j.adolescence.2016.05.008.

Wray-Lake, L., Wilf, S., Kwan, J. Y., & Oosterhoff, B. (2022). Adolescence during a pandemic: Examining US adolescents' time use and family and peer relationships during COVID-19. *Youth*, *2*(1), 80-97. https://doi.org/10.3390/youth2010007.

Yan, L., Gan, Y., Ding, X., Wu, J., & Duan, H. (2021). The relationship between perceived stress and emotional distress during the COVID-19 outbreak: Effects of boredom proneness and coping style. *Journal of anxiety disorders*, *77*, 102328.

https://doi.org/10.1016/j.janxdis.2020.102328.

Zhang, Y., Zhang, H., Ma, X., & Di, Q. (2020). Mental Health Problems During the COVID-19 Pandemics and the Mitigation Effects of Exercise: A Longitudinal Study of College Students in China. *International Journal of Environmental Research and Public Health*, 17(10), 3722. https://doi.org/10.3390/ijerph17103722.

Zhong, B., Huang, Y., & Liu, Q. (2021). Mental health toll from the Coronavirus: Social media usage reveals Wuhan residents' depression and secondary trauma in the COVID-19 outbreak. *Computers in Human Behavior*, 114, 106524. https://doi.org/10.1016/j.chb.2020.106524.

Zhu, S., Zhuang, Y., & Ip, P. (2021). Impacts on children and adolescents' lifestyle, social support and their association with negative impacts of the COVID-19 pandemic. *International journal of environmental research and public health*, *18*(9), 4780. https://doi.org/10.3390/ijerph18094780.

Table 1. *The Correlation Matrix for the Nine Variables on Adolescent Technology Use and Activities* (*N* =1,196).

Features	Technology Use (Media Use)						Activity		
	TV	**Playing**	**Social Media**	**Messaging**	**Video**	**Playing Voice**	**Exercise Inside**	**Exercise Outside**	**Exercise Outside2**
TV	1								
Playing	0.225475	1							
Social Media	0.329044	0.238076	1						
Messaging	0.096508	0.144764	0.243519	1					
Video	0.011226	0.054909	0.116432	0.145786	1				
Playing Voice	0.061819	0.158659	0.218205	**0.430989**	0.257806	1			
Exercise Inside	-0.03053	-0.02823	0.029121	0.039528	0.069445	-0.01499	1		
Exercise Outside	-0.07703	0.021421	0.098921	0.009706	-0.03932	-0.00519	0.196706	1	
Exercise Outside2	-0.00505	-0.00436	0.109162	0.007306	-0.05078	-0.03156	0.074143	0.370785	1

Table 2. *The Comparison of the Model Results Using Three Clustering Algorithms*.

Variable Mean	Total Sample (n=556)	K-Means (ASW = 0.44)			K-Medoids (ASW = 0.24)			Hierarchical (ASW = 0.29)		
		Cluster 1 (n=43)	Cluster 2 (n=87)	Cluster 3 (n=426)	Cluster 1 (n=352)	Cluster 2 (n=153)	Cluster 3 (n=51)	Cluster 1 (n=380)	Cluster 2 (n=153)	Cluster 3 (n=23)
TV	4.14	3.86	6.69	3.65	3.11	6.69	3.59	3.20	6.59	3.35
Playing	1.74	1.53	4.52	1.19	0.88	3.90	1.14	1.11	3.27	1.83
Social Media	3.14	4.29	5.83	2.48	2.19	5.29	3.27	2.55	4.57	3.52
Messaging	1.46	1.25	4.07	0.95	1.26	2.02	1.25	0.91	2.82	1.62
Video	0.97	0.47	2.31	0.75	0.89	1.31	0.49	0.63	1.91	0.39
Playing Voice	0.72	0.23	2.59	0.38	0.46	1.44	0.31	0.36	1.69	0.19
Exercise Inside	0.97	3.85	0.89	0.69	0.68	0.83	3.37	0.83	0.78	4.46
Exercise Outside	1.34	5.33	1.03	1.00	0.98	0.91	5.08	1.18	0.95	6.60
Exercise Outside2	1.26	5.62	1.24	0.82	0.86	1.05	4.60	1.02	1.02	6.72

Note. ASW = Average silhouette width

Table 3. *Cross-Cluster Comparison on Demographic Factors*.

Group	Female	Heterosexual	White	Single	Urban	Below HS	At School	Non-Smoker	Non-Drinker
Total Sample	**79.1%**	**63.1%**	72.7%	**81.7%**	68.4%	**77.8%**	93.3%	95.3%	**72.1%**
Cluster 1	**82.9**	**64.2%**	73.4%	**83.9%**	**65.8%**	**40.4%**	96.6%	95.5%	**74.7%**
Cluster 2	**69.9%**	**90.2%**	**69.3%**	**74.5%**	**73.7%**	**41.7%**	95.4%	95.4%	**64.7%**
Cluster 3	78.3%	60.9%	**82.6%**	**91.3%**	**77.3%**	**43.5%**	91.3%	91.3%	**78.3%**

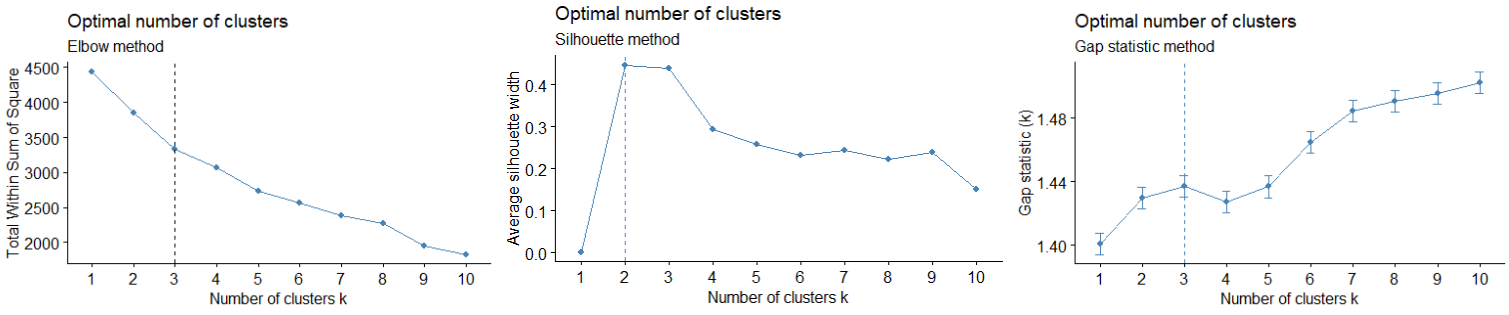


Figure 1.1. *Validation of the Optimal K Number for K-Means and K-Medoids Clustering*.

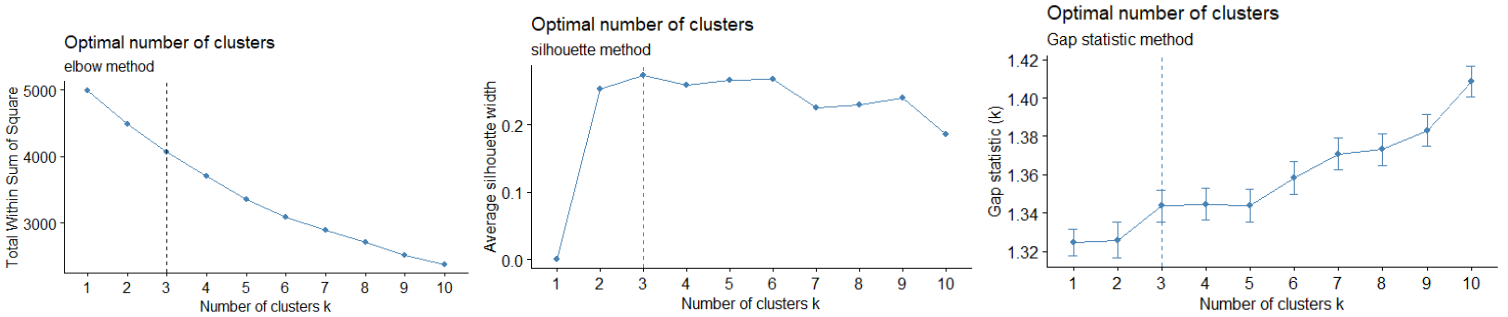
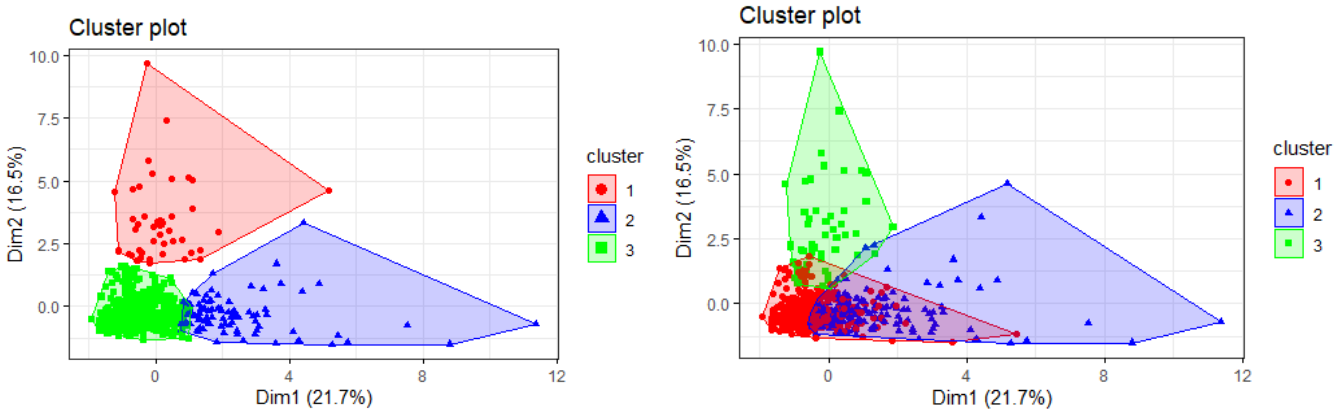
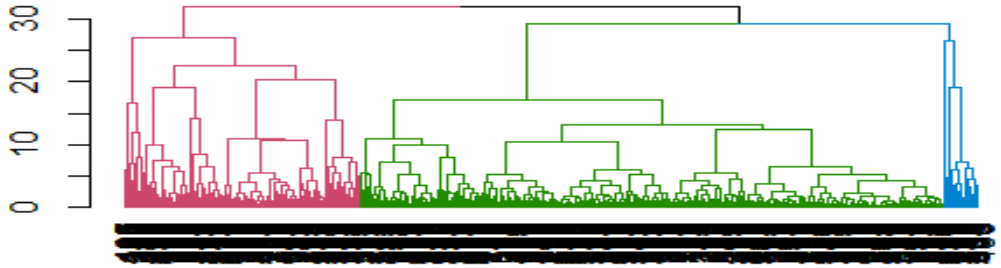


Figure 1.2. *Validation of the Optimal K Number for Agglomerative Clustering*.



K-means K-medoids



Hierarchical Clustering

Figure 2. *Visualization of the Three Clustering Models*.

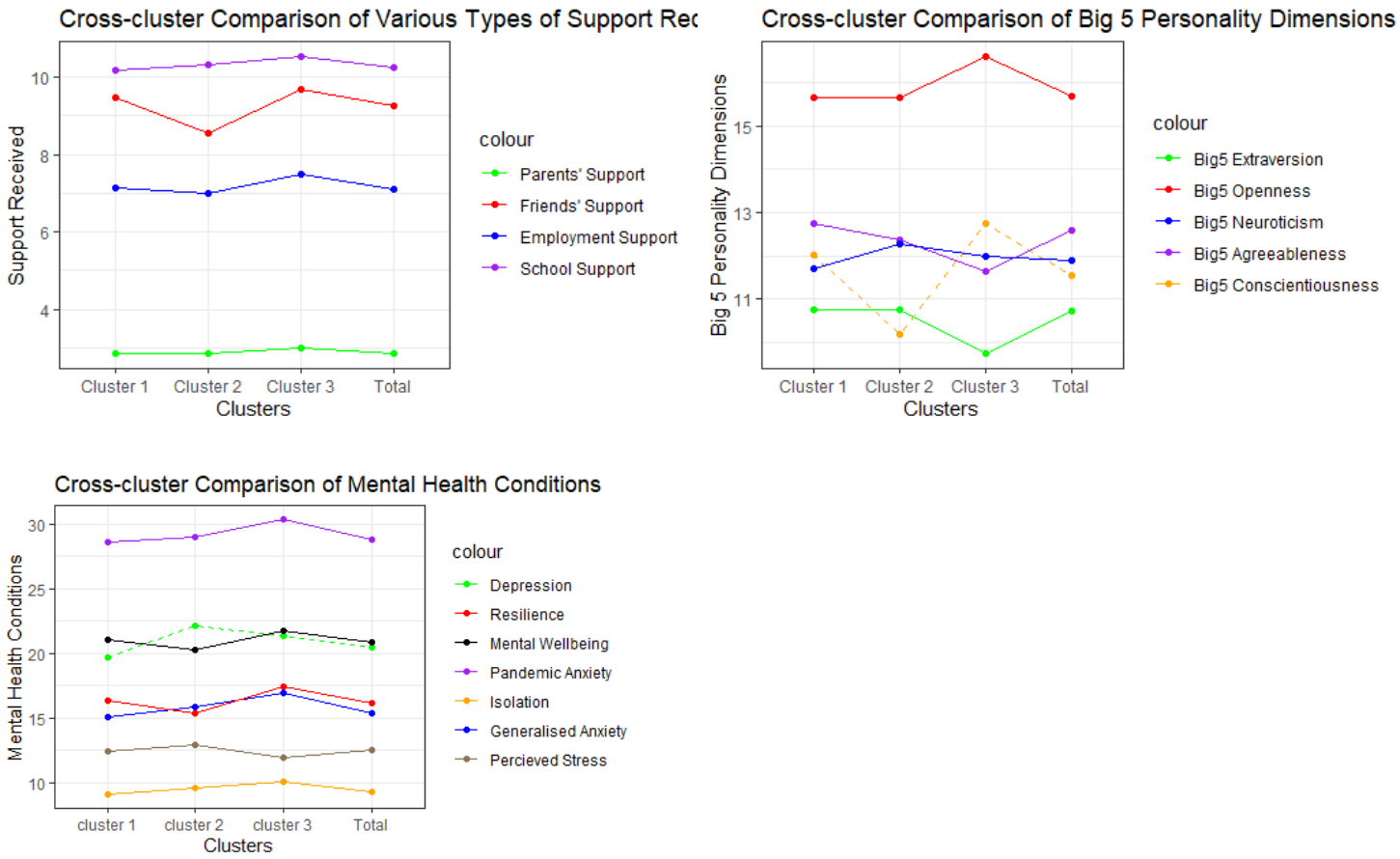


Figure 3. *Cross-Cluster Comparison on Adolescent Social Support, Personality, and COVID Mental Health Conditions*.