Bidirectional Associations Between Screen Time and Irritability in Pre-adolescence: A Temporal Network Analysis

Lanting Zhang[1,2], Nellia Bellaert[2,3], Haoran Zhuo[4,5], Zeyan Liew[4,5], Wan-Ling Tseng[2]

[1] Nuffield Department of Clinical Neuroscience, University of Oxford, Oxford, UK

[2] Yale Child Study Center, Yale School of Medicine, Yale University, New Haven, Connecticut, USA

[3] Department of Cognitive Psychology and Neuropsychology, University of Mons, Mons, Belgium

[4] Department of Environmental Health Sciences, Yale School of Public Health, Yale University, New Haven, USA

[5] Yale Center for Perinatal, Pediatric, and Environmental Epidemiology, Yale School of Public Health, Yale University, New Haven, USA

Running Head: Screen Time and Irritability

Keywords: Screen time; irritability; emotion dysregulation; youth; temporal network approach; ABCD study.

Correspondence to Lanting Zhang, John Radcliff Hospital, OX3 9DU, Oxford, UK; email: lanting.zhang@ndcn.ox.ac.uk

ABSTRACT

Introduction: Irritability, a form of emotion dysregulation, is a transdiagnostic symptom cutting across internalizing and externalizing problems. Clinical practitioners and parents have expressed concerns about the potential negative impact of screen use on irritability in youth. Despite the significant concerns, no studies have examined the association between screen usage and irritability and its directionality. Using a novel temporal network approach, this study investigated bidirectional associations between irritability and screen time across different activities in pre-adolescents.

Materials and Methods: We used data from the Adolescent Brain and Cognitive Development (ABCD) study. Data from baseline, one-year, and two-year follow-ups were included (N=8979, baseline mean age = 9.5 years, 49.1% females). All data used in the study were collected from 2016 to 2019. At each timepoint, time spent on different screen activities was self-reported by youth using the ABCD Youth Screen Time Survey, and irritability was measured using parent-rated Child Behavior Checklist.

Results: Cross-sectional Gaussian Graphical Model showed that irritability was negatively associated with time spent on video streaming at Year 2. The temporal network, estimated by Graphical Vector Autoregressive Model, revealed bidirectional associations between irritability online chatting. Specifically, online chatting predicted decreases in irritability over time, whereas irritability predicted increased time spent on online chatting. Additionally, watching TV and using social media were both associated with subsequent increases in irritability. Results controlled for co-occurring ADHD (attention-deficit/hyperactivity disorder), anxiety, and depressive symptoms.

Conclusions: These findings suggest a bi-directional association between irritability and online chatting. TV watching and social media unidirectionally predicted increased irritability. These associations highlighted the importance of monitoring screen use patterns as both potential behavioral symptoms and modifiable risk factors in interventions targeting emotion dysregulation. More research is needed to better understand how various screen activities and contents and adolescents' motives to use them are linked to irritability.

Irritability can be defined as “proneness to anger that may impair an individual’s functioning” (Leibenluft et al., 2024) and manifests in youth as a low threshold for frustration, persistently angry mood, and/or temper outbursts (Klein et al., 2021; Leibenluft et al., 2024). Irritability is a form of emotion dysregulation and a transdiagnostic symptom predictive of internalizing and externalizing problems later in life (Chad-Friedman et al., 2023). A crucial yet understudied area of irritability research concerns environmental factors in the development and mechanisms of irritability (Klein et al., 2021). Screen use, normally measured as time spent on digital media (Twenge and Farley, 2021), is such an environmental factor that has been linked to various mental health problems including internalizing and externalizing problems (Eirich et al., 2022). Clinical practitioners and parents have expressed concerns about the potential negative impact of screen use on irritability in youth. For instance, parents have reported that their children become frustrated when not allowed to use screen (Domoff et al., 2019) and noticed an increased irritability in their children around screen use (Eales et al., 2021). Despite these observations and concerns, limited studies have investigated the association between screen use and irritability, and little is known about the directionality of this association.

Recent evidence suggests that the association between screen use and psychopathology is likely bidirectional (Neville et al., 2021). Irritable youth are prone to adopt maladaptive emotion coping strategies, like using screens, for regulating negative affects (Radesky et al., 2023; Roberts et al., 2022), which could contribute to the maintenance and further development of irritability (Evans et al., 2020). Screen use may provide short-term relief from frustration and negative affect for irritable youth, but in the long term, screen use could impede the development of effective emotion regulation strategies, exacerbating irritability and prolonging the course of symptoms. Further investigation is needed to understand the precise manner and context in which irritable youth excessively engage with screens across media platforms.

Adolescents engage in various screen activities for diverse motives and under varied circumstances (Twenge and Farley, 2021). For instance, social media use and online chatting usually involve more social communications (Orben, 2020), whereas video and TV watching typically involve more passive reception of screen-based information, often in solitary settings (Kim et al., 2020). Most prior studies focus on limited media types (Vuorre et al., 2021; Zhao et al., 2023) or are cross-sectional (Orben, 2020). It is necessary to differentiate between various types of digital media use to understand whether specific forms of screen time

pose different risks (Twenge and Farley, 2021). Despite these limitations, some consistent findings emerged. That is, social media and internet use are associated with self-harm behaviours and depressive symptoms (Kim et al., 2020; Twenge and Farley, 2021), whereas videogame-playing is associated with externalizing problems (Coyne et al., 2020). These findings suggest that time spent on different types of screen activities may be associated with different forms of psychopathology. Given that irritability cuts across the internalizing and externalizing boundary of psychopathology, research is needed to examine the link between irritability and different types of screen time.

The few existing longitudinal studies examined bidirectional associations between screen use and emotional problems reported mixed results. Some studies have found positive bidirectional associations. For instance, Neville et al. (2021) observed bidirectional associations between screen time and internalizing behaviors among preschoolers (Neville et al., 2021). Other studies have reported unidirectional associations. For example, Fitzpatrick et al. (2023) found that screen use predicted increase proneness to anger and frustration among pre-schoolers (Fitzpatrick et al., 2023), whereas in Coyne et al. (2021), negative affectivity including tendency to experience anger and temper tantrums contributes to more problematic media use in childhood (Coyne et al., 2021). None of these studies focused on the pre-adolescence period (e.g., age 9 to 12 years). Pre-adolescence marks a vulnerable period for irritable youth, as a recent study found that the pre-adolescence (beginning at age 9) is an inflection point when the developmental trajectories of irritability diverge (Yu et al., 2023). In addition, screen use patterns shift from childhood to adolescence, e.g., texting and social media use start to rise in adolescence (Shawcroft et al., 2022), while TV-watching and videogame-playing seem to remain stable across childhood and adolescence (Coyne et al., 2021). Research is needed to understand the specific bidirectional associations between screen time across activities and irritability in pre-adolescence.

The limited longitudinal evidence in the literature (Orben, 2020) and the lack of research focusing on irritability—a phenotype cutting across externalizing and internalizing symptoms—highlight the need for further research on the longitudinal bidirectional associations between time spent on various screen activities and irritability. Temporal network analysis provides a novel approach to disentangle the longitudinal between- and within-person effects, leading to more accurate estimation of how variables predict each other over time between and within individuals (Epskamp, 2020). This approach allows for a better understanding

of the temporal (and potentially bidirectional) associations. Furthermore, temporal network analysis evaluates the centrality of each variable in the model, enabling the identification of the most important and influential nodes in the network. This approach effectively aids in differentiating among time spent on various screen activities and their specific associations with irritability. Network analysis has been increasingly applied to screen time research, including studies examining associations between screen use and mood symptoms (e.g. Lin et al., 2020; Xu et al., 2025), and temporal network models have shown particular promise in youth mental health research for capturing dynamic symptom processes (Bellaert et al., 2023). Taken together, this study aimed to use three-wave longitudinal data from a large national representative sample in the United States (US), i.e., the Adolescent Brain Cognitive Development (ABCD) study, to examine the dynamic influence between screen time spent on various activities and irritability using a network approach.

METHOD

Study Design

This study used data from the ABCD study (Data Release 4.0), an ongoing longitudinal study beginning in 2016 across 21 research sites in the US (Garavan et al., 2018). Data from baseline (occurring between 2016 and 2018), one-year follow-up (Year 1), and two-year follow-up (Year 2; full cohort data collected until December 31, 2019) were analyzed (Bagot et al., 2022). Recruitment primarily occurred through public and private elementary schools using a probability-based sampling frame designed to approximate the demographic composition of the US population (Garavan et al., 2018; Karcher and Barch, 2021). Inclusion criteria required children to be aged 9-10 years old and living within a reasonable distance of a study site. Exclusion criteria for participation were: (1) lack of English proficiency in the child; (2) the presence of severe sensory, neurological, medical or intellectual limitations that would inhibit the child's ability to comply with the study protocol; and (3) an inability to complete an MRI scan at baseline (Smith et al., 2023). In total, 11,875 eligible children completed the baseline assessment.

The ABCD study obtained approval from the central Institutional Review Board (IRB) at the University of California, San Diego, as well as local IRBs at specific research sites (e.g., Washington University in St. Louis) (Auchter et al., 2018). Parents provided written informed consent and children provided assent.

Participants

The analytic sample in this study includes 8979 participants (4405 females [49.1%] and 4574 males [50.9%]) with complete data for three waves. Participants with missing data in screen time and Child Behavior Checklist (CBCL) measures were excluded (n = 2897). Demographics of the final sample are reported in Table 1.

Measures

Screen time. Screen time was assessed using youth self-report of the ABCD Youth Screen Time Survey (Bagot et al., 2022). At baseline and Year 1, participants were asked to report the typical hours per day (separately for weekdays and weekends) they spent engaging in six different screen activities, including viewing/streaming TV shows or movies, watching/streaming videos (e.g., YouTube), playing videogames, texting, video chatting (e.g., Facetime), and using social media platforms (e.g., Instagram). Children responded to each question using a 7-point scale: none (0), < 30 min (0.25), 30 min (0.5), 1 h (1), 2 h (2), 3 h (3), or4 + hours (4) (Bagot et al., 2022). Due to the low engagement of texting and video chatting, we combined these two types, labelled as online chat. We calculated a weighted average of participants' typical screen time consumption for each type of screen activity: [(weekday average * 5) + (weekend average * 2)]/7 (Guerrero et al., 2019). Beginning in Year 2, the screen activities were rephrased slightly (Bagot et al., 2022). To be consistent with measures in previous years, we recoded the responses in Year 2, calculated the weighted average and used them as continuous variables.

Irritability symptoms. Children's irritability was measured using the mean scores of five items (e.g., mood swings, temper tantrums) from the parent-rated CBCL based on a previously validated measure for irritability (Cordova et al., 2022). Items were rated on a three-point scale ranging from 0 to 2, with higher scores indicating greater problems. Cronbach's alphas for this sample were 0.806 to 0.810 across three timepoints, indicating good internal consistency. The irritability variable was treated as an ordinal variable in the network analysis.

Co-occurring symptoms. Given the high comorbidity of irritability with attention-deficit/hyperactivity disorder (ADHD), depression, and anxiety (Leibenluft et al., 2024), parent-reported CBCL DSM-5 ADHD, Depression, and Anxiety scales were included as covariates.

Analysis Plan

All analyses were conducted in R. Prior to network modelling, we conducted descriptive analysis (means, standard deviations) and correlational analysis of all study variables. We used Gaussian Graphical Models (GGM) and Graphical Vector Autoregressive Models (GVAR) to examine the multivariate temporal associations among irritability and screen time spent on five types of screen activities while controlling for co-occurring psychopathologies. Results without covariates can be found in the Supplement. GGM and GVAR approaches are well suited for modeling high-dimensional systems involving multiple interrelated behaviors, as they simultaneously estimate contemporaneous, autoregressive, and lagged associations while accounting for the shared variance among all variables. Unlike Random Intercept Cross-Lagged Panel Models (RI-CLPM), which test pre-specified directional effects between pairs of variables, GVAR captures the full temporal network structure to quantify how each screen activity predicts and is predicted by irritability when all other behaviors are held constant. This within-person, flexible modeling approach is particularly appropriate for exploratory analysis probing dynamic behavioral processes such as screen time of various activities and mental health.

Cross-sectional network. To investigate the cross-sectional associations between screen time and irritability, we used GGM (Epskamp et al., 2018) to construct three networks, one for each timepoint. The edge in the network model represents partial correlations between nodes (i.e., variables) after controlling for all other nodes in the network. To account for the non-normality of the data, we implemented a nonparanormal transformation for all study variables using the "huge" R package. To limit spurious edges, retaining only the most relevant edges, we conducted regularization of the Gaussian graphical model with the graphical LASSO (least absolute shrinkage and selection operator) algorithm with a rank-order transformation (Spearman correlations).

To characterize edge strengths and node centrality indices of the network structures, we computed three indices, including node strength, closeness, and betweenness. Node strength measures direct connectivity between nodes reflecting how well a node is directly connected to other nodes in the network, calculated by summing the weights of all edges connected to a node. Closeness and betweenness describe indirect connectivity. Closeness quantifies the distance between one node and every other node in the network, indicating how easily a node can reach all other nodes and its overall efficiency in the network; betweenness represents how often a node is on the shortest path connecting two other nodes, indicating its

role as a connector (Epskamp et al., 2018). We assessed robustness of the network parameters by examining the accuracy of edge weights and the stability of centrality indices through bootstrapping methods (Epskamp et al., 2018; see the Supplement for details). The network estimation was performed using the "bootnet" and "psychonetrics (version 0.10)" R packages, and visualization of all network structures was accomplished using "qgraph" (version 1.9.2). All networks were described following the most recent guidelines (Burger et al., 2022).

Temporal network. We built a GVAR model to estimate the temporal network from the panel data using the *panelgvar* function in R. The temporal network represents an averaged within-person association between variables from one timepoint to the next, while controlling for all variables at the previous timepoint as partial correlations (Epskamp, 2020). To facilitate stationarity, we first detrended our variables that showed significant trends before estimating networks, including video-watching, videogame-playing, online-chatting, social media use, irritability and co-occurring symptoms. We used unweighted least squares estimator to fit the GVAR model because irritability and co-occurring symptoms variable was treated as an ordinal variable. The model fit was evaluated by several model fit statistics including root mean square error of approximation (RMSEA), comparative fit index (CFI), and Tucker-Lewis index (TLI). Guidelines from structural equation models were used as a frame of reference. Specifically, CFI > .90, TLI > .80, and RMSEA between 0.05 and 0.10 was considered an indication of fair fit, while CFI and TLI > .95 and RMSEA < 0.05 indicated good fit (Hooper et al., 2008). To make the model robust against false positives, the "stepup" estimator pruning method was implemented with a significance level of $\alpha = .05$ (Epskamp, 2020). Bootstrap analyses were conducted to assess the precision and consistency of the findings. Robustness of the edge weights was evaluated by how often each edge were included in the 1000 bootstrap iterations. Model estimation was performed using the "psychometrics" package, and the network structure was visualized using the "qgraph" package in R.

RESULTS

Descriptive Results

Means, standard deviations, and bivariate correlations of the study variables across three timepoints are presented in Table 2. Irritability at baseline and Year 1 were positively associated with most types of screen time, besides social media and online chat, within and across all timepoints (*r*'s = .03-.06), with a few

exceptions— irritability at baseline, but not Year 1, was positively correlated with TV-watching and videogame-playing in Year 2. Irritability in Year 2 was only positively correlated with TV-watching, videogame-playing, and social media in Year 1, and videogame-playing in Year 2 (*r*'s = .03-.05). The link between videogame-playing and irritability in Year 1 and Year 2 became insignificant after controlling for demographic variables (Figure S1).

Cross-sectional Networks

The cross-sectional networks at each timepoint (Figure 1) revealed a clustering of all screen time activities, with only a weak edge linked to irritability: irritability was negatively associated with video streaming (edge weights = -0.03 at Year 2).

Accuracy and stability checks. The bootstrapped confidence intervals around the edge-weights were narrow (Figure S2), indicating good edge accuracy. The CSC suggested that node strength exhibited high stability across timepoints (CSC(cor = 0.7) = 0.75) and closeness showed high stability at both baseline and Year 2 (CSC(cor = 0.7) = 0.75). Betweenness and closeness at Year 1 were only moderately stable or unstable and thus not interpreted.

Centrality indices. Figure 2 shows the strength, closeness and betweenness indices. The three nodes with the highest strength at each timepoint were: depression, ADHD, irritability, and video-streaming at baseline; depression, video-streaming, videogame-playing, and ADHD in Year 1; and depression, ADHD, and irritability in Year 2. Across baseline and Year 2, the closeness index indicated that videogame-playing and video-streaming had the highest closeness in the network. Other centrality indices were not stable and thus were not interpreted.

Temporal Network

The saturated GVAR network provided a good fit to the data (CFI=0.99, TLI=0.98, RMSEA=0.092). Only the "stable" edges, i.e., those with at least a 50% chance of replication in the bootstrapped model (Table S1; and the exact edge weights are detailed in Table S2) were retained. Figure 3 shows the temporal network of screen time and irritability after controlling for co-occurring psychopathologies. Specifically, TV-watching and social media predicted increased irritability over time (0.03 and 0.12, respectively), while online chat predicted decreased irritability over time (-0.03). Irritability predicted increased time spent on online chat (0.03).

Supplementary Results

Significant gender differences in edge strength were identified in both cross-sectional (Figure S3) and temporal networks (Figure S4). In the temporal network, the edge strengths from video-streaming and videogame-playing to irritability were stronger in females (edge estimates 0.29 and 0.04, respectively) than in males (edge estimates were zero; p=.007 and .016, respectively), while the edge strength from online chat to irritability was stronger in males (0.37) than in females (0.14, p=.047).

The cross-sectional association between screen time and general psychopathology is presented in Figure S5. In the temporal network with internalizing and externalizing problems (Figure S6), online chat and social media predicted increases in both psychopathologies (estimates ranging from 0.02 to 0.04).

The cross-sectional and temporal network models examining the associations between irritability and screen time without adjusting for covariates are presented in supplementary information (Figure S7 and S8).

Detailed supplementary methods and results are available in the Supplementary Information, including Tables S3 and S4.

DISCUSSION

The impact of excessive childhood screen use on irritability has caused concerns among parents and clinicians. However, no research has examined the association between time spent on diverse screen activities and irritability, either cross-sectionally or longitudinally, and thus little is known about the directionality of this association. The current study fills these gaps by conducting a novel temporal network analysis using data from three timepoints in the ABCD study to examine bidirectional associations between irritability and time spent on various screen activities. Longitudinally, we identified a bidirectional association between irritability and online chatting. We also found unidirectional associations such that TV-watching and social media predicted increased irritability. The effect size is modest but is consistent with prior literature indicating that digital media effects on youth mental health tend to be small due to the complex and multifactorial nature of screen time and psychological development (Liu et al., 2019; Orben, 2020). The results extend the bidirectional associations found in previous studies on screen usage in infants (Radesky et al., 2023) and early childhood (Neville et al., 2021) to pre-adolescence, suggesting continuity of the association across different developmental stages. Different screen activities serve distinct functions

(Twenge and Farley, 2021). Understanding the contexts in which pre-adolescents engage in various screen activities are crucial for comprehending the association between screen use and irritability.

We found a small bidirectional association between irritability and online chatting: irritable youth were more likely to engage in online chat, and greater engagement in online chatting was associated with reductions in irritability after controlling for ADHD, depression, and anxiety symptoms. In the model without covariates, more time spent chatting was associated with increased irritability over time. This shift implies that the positive link may have been confounded by broader psychopathological vulnerability, and that in the absence of those symptoms, online social interactions may play a more adaptive role in irritability. Previous work has suggested that digital communication can enhance social connectedness and emotional buffering when used in appropriate contexts (Orben, 2020). Irritable youth tend to have impaired peer functioning (Bellaert et al., 2023), which may result in limited in-person, real-world social interactions and lead irritable youth to seek online peer interactions. Thus, the emotional consequences of online chattingay depend heavily on individual psychopathology profiles and social context, warranting more nuanced investigation into how and why preadolescents engage with digital social platforms.

Our study found that TV watching predicted increased irritability over time. Watching TV as passive screen use has been found to be associated with mood problems (Kim et al., 2020). Recent evidence suggests that watching TV and video as a way of emotion regulation may be problematic longitudinally. Radesky et al. (2023) found that the frequent use of digital devices for calming children aged 3–5 years was associated with children's higher emotional reactivity 6 months later. As children receive less opportunities to practice emotion regulation skills and instead avoid or distract from their emotions, they may be more likely to develop emotion problems (McLaughlin et al., 2011). Irritable children who are easily frustrated and lack emotion regulation skills are more likely to be offered by their parents this "effective" way to regulate their anger and temper outbursts (Rizakos et al., 2022), potentially resulting in more irritability later. Moreover, the link that irritability predicted increased use of TV disappeared after controlling for co-occurring psychopathologies. Youth with higher levels of depression and anxiety symptoms predicted greater TV-watching, indicating that the observed association without covariates may have been accounted for by internalizing symptomatology. Our study thus highlights the need for future research to examine the

potential role of emotion regulation, as well as co-occurring symptoms, on the association between TV-watching and irritability.

In our model without covariates, the strongest bi-directional association was between irritability and video-streaming. However, the link disappeared after controlling for co-occurring psychopathologies. Modern streaming platforms differ from traditional media by providing personalized and continuously engaging content (Alter, 2017). The effects of modern streaming video consumption on youth mental health outcome remain inconclusive (Balcombe and De Leo, 2023). Our results suggest that video watching predicts increased symptoms of anxiety and depression. This association may reflect the differential emotional and neurocognitive effects of various types of streaming content, with some forms potentially exacerbating internalizing symptoms more than others. For example, recent study found that watching dog videos reduced subjective anxiety and increased positive affect more so than nature videos (Ein et al., 2022), whereas exposure to non-child-directed programs was associated with both internalizing and externalizing mental health problems (Mallawaarachchi et al., 2024). Thus, our result highlights the urgency of investigating the content and motivations underlying the video streaming choices of youth to better understand its distinct effect.

We also found that after controlling for co-occurring psychopathologies, social media predicted increased irritability, with small effect sizes consistent with prior research demonstrating similarly modest associations between social media and mental health outcomes (Liu et al., 2019) and heightened psychological distress (Thorisdottir et al., 2020). Unlike online chat, social media allow for many activities that feel social but are not interactive, which does not always fulfill needs for acceptance and belonging (Clark et al., 2018). Therefore, it often failed to provide social support that could regulate emotions such as irritability. Moreover, digital FOMO (fear of missing out), which is usually driven by social media, may make individuals feel inadequate and left out when they saw others' online posts and thereby elicit emotions such as frustration, sadness and anxiety (Littman-Ovadia and Russo-Netzer, 2024). The negative emotional impact of social media use on irritability may therefore be particularly pronounced when the need for social connection is unmet by the content consumed. Thus, future research should focus on tracking the content and context youth use to better understand how social media may impact on youth's irritability.

Our model without covariates also found an association between videogame-playing and irritability cross-sectionally and longitudinally (i.e., irritability predicted increased videogame-playing over time). However, the effect disappeared after controlling for co-occurring psychopathologies. The results suggest that the association between irritability and videogame-playing was likely confounded by these other emotional and behavioral symptoms, as depression, ADHD, and anxiety were all longitudinally associated with increased time spent on videogame-playing, and videogame-playing was cross-sectionally linked to ADHD symptoms. This suggests that videogame-playing may not be inherently linked to irritability, but rather that irritability and its co-occurring psychopathologies may be consequences of shared underlying vulnerabilities such as poor emotional regulation, attention problems, or internalizing symptoms. Different typology of video games seems to have distinct associations with mental health, such that education video games may confer benefits for attention skills (Samson et al., 2021) and game-based biofeedback has shown promising results for helping young individualsregulating emotions such as anxiety (Pinheiro et al., 2021). These findings underscore the importance of considering not only the amount but also the content and context of videogame engagement when evaluating its impact on child psychopathology. Future research should examine how specific genres, gameplay features, and usage patterns may differentially influence emotional and behavioral outcomes in youth.

Our supplementary analysis found that longitudinally, the negative impact of video-streaming and videogame-playing on irritability were more prominent in females, while the impact of online chatting was more prominent in males. This is generally contradictory to previous studies reporting that females are more susceptible to mental health problems associated with social media and internet use (Twenge and Farley, 2021), whereas males are more vulnerable to the negative impact of video gaming (Koncz et al., 2023). One possible explanation may involve gender non-conformity behaviors, which are defined as behaviors that do not conform to culturally defined gender norms based on their sex assigned at birth (MacMullin et al., 2021). In our sample, this could manifest as girls playing video games and boys engaging in online chatting. Children exhibiting gender non-conforming behaviors are more likely to face peer-rejection, leading to victimization and exclusion (MacMullin et al., 2021), which has been linked longitudinally to irritability (Bellaert et al., 2023). More research is needed to understand gender differences in the association between screen use and psychopathology while taking gender non-conformity into account.

To make results comparable to previous studies investigating general psychopathology, our supplementary analysis showed that social media and online chatting predicted increased internalizing and externalizing problems over time in pre-adolescence, although the effects were smaller compared to our main results with irritability. This is consistent with a recent meta-analysis (Eirich et al., 2022) and a ABCD study (Zhao et al., 2023) examining associations between total screen time and internalizing and externalizing problems (Zhao et al., 2023). Our study extends these prior studies by investigating time spent on different types of screen activities and suggests that social media and online chatting may be driving the association of total screen time and internalizing/externalizing problems reported in Zhao et al. (2023).

Our study is the first to investigate the potential bidirectional association between screen time spent on various modern screen activities and irritability using a novel temporal network approach in a large representative sample. Although the observed associations were small in magnitude, they may still hold meaningful public health implications. When scaled across large populations of youth, even modest effects can influence clinical caseloads, inform school-based interventions, and shape policy recommendations. Moreover, the cumulative impact of persistent screen use over time may amplify these effects, underscoring the importance of early monitoring and targeted guidance. However, several limitations are worth noting. First, the screen time data were collected through youth-reports. Adolescents tend to underestimate their smartphone use in self-reports (Orben, 2020). Time perception are known to be altered in impulsive disorders, with the passage of time often perceived as more insufferable and elongated during effortful or unpleasant tasks (Noreika et al., 2013). Given that screen activities are typically engaging, it is unclear whether irritability introduces systematic bias in time-duration recall. Future study could use objective measurements, e.g., smartphone monitoring app, and/or ecological momentary assessment, to capture real-time screen behaviors and experiences. Relatedly, our measure of screen time captured only the amount of time spent on different platforms, without accounting for the content or quality of the material (e.g., educational, violent, interactive, or prosocial). Given that content features may be strongly related to cognitive and socioemotional outcomes (Mallawaarachchi et al., 2024), future studies using finer-grained screen time measures and models such as Generalized Additive Models (GAMs) may be better positioned to address dose–response hypotheses directly. Second, we were unable to control for social-demographic variables in our temporal network because socio-demographic data were only assessed at baseline. The

ABCD participants whose data were incomplete were in general more likely to be non-White and with lower family income. Previous research has reported an inversive association between socio-economic status and screen use (Lee et al., 2022), limiting the generalizability to the full ABCD sample or other samples. Third, although the temporal network can inform the directionality of findings, results are correlational in nature and cannot indicate causality. Fourth, the measurement of irritability was not designed *a priori* to assess irritability and relied on parent-reports only. Incorporating clinicians or child self-reports may provide a more comprehnsive understanding of the irritability phenotype.

Current US pediatric guidelines, such as the American Academy of Pediatrics' "5Cs of Media Use," emphasize the quality and developmental appropriateness of digital media, as well as the importance of balancing screen use with offline activities, rather than prescribing strict limits on daily screen time (Williams and Radesky, 2025). Our findings align with this framework by demonstrating that different types of screen activities show distinct developmental patterns and emotional correlates. Thus, our study highlighted the need for nuanced, content-specific guidance that considers not only the duration of children's screen use but also the motivations for use and the emotional states accompanying it. For parents and educators, recommendations may be most effective when tailored to screen usage context and gender, with an emphasis on supporting non-digital emotion-regulation strategies. For clinicians, incorporating screen-use patterns into routine assessments of irritability and providing families with emotion-regulation training may help reduce reliance on screen-based soothing and promote healthier coping mechanisms.

Taken together, our study found a bidirectional association between irritability and online chatting: while higher irritability predicted increased time spent chatting online, greater engagement in online chatting was associated with reductions in irritability. Both TV-watching and social media use unidirectionally predicted increased irritability. The different platforms and technologies are constantly changing, advancing, gaining or losing popularity within adolescents (Vuorre et al., 2021). Future research is needed to better understand the nuanced differences in various digital media activities and contents and adolescents' motives for their use and how these factors impact adolescent mental health.

Acknowledgement:

Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development (ABCD) Study (https://abcdstudy.org), held in the NIMH Data Archive (NDA). This is a multisite, longitudinal study designed to recruit more than 10,000 children aged 9-10 and follow them over 10 years into early adulthood. The ABCD Study is supported by the National Institutes of Health and additional federal partners under award numbers U01DA041022, U01DA041028, U01DA041048, U01DA041089, U01DA041106, U01DA041117, U01DA041120, U01DA041134, U01DA041148, U01DA041156, U01DA041174, U24DA041123, U24DA041147, U01DA041093, and U01DA041025. A full list of supporters is available at https://abcdstudy.org/federal-partners.html. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/Consortium_Members.pdf. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or ABCD consortium investigators. The ABCD data repository grows and changes over time. The ABCD data used in this report came from NDA Release 4.0 (https://doi.org/10.15154/1523041). The authors thank the youth and families participating in the Adolescent Brain Cognitive Development (ABCD) Study.

Author contributions: All authors have contributed to the manuscript substantially and consent for the publication of this manuscript. Lanting Zhang: Conceptualization, Methodology, Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing. Nellia Bellaert: Methodology, Writing - Review & Editing. Haoran Zhuo: Data curation, Writing - Review & Editing. Zeyan Liew: Data curation, Writing - Review & Editing. Wan-Ling Tseng: Conceptualization, Methodology, Formal analysis, Writing - Review & Editing, Supervision

Statements and declarations:

Conflict of interest: There are no actual or perceived conflicts of interest in the conduct and reporting of this research by any of the authors.

Funding statement: Dr. Tseng is supported by research grants from the NIMH (R00MH110570, DP2MH140132), Charles H. Hood Foundation, and Fund to Retain Clinical Scientists from the Yale School of Medicine and the Yale Center for Clinical Investigation. Ms. Bellaert is supported by PhD research grants from the Belgian American Educational Foundation, and the Belgian National Fund for Scientific Research (F.R.S.–FNRS).

Ethical approval: The ABCD study obtained approval from the central Institutional Review Board (IRB) at the University of California, San Diego, as well as local IRBs at specific research sites (e.g., Washington University in St. Louis).

REFERENCES

Alter A. Irresistible: The Rise of Addictive Technology and the Business of Keeping Us Hooked. Penguin; 2017.

Bagot K, Tomko R, Marshall AT, et al. Youth Screen Use in the ABCD® Study. Dev Cogn Neurosci 2022;57:101150; PubMed doi: 10.1016/j.dcn.2022.101150.

Balcombe L and De Leo D. The Impact of YouTube on Loneliness and Mental Health. Informatics 2023;10(2):39 PubMed ; doi: 10.3390/informatics10020039.

Bellaert N, Morreale K and Tseng W-L. Peer Functioning Difficulties May Exacerbate Symptoms of Attention-Deficit/Hyperactivity Disorder and Irritability over Time: A Temporal Network Analysis. J Child Psychol Psychiatry 2023;n/a(n/a); doi: 10.1111/jcpp.13911.

Burger J, Isvoranu A-M, Lunansky G, et al. Reporting Standards for Psychological Network Analyses in Cross-Sectional Data. Psychol Methods 2022.

Chad-Friedman E, Galano MM, Lemay EP, et al. Parsing Between-and within-Person Effects: Longitudinal Associations between Irritability and Internalizing and Externalizing Problems from Early Childhood through Adolescence. Dev Psychopathol 2023;35(3):1371 PubMed –1381.

Clark JL, Algoe SB and Green MC. Social Network Sites and Well-Being: The Role of Social Connection. Curr Dir Psychol Sci 2018;27(1):32–37; doi: 10.1177/0963721417730833.

Cordova MM, Antovich DM, Ryabinin P, et al. Attention-Deficit/Hyperactivity Disorder: Restricted Phenotypes Prevalence, Comorbidity, and Polygenic Risk Sensitivity in the ABCD Baseline Cohort. J Am Acad Child Adolesc Psychiatry 2022;61(10):1273–1284; doi: 10.1016/j.jaac.2022.03.030.

Coyne SM, Shawcroft J, Gale M, et al. Tantrums, Toddlers and Technology: Temperament, Media Emotion Regulation, and Problematic Media Use in Early Childhood. Comput Hum Behav 2021;120:106762; PubMed doi: 10.1016/j.chb.2021.106762.

Coyne SM, Stockdale LA, Warburton W, et al. Pathological Video Game Symptoms from Adolescence to Emerging Adulthood: A 6-Year Longitudinal Study of Trajectories, Predictors, and Outcomes. Dev Psychol 2020;56(7):1385 PubMed .

Domoff SE, Harrison K, Gearhardt AN, et al. Development and Validation of the Problematic Media Use Measure: A Parent Report Measure of Screen Media “Addiction” in Children. Psychol Pop Media Cult 2019;8(1):2–11; doi: 10.1037/ppm0000163.

Eales L, Gillespie S, Alstat RA, et al. Children’s Screen and Problematic Media Use in the United States before and during the COVID-19 Pandemic. Child Dev 2021;92(5):e866–e882; doi: 10.1111/cdev.13652.

Ein N, Reed MJ and Vickers K. The Effect of Dog Videos on Subjective and Physiological Responses to Stress. Anthrozoös 2022;35(3):463–482; doi: 10.1080/08927936.2021.1999606.

Eirich R, McArthur BA, Anhorn C, et al. Association of Screen Time With Internalizing and Externalizing Behavior Problems in Children 12 Years or Younger: A Systematic Review and Meta-Analysis. JAMA Psychiatry 2022;79(5):393–405; doi: 10.1001/jamapsychiatry.2022.0155.

Epskamp S. Psychometric Network Models from Time-Series and Panel Data. Psychometrika 2020;85(1):206–231; doi: 10.1007/s11336-020-09697-3.

Epskamp S, Waldorp LJ, Mõttus R, et al. The Gaussian Graphical Model in Cross-Sectional and Time-Series Data. Multivar Behav Res 2018;53(4):453–480.

Evans SC, Blossom JB and Fite PJ. Exploring Longitudinal Mechanisms of Irritability in Children: Implications for Cognitive-Behavioral Intervention. Behav Ther 2020;51(2):238–252; doi: 10.1016/j.beth.2019.05.006.

Fitzpatrick C, Binet M-A, Harvey E, et al. Preschooler Screen Time and Temperamental Anger/Frustration during the COVID-19 Pandemic. Pediatr Res 2023;1–6; doi: 10.1038/s41390-023-02485-6.

Garavan H, Bartsch H, Conway K, et al. Recruiting the ABCD Sample: Design Considerations and Procedures. Dev Cogn Neurosci 2018;32:16–22 PubMed ; doi: 10.1016/j.dcn.2018.04.004.

Guerrero MD, Barnes JD, Chaput J-P, et al. Screen Time and Problem Behaviors in Children: Exploring the Mediating Role of Sleep Duration. Int J Behav Nutr Phys Act 2019;16(1):105; doi: 10.1186/s12966-019-0862-x.

Hooper D, Coughlan J and Mullen M. Structural Equation Modelling: Guidelines for Determining Model Fit. 2008;6(1).

Karcher NR and Barch DM. The ABCD Study: Understanding the Development of Risk for Mental and Physical Health Outcomes. Neuropsychopharmacology 2021;46(1):131–142; doi: 10.1038/s41386-020-0736-6.

Kim S, Favotto L, Halladay J, et al. Differential Associations between Passive and Active Forms of Screen Time and Adolescent Mood and Anxiety Disorders. Soc Psychiatry Psychiatr Epidemiol 2020;55(11):1469–1478; doi: 10.1007/s00127-020-01833-9.

Klein DN, Dougherty LR, Kessel EM, et al. A Transdiagnostic Perspective on Youth Irritability. Curr Dir Psychol Sci 2021;30(5):437–443; doi: 10.1177/09637214211035101.

Koncz P, Demetrovics Z, Takacs ZK, et al. The Emerging Evidence on the Association between Symptoms of ADHD and Gaming Disorder: A Systematic Review and Meta-Analysis. Clin Psychol Rev 2023;106:102343; PubMed doi: 10.1016/j.cpr.2023.102343.

Lee S, Kim S, Suh S, et al. Relationship between Screen Time among Children and Lower Economic Status during Elementary School Closures Due to the Coronavirus Disease 2019 Pandemic. BMC Public Health 2022;22(1):160 PubMed ; doi: 10.1186/s12889-022-12559-5.

Leibenluft E, Allen LE, Althoff RR, et al. Irritability in Youths: A Critical Integrative Review. Am J Psychiatry 2024;appi.ajp.20230256; doi: 10.1176/appi.ajp.20230256.

Lin S-Y, Eaton NR and Schleider JL. Unpacking Associations between Mood Symptoms and Screen Time in Preadolescents: A Network Analysis. J Abnorm Child Psychol 2020;48(12):1635–1647; doi: 10.1007/s10802-020-00703-x.

Littman-Ovadia H and Russo-Netzer P. Exploring the Lived Experience and Coping Strategies of Fear of Missing Out (FoMO) among Emerging Adults. Curr Psychol 2024;43(42):32665–32685; doi: 10.1007/s12144-024-06793-w.

Liu D, Baumeister RF, Yang C, et al. Digital Communication Media Use and Psychological Well-Being: A Meta-Analysis. J Comput-Mediat Commun 2019;24(5):259–273; doi: 10.1093/jcmc/zmz013.

MacMullin LN, Bokeloh LM, Nabbijohn AN, et al. Examining the Relation Between Gender Nonconformity and Psychological Well-Being in Children: The Roles of Peers and Parents. Arch Sex Behav 2021;50(3):823–841; doi: 10.1007/s10508-020-01832-6.

Mallawaarachchi S, Burley J, Mavilidi M, et al. Early Childhood Screen Use Contexts and Cognitive and Psychosocial Outcomes: A Systematic Review and Meta-Analysis. JAMA Pediatr 2024;178(10):1017–1026; doi: 10.1001/jamapediatrics.2024.2620.

McLaughlin KA, Hatzenbuehler ML, Mennin DS, et al. Emotion Dysregulation and Adolescent Psychopathology: A Prospective Study. Behav Res Ther 2011;49(9):544–554; doi: 10.1016/j.brat.2011.06.003.

Neville RD, McArthur BA, Eirich R, et al. Bidirectional Associations between Screen Time and Children's Externalizing and Internalizing Behaviors. J Child Psychol Psychiatry 2021;62(12):1475–1484.

Noreika V, Falter CM and Rubia K. Timing Deficits in Attention-Deficit/Hyperactivity Disorder (ADHD): Evidence from Neurocognitive and Neuroimaging Studies. Spec Issue Does Brain Process Time 2013;51(2):235–266; doi: 10.1016/j.neuropsychologia.2012.09.036.

Orben A. Teenagers, Screens and Social Media: A Narrative Review of Reviews and Key Studies. Soc Psychiatry Psychiatr Epidemiol 2020;55(4):407–414; doi: 10.1007/s00127-019-01825-4.

Pinheiro J, Simões de Almeida R and Marques A. Emotional Self-Regulation, Virtual Reality and Neurofeedback. Comput Hum Behav Rep 2021;4:100101; PubMed doi: 10.1016/j.chbr.2021.100101.

Radesky JS, Kaciroti N, Weeks HM, et al. Longitudinal Associations Between Use of Mobile Devices for Calming and Emotional Reactivity and Executive Functioning in Children Aged 3 to 5 Years. JAMA Pediatr 2023;177(1):62 PubMed ; doi: 10.1001/jamapediatrics.2022.4793.

Rizakos S, Parmar A, Siden HH, et al. The Parental Experience of Caring for a Child With Pain and Irritability of Unknown Origin. J Pain Symptom Manage 2022;63(2):330–340; doi: 10.1016/j.jpainsymman.2021.07.026.

Roberts MZ, Flagg AM and Lin B. Context Matters: How Smartphone (Mis)Use May Disrupt Early Emotion Regulation Development. New Ideas Psychol 2022;64:100919; PubMed doi: 10.1016/j.newideapsych.2021.100919.

Rzepa E and McCabe C. Dimensional Anhedonia and the Adolescent Brain: Reward and Aversion Anticipation, Effort and Consummation. BJPsych Open 2019;5(6): PubMed e99; doi: 10.1192/bjo.2019.68.

Samson AD, Rohr CS, Park S, et al. Videogame Exposure Positively Associates with Selective Attention in a Cross-Sectional Sample of Young Children. PLOS ONE 2021;16(9): PubMed e0257877; doi: 10.1371/journal.pone.0257877.

Shawcroft J, Gale M, Coyne SM, et al. Teens, Screens and Quarantine; the Relationship between Adolescent Media Use and Mental Health Prior to and during COVID-19. Heliyon 2022;8(7): PubMed e09898; doi: 10.1016/j.heliyon.2022.e09898.

Smith DM, Loughnan R, Friedman NP, et al. Heritability Estimation of Cognitive Phenotypes in the ABCD Study(®) Using Mixed Models. Behav Genet 2023;53(3):169–188; doi: 10.1007/s10519-023-10141-2.

Thorisdottir IE, Sigurvinsdottir R, Kristjansson AL, et al. Longitudinal Association between Social Media Use and Psychological Distress among Adolescents. Prev Med 2020;141:106270; PubMed doi: 10.1016/j.ypmed.2020.106270.

Twenge JM and Farley E. Not All Screen Time Is Created Equal: Associations with Mental Health Vary by Activity and Gender. Soc Psychiatry Psychiatr Epidemiol 2021;56(2):207–217; doi: 10.1007/s00127-020-01906-9.

Vuorre M, Orben A and Przybylski AK. There Is No Evidence That Associations Between Adolescents' Digital Technology Engagement and Mental Health Problems Have Increased. 2021.

Williams E and Radesky JS. The 5Cs Approach to Digital Media: Empowering Families and Professionals to Foster Healthy Screen Use for Young Children. Int J Birth Parent Educ 2025;12(2):20–24.

Xu L, Song K, Deng H, et al. Beyond Screen Time: The Core Influences of Problematic Screen Use on Adolescent Development Networks. J Behav Addict 2025;14(2):724 PubMed –737; doi: 10.1556/2006.2025.00035.

Yu Q, Hodgdon EA, Kryza-Lacombe M, et al. Roads Diverged: Developmental Trajectories of Irritability From Toddlerhood Through Adolescence. J Am Acad Child Adolesc Psychiatry 2023;62(4):457–471; doi: 10.1016/j.jaac.2022.07.849.

Zhao Y, Paulus MP and Potenza MN. Brain Structural Co-Development Is Associated with Internalizing Symptoms Two Years Later in the ABCD Cohort. J Behav Addict 2023;12(1):80 PubMed –93; doi: 10.1556/2006.2023.00006.

Table 1. Socio-demographic characteristics of the sample

Socio-demographic variable		M (SD), or *n* (%)
Age, in years		9.48 (0.51)
Gender	Male	4574 (50.90%)
	Female	4405 (49.10%)
Race	White	6144 (68.43%)
	Black	1014 (11.29%)
	Asian	52 (0.58%)
	Native American	196 (2.18%)
	Mixed	479 (5.33%)
	No Answer/Other	1094 (12.18%)
Ethnicity	Hispanic	1707 (19.03%)
	Not Hispanic	7160 (79.81%)
	No Answer	104 (1.16%)
Education (Parent 1)	Below high school	462 (5.15%)
	High school/GED	779 (8.68%)
	Some college/associate degree	2424 (27.00%)
	Bachelor	2769 (30.84%)
	Postgraduate	2533 (28.21%)
	No Answer	12 (0.13%)
Education (Parent 2)	Below high school	495 (5.51%)
	High school/GED	973 (10.84%)
	Some college/associate degree	1757 (19.57%)
	Bachelor	2207 (24.58%)
	Postgraduate	1988 (22.14%)
	No answer	1559 (17.36%)
Household income	$25,000 and below	945 (10.53%)
	$25,000-49,999	1090 (12.14%)
	$50,000-74,999	1121 (12.49%)
	$75,000-99,999	1295 (14.42%)
	$100,000-199,999	2805 (31.24%)
	$200,000 and above	1059 (11.79%)
	No Answer	664 (7.39%)

Table 2. Means, standard deviations and correlations of the study variables

		M (SD)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	TV (baseline)	1.19 (0.99)																	
2	Video	0.86 (1.04)	.30**																
3	VG	0.91 (1.01)	.32**	.41**															
4	SNS	0.09 (0.34)	.13**	.24**	.12**														
5	Chat	0.31 (0.58)	.20**	.28**	.23**	.45**													
6	TV_1 (year 1)	1.18 (0.98)	.40**	.16**	.17**	.11**	.11**												
7	Video_1	1.04 (1.10)	.21**	.51**	.30**	.17**	.18**	.30**											
8	VG_1	1.07 (1.11)	.17**	.32**	.46**	.08**	.13**	.28**	.47**										
9	SNS_1	0.18 (0.50)	.07**	.18**	.06**	.30**	.24**	.13**	.26**	.14**									
10	Chat_1	0.49 (0.77)	.11**	.21**	.11**	.25**	.34**	.18**	.32**	.23**	.52**								
11	TV_2 (year 2)	1.16 (1.02)	.28**	.17**	.11**	.09**	.10**	.32**	.18**	.12**	.09**	.14**							
12	Video_2	0.92 (1.04)	.16**	.38**	.24**	.09**	.10**	.12**	.44**	.29**	.10**	.14**	.22**						
13	VG_2	1.16 (1.27)	.12**	.27**	.37**	.03*	.07**	.14**	.29**	.47**	.03*	.09**	.23**	.40**					

14	Chat_2	0.60 (0.90)	.09**	.16**	.06**	.19**	.23**	.11**	.19**	.09**	.29**	.36**	.23**	.20**	.18**				
15	SNS_2	0.41 (0.78)	.07**	.18**	.03*	.22**	.20**	.09**	.22**	.06**	.36**	.31**	.21**	.19**	.10**	.52**			
16	IRR	0.30 (0.39)	.04*	.05**	.06**	.04**	.01	.06**	.04**	.06**	.01	0	.05**	.03*	.06**	0	.01		
17	IRR_1	0.29 (0.38)	.03*	.04*	.05**	.03	.02	.06**	.04**	.06**	.02	0	.03	.03	.05**	0	.01	.67**	
18	IRR_2	0.28 (0.37)	.02	.02	.03	.02	.01	.05**	.02	.04*	.03*	.01	.03	.02	.04*	.02	.03	.61**	.66**

VG, video game; SNS, social media; chat, online chat; IRR, Irritability * $p < 0.5$; **$p < 0.01$