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The Longitudinal Impact of Screen Time on Adolescent Development: Moderation by Respiratory Sinus Arrhythmia

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A B S T R A C T

Purpose: To date, little is known about underlying psychophysiological contributions to the impact of media content and overall screen time on adolescent psychological functioning. In the present study we examine respiratory sinus arrhythmia (RSA) as a moderator of the link between specific types of media content use, overall media exposure, and the development of internalizing and aggressive symptoms in youth.
Methods: A sample of 374 adolescents (mean age = 15) reported on their media use, internalizing behavior, and aggressive behavior at time 1 (2011) and 1-year follow-up (2012). RSA reactivity was gathered during a challenging laboratory task. Path analyses were conducted to test the hypothesized three-way interaction model between media use, media content, and RSA reactivity, separately for internalizing and aggressive problems.
Results: Significant interactions were found for aggressive, but not prosocial, media content. For aggressive content, youth exhibiting RSA withdrawal reported significantly greater internalizing and aggressive symptoms when exposed to higher amounts of screen time and aggressive content.
Conclusions: These findings suggest that profiles of heightened RSA withdrawal may place adolescents at greater risk to the negative impact of violent media, whereas prosocial media content may not significantly impact youth development of psychopathology. Implications for the role of psychophysiology in our understanding of media effects are discussed.

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IMPLICATIONS AND CONTRIBUTION

This study identifies risk factors for media use and adolescent mental health based on underlying psychophysiology and exposure to media content. Findings suggest that adolescent psychophysiology may significantly affect the impact of problematic media use on adolescent mental health.

In only a few years, the use of mobile technology (e.g., smartphones, tablets, and e-readers) in the United States has changed dramatically. Total daily screen time, a metric of summed exposure to devices capable of displaying video content (e.g., smartphones, tablets, TVs) for children 8–18 years old, has nearly doubled since 1999 [1,2]. Screen time among adolescents is particularly high with recent reports suggesting that 97% of adolescents engage with media on a daily basis, averaging nearly 9 hours per day across all devices [1]. Increased exposure to media has been linked with a broad range of both beneficial and detrimental outcomes, depending upon the type of media content being examined [2,3]. For example, a robust literature suggests that excessive screen time exposure is

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associated with increases in externalizing symptoms, particularly aggressive behavior [4,5], and recent evidence indicates that children may also suffer from increases in internalizing symptomatology, including depressive symptoms [6].

Past research has suggested that an individual's dispositional characteristics may impact his or her response to environmental influences, such that some children are much more sensitive than others to both harmful and beneficial contexts [7]. Youth who exhibit a sensitive profile may demonstrate the worst adjustment in negative environments but also superior adjustment in positive environments, a pattern of plasticity sometimes referred to as "for better and for worse" [8]. Given these nuanced findings, to examine independent contributions of youth characteristics and environments to youth development is likely insufficient. Rather, the incorporation of interactions with physiology is necessary to elucidate effects that would otherwise be obscured [9].

Researchers have explored a number of factors that may represent plasticity, including temperament, genetics, and psychophysiology [9]. In this study, we examined respiratory sinus arrhythmia (RSA) as an indicator of plasticity. According to Polyvagal theory, RSA is an indicator of the innervation of the vagus nerve, the 10th cranial nerve responsible for changes in heart rate in response to stress [10]. RSA reflects the amplitude of heart rate oscillations between inhaling and exhaling. RSA reactivity represents change in RSA from baseline to RSA measured during exposure to stress [11,12]. RSA reactivity has been conceptualized as an important mechanism by which the body physiologically allocates resources for self-regulation in times of stress [13,14]. RSA withdrawal reduces parasympathetic nervous system (PNS) activation, allowing for a potential increase in heart rate and subsequently more resources to devote to engaging in a challenging situation. Thus, a reduction of PNS activity, or a *withdrawal* of RSA, in response to stress allows for sympathetic nervous system activity to provide the body with resources to respond to a stressful situation, whereas increases of RSA in response to stress, or *RSA augmentation,* suggest an increase of PNS activity that deprives the body of physiological resources to manage challenge or distress [14,15]. We selected RSA reactivity as an indicator of plasticity given its relevance to psychosocial adjustment, our outcome of interest.

Although researchers have called for greater attention to psychophysiology to better understand media effects on psychosocial adjustment [16], few studies have addressed this gap in the literature. In one study, Coyne et al. [17] found that low RSA withdrawal (i.e., greater parasympathetic activation) was associated with more video game addiction symptoms in adolescents, a finding concordant with much of the literature suggesting patterns of parasympathetic activation in response to a stressor may be maladaptive [18]. To our knowledge, the present study is the first investigation of RSA reactivity as a moderator of the effects of media exposure on youth development.

The goal of the current study is to build upon prior research [19] and examine adolescent physiological stress response as a moderator of the association between exposure to media and psychosocial adjustment in adolescence. Further, we heed the call of previous researchers [20,21] by examining the role of both physically aggressive and prosocial media content as well as total screen time in order to better understand both potential positive and negative contributions of media to adolescents' adjustment behavior. By considering both adolescent physiological stress response and media content, we aim to better understand under what conditions and for whom excessive screen time in adolescence leads to detrimental outcomes. Using a multimodal, multi-informant, longitudinal design, we tested whether the prospective association between screen time exposure and adolescent adjustment varied as a function of adolescents' RSA reactivity and media content (aggressive and prosocial content).

Given that RSA withdrawal reflects increased sensitivity to environmental stimuli, we hypothesized that adolescents displaying RSA withdrawal, but not augmentation, would exhibit heightened sensitivity to excessive screen time and that this would enhance the negative impact of aggressive media content, as well as the positive impact of prosocial media content. Specifically, we hypothesized that aggressive media content would predict *greater* internalizing and aggressive behavior symptoms at high levels of screen time among adolescents showing RSA withdrawal but not among adolescents showing RSA augmentation. Similarly, we hypothesized that prosocial media content would predict *fewer* internalizing and aggressive symptoms at higher screen time amounts among adolescents showing RSA withdrawal but not among adolescents showing RSA augmentation.

Methods

Participants

The participants for this study were taken from waves 5 (2011) and 6 (2012) of the Flourishing Families Project (FFP), a longitudinal study of inner-family life involving families with a child between the ages of 13 and 18 (N = 500). For the current study, families were included only if they participated in the physiological assessment at wave 5 (n = 374). The final sample of participants involved 181 boys and 193 girls (mean age 15.29; standard deviation [SD] 1.05; range 13–18). Sixty-five percent identified as white, 13% as African-American, and 22% as other or mixed race. Thirty percent were from single-parent homes and average combined monthly income (mother-reported) was ~$5,500 (~$66,000 yearly), but 21% of the sample reported making less than $3,000 monthly.

Procedure

Participant families for the FFP were selected from a large city in the Pacific Northwest and were interviewed during the first 8 months of 2007 at Wave 1. Families were primarily recruited using a purchased national telephone survey database (Polk Directories, InfoUSA, Papillion, NE). Families identified using the Polk Directories were randomly selected from targeted census tracts that mirrored the socioeconomic and racial stratification of reports of local school districts. All families with a child between the ages of 10 and 14 living within target census tracts were deemed eligible to participate in the FFP and no additional exclusionary criteria were utilized. Of the 692 eligible families contacted, 423 agreed to participate, resulting in a 61% response rate. However, the Polk Directory national database was generated using telephone, magazine, and internet subscription reports; so families of lower socioeconomic status were under-represented. Therefore, in an attempt to more closely mirror the demographics of the local area, a limited number of families was recruited into the study through other means (e.g., referrals, fliers; n = 77, 15%). By broadening the approach, the social-economic and ethnic diversity of the sample was increased. At each wave of data collection, interviewers visited the individual family's homes and conducted an assessment interview as well as questionnaires that were completed in the home. This study was approved by a University Institutional Review Board.

Measures

Media content. Youth were asked to list their three favorite television shows and video games. Adolescents' media preferences were then coded for physical aggression and prosocial behavior; prosocial behavior was defined as "behaviors intended to help others or benefit society as a whole (e.g., helping, sharing, cooperating, and supporting others)." All the programs identified by participants were then distributed to 752 independent raters (37% male, M age = 23.67, SD = 8.69) who were asked to rate how much physical aggression and prosocial behavior were in each program they were familiar with (viewed regularly). Ratings for physical aggression were based on a 1 (not physically aggressive) to 5 (extremely physically aggressive) Likert scale. Ratings for prosocial behavior were based on a 1 (not prosocial) to 5 (extremely prosocial) Likert scale. The mean rating of all raters for a particular show (at least two raters per show) was determined. Expert ratings are commonly used in media violence research [22,23] and show high reliability, convergent validity, predictive validity, and discriminant validity across multiple cultures and ages [22]. Intercoder reliability was assessed using interclass correlations (ICCs) that are specifically appropriate when using continuous data. ICCs showed moderate-to-strong reliability in the current study (physical aggression ICC = .80; prosocial behavior ICC = .66).

Youth screen time. Youth reported how many hours they spend in a typical day watching TV programs and playing video games. Response categories ranged from 1 (*none*) to 9 (>*8 hours*) for each of the two types of media. Ratings across TV and video game media activities were then summed (range 2–18).

Respiratory sinus arrhythmia. Collection of RSA data proceeded as follows: after electrodes were placed and after a period of acclimatization, a 3-minute resting baseline was taken. After the baseline, participants were given a 4 × 4 Rubik's Cube to solve for 3 minutes, which served as the challenging task. No additional incentive or negative consequence was provided for completion of this task. Participants were told to complete the blue side of the Rubik's cube first and then complete the red side. As typical for assessing autonomic nervous system reactions to cognitively challenging tasks, the Rubik's Cube was novel and challenging for the vast majority of participants (cf. the star-tracing task) [24]. Indeed, only 10 participants completed a single side and none completed two. RSA data were collected, extracted, and cleaned using MindWare data-capturing equipment and software (MindWare Technologies, Ltd., Gahanna, OH; http://www.mindwaretech.com). Standard methods for acquiring RSA, including electrode placement, were followed [25]. RSA was derived in accordance with recommendations of the Society for Psychophysiological Research Committee on Impedance Cardiography [26].

Youth internalizing problems. Internalizing behavior problems were measured using depression and anxiety-related items representative of core symptoms in each domain [27,28]. Sample items included "I am unhappy, sad or depressed" and "I am fearful or anxious." Responses ranged from 0 (*not true*) to 2 (*very true or often true*) with higher scores representing higher levels of depression/anxiety symptoms. There is extensive evidence of both reliability and validity of this measure, and there is evidence that this scale has cross-ethnic equivalence [28]. Internal consistency for the 13-item internalizing scale was found to be .88 and .75 at waves 5 and 6, respectively.

Youth aggressive behavior. Adolescents' aggressive behavior was assessed using five items taken from the Emotional Restraint Scale of the Weinberger Adjustment Inventory [29]. Participants rated the degree to which items described them using a five-point Likert scale ranging from 1 (*does not describe me*) to 5 (*describes me very well*). Sample items included, "If someone tries to hurt me, I make sure I get even with them," and "I lose my temper and let people have it when I'm angry." Internal consistency for the current sample was found to be .87 and .88 for waves 5 and 6, respectively.

Data analytic plan

Respiratory sinus arrhythmia reactivity. In the current study, we used latent curve models (LCMs) for estimation of basal and reactivity scores of RSA. We modeled reactivity scores in two steps. In the first step, we estimated an unconditional LCM with latent baseline and reactivity factors. For the latent baseline variable (i.e., intercept), all six indicators were set to one. For the latent reactivity variable, the three 1-minute task indicators were set to zero, the first minute epoch of the problem-solving task was set to 1, and the remaining two 1-minute RSA epochs were freely estimated. In the second step, we saved the factor scores derived from the unconditional LCM to be used as observed RSA basal (i.e., intercept) and reactivity (i.e., slope) scores. Positive RSA reactivity factor scores represent an increase in RSA during the stress task (RSA augmentation) and negative RSA reactivity factor scores represent a decrease in RSA during the stress task (RSA withdrawal). With regard to missing data, full information maximum likelihood estimation techniques were used for inclusion of all available data.

Evaluation of the primary model. Path analysis was used to test the hypothesized three-way interaction model (screen time × media content × RSA reactivity) and was conducted with Mplus 7.2 software (Muthén & Muthén, Los Angeles, CA). Two separate structural models were examined, each with internalizing problems and aggressive behavior outcomes simultaneously predicted: Model 1 with the three-way interaction with aggressive media content and Model 2 with prosocial media content. In both models, resting RSA and baseline problem behaviors were included as covariates. Both forms of media content exposure were included in each model to isolate the impact of prosocial and aggressive content on internalizing and aggressive symptoms. Finally, when significant interactions emerged, figures were created that illustrated the form of the interaction by depicting the regression lines of the relation between screen time and adolescent problem behavior at high (+1.5 SD for a positive score to represent RSA augmentation) and low (−1.5 SD for a negative score to represent RSA withdrawal) scores of RSA reactivity separately for high (a score of 4 out of 5) and low (a score of 2 out of 5) levels of physical aggression or prosocial media content exposure [30]. Simple slopes analysis was used to aid interpretation of the interaction plots. Lastly, sensitivity analyses were conducted to examine if youth sex influenced model results and a four-way interaction involving both types of media content was tested.

Results

The unconditional free loading LCM of resting RSA and RSA reactivity demonstrated acceptable fit, χ^2 (14, N = 373) = 63.24, $p <$ .05, root mean square error of approximation (RMSEA) = .097, 95% confidence interval (CI) .074–.122, confirmatory fit index (CFI) = .97, standardized root mean square residual (SRMR) = .07.

Table 1
Descriptive statistics and bivariate correlations of main study variables

	M (SD)	Range	2	3	4	5	6	7	8	9
1. RSA baseline	6.79 (.95)	3.9–9.5	−.36*	−.07	.07	.02	−.06	−.02	−.07	−.09
2. RSA reactivity	−.44 (.59)	−3 to 1.2	–	−.02	−.06	.09	.06	.06	.09	−.03
3. Screen time	6.32 (.87)	2–18		–	.13*	−.09	.01	.23*	.16*	.22*
4. Physical aggression media	3.15 (.87)	1–5			–	.18*	−.11*	.14*	.22*	.14*
5. Prosocial media	2.97 (.60)	1–5				–	.10	.03	−.02	−.05
6. Internalizing problems W5	5.59 (5.1)	0–25					–	.17*	.17*	.11*
7. Aggressive behavior W5	10.5 (4.5)	5–25						–	.30*	.66*
8. Internalizing problems W6	2.78 (2.8)	0–13							–	.35*
9. Aggressive behavior W6	10.2 (4.3)	5–25								–

RSA = respiratory sinus arrhythmia; SD = standard deviation.
* $p < .05$.

Descriptive statistics and correlations among main study variables and the RSA factor scores are presented in Table 1.

Physical aggression media content model (Model 1)

The standardized estimates are presented in the top half of Table 2 along with bias-corrected bootstrap CIs for all effects in the model. Of primary interest, the screen time by physical media content exposure by RSA reactivity three-way interaction was significantly different from zero for both internalizing problems and aggressive behavior outcomes. Figures 1 and 2 illustrate the form of the interactions for internalizing problems ($\beta = .27$, $p < .05$) and aggressive behavior ($\beta = .25$, $p < .05$), respectively. The form of the interaction indicates that, for both internalizing problems and aggressive behavior, greater levels of media exposure that is high in physical aggression content predicted higher levels of problem behavior among youth who evidenced RSA withdrawal during the cognitive stress task. For the aggressive behavior outcome, this interpretation is supported by the significant conditional effect of screen time on youth aggressive behavior for those who had greater amounts of media exposure that was high in physical aggression content and who exhibited RSA withdrawal during the stress task (b = .25, $p < .05$) but not for any other combination (all p values >.10). Congruent with the aggressive behavior outcome, the slope for the conditional effect of screen time on internalizing problems for RSA withdrawal and high (b = .27, $p < .05$), but not low (b = .02, $p > .10$), aggression media content was significant.

The prosocial media content model (Model 2)

The standardized estimates are presented in the bottom half of Table 2 along with bias-corrected bootstrap CIs for all effects in the model. Main effects were similar to Model 1. All interactions involving prosocial media content exposure were not significantly different from zero.

Sensitivity analyses

To examine the robustness of findings in Model 1, the effect of youth sex on the model was examined by running a multiple-

Table 2
Path model results

	Outcome: internalizing		Outcome: aggressive	
	β	95% CI	β	95% CI
Model 1: physical aggression				
W5 internalizing/aggressive	.15**	.04 to .25	.59**	.46 to .71
Screen time	.14	−.06 to .33	.06	−.12 to .24
RSA baseline	−.03	−.11 to .05	−.11*	−.20 to −.02
RSA reactivity	−.05	−.36 to .26	−.13	−.35 to .09
Physical aggression media	.17*	.01 to .33	.08	−.05 to .22
Prosocial media	−.06	−.15 to .03	−.06	−.16 to .02
Physical media × RSA reactivity	.17*	−.12 to .46	.16	−.02 to .36
Physical media × screen time	−.06	−.31 to .19	−.08	−.31 to .15
Screen time × RSA reactivity	.39**	.13 to .65	.11	−.19 to .40
Three-way interaction	−.47**	−.71 to −.23	−.26*	−.52 to −.01
Model 2: prosocial behavior				
W5 internalizing/aggressive	.17**	.07 to .28	.60**	.48 to .72
Screen time	−.01	−.29 to .27	.08	−.12 to .27
RSA baseline	−.03	−.11 to .06	−.11*	−.20 to -.01
RSA reactivity	.31*	.06 to .55	−.08	−.35 to .18
Physical aggression media	.21**	.11 to .31	.06	−.02 to .14
Prosocial media	−.11	−.24 to .03	−.04	−.16 to .08
Prosocial media × RSA reactivity	−.17	−.40 to .06	.12	−.10 to .35
Prosocial media × screen time	.11	−.14 to .36	−.09	−.27 to .09
Screen time × RSA reactivity	−.27	−.63 to .09	.07	−.29 to .44
Three-way interaction	.21	−.04 to .46	−.24	−.52 to .05

Correlations between predictors or outcomes not depicted.
CI = confidence interval; RSA = respiratory sinus arrhythmia.
* $p \le .05$.
** $p < .01$.

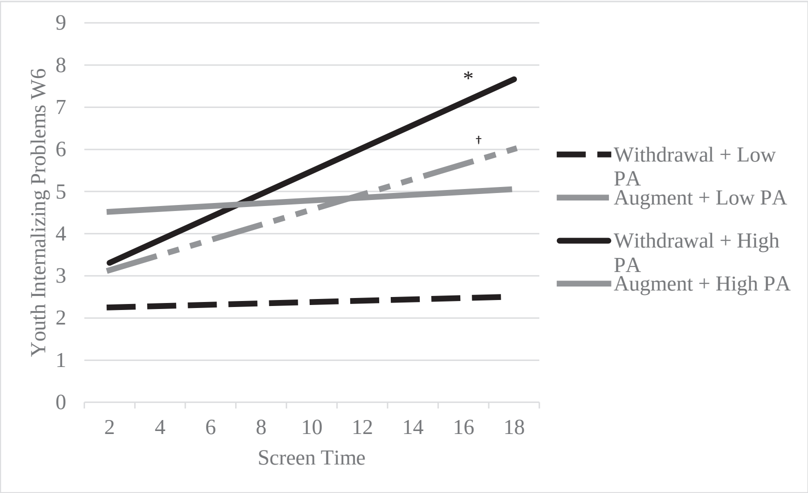

Figure 1. Screen time at wave 5 predicting internalizing problems at wave 6 at RSA withdrawal (−1.5 SD) and RSA augmentation (+1.5 SD), and at high (+1.5 SD) and low (−1.5 SD) levels of physical aggression (PA) media content. * indicates a significant simple slope at $p < .05$. † indicates marginal significance.

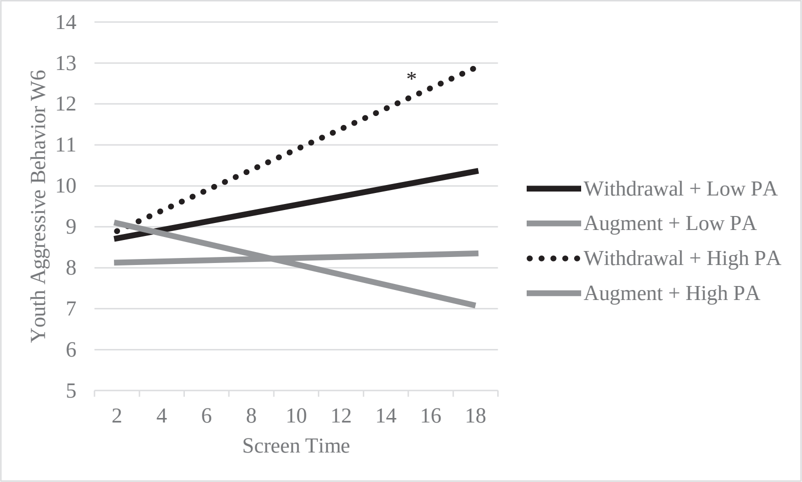

Figure 2. Screen time at wave 5 predicting aggressive behavior at wave 6 at RSA withdrawal (−1.5 SD) and RSA augmentation (+1.5 SD), and at high (+1.5 SD) and low (−1.5 SD) levels of physical aggression (PA) media content. * indicates a significant simple slope at $p < .05$.

indicator/multiple-cause model [31] in which both outcomes of the final structural model were regressed on youth sex. The significance of the three-way interactions and their subsequent interpretation remained unchanged by the inclusion of youth sex. Therefore, it was concluded that youth sex did not influence the original relationships among variables in the model.

Discussion

In the present study, we examined the interactive contributions of media content, RSA reactivity, and screen time to the development of internalizing and aggressive symptoms in adolescence. Our hypotheses were primarily supported for physical aggression content but not prosocial content. The relationship between physical aggression content and the development of problem behaviors in our sample of adolescents was explained by a three-way interaction, such that in the context of high levels of physical aggression content, greater RSA withdrawal was associated with more internalizing problems and aggressive behavior as youth was exposed to higher amounts of screen time. Prosocial content did not directly predict problem behaviors, nor did RSA moderate this relationship. The implications of each of these findings are discussed below.

Our findings suggest that screen time does not impact all adolescents equally, and that excessive screen time may contribute to increased internalizing and externalizing symptomatology among adolescents who consume *both* high levels of physically aggressive media content *and* experience RSA withdrawal when engaging in a challenging task. These findings suggest that adolescents exhibiting RSA withdrawal may be more sensitive to the negative effects of excessive screen time than those exhibiting RSA augmentation, particularly at high levels of exposure to aggressive content. RSA withdrawal is posited to prepare the body for engagement with stressors in the environment [15], an adaptive behavior that allows for effective responses to external stressors [14,15]. However, others have observed that RSA withdrawal functions as a diathesis, making youth with this reactivity profile more likely to suffer the adverse consequences of negative environments [32]. Additionally, heightened RSA withdrawal may function as a risk factor for adjustment through increased emotional lability [16,33]. The present findings indicate a compounding of risk factors that include overall high screen time, aggressive media content, and a sensitive profile of physiological reactivity. Thus, for youth exhibiting increased psychophysiological sensitivity, it may be especially important for parents to reduce their child's exposure to aggressive media content.

In contrast to our findings for physically aggressive content, adolescent exposure to prosocial content did not impact adjustment and was not moderated by RSA reactivity or screen time. Although these results contradict previous findings in the literature [21], demographic and measurement differences in the present study may have contributed to these results. First, much of the literature examining the impact of prosocial content on youth adjustment has focused on a younger period of development. Researchers have argued convincingly that the impact of prosocial content may be less salient for adolescents [21], whereas the development of prosocial norms in early childhood may be impacted to a greater extent [34]. Further complicating this picture is the mixture of both prosocial and aggressive content in the media adolescents reported consuming. In contrast to content aimed at younger viewers, the majority of media consumed today by adolescents includes enormous amounts of aggressive/violent content [35], but may also include some prosocial narratives such as cooperation and empathy for others. For example, the video game *The Legend of Zelda* and television show *Doctor Who* involve characters helping others through aggressive means, such as sword fighting or other forms of combat. Subsequently, both received relatively similar ratings of aggression and prosocial content. Thus, it may be that the violent/aggressive content included within the same television show or video game "washes out" the potentially beneficial effects of any accompanying prosocial content.

Some limitations should be noted. Although efforts were made in the present study to include a diverse sample, greater inclusion of racial and economic diversity in future studies will help to elucidate additional demographic differences implicated in the link between RSA reactivity and media influences. Our study is also limited by the nature of the task used. We chose to utilize a challenging cognitive task by asking adolescents to solve a Rubik's Cube; however, researchers have noted psychophysiological differences across different tasks [36]. Examination of physiological reactivity within the context of stressors, such as emotion-oriented tasks or those specific to media use, may help to elucidate differences in psychophysiological responses by adolescents. The present findings are also limited by the assessment of the media content examined. We chose to focus broadly on physically aggressive and prosocial content as a first step in this line of research; however, greater granularity within media content will likely provide additional nuances within these findings. Similarly, future research should expand the range of behavioral difficulties associated with media content and adolescent psychophysiology to include a broader range of aggressive difficulties, including both physical and relational aggression. Additionally, future work would benefit from inclusion of online behaviors (e.g., social networks, cyberbullying, and pornography), which may be impacted by psychophysiological sensitivity. Finally, efforts to develop comprehensive objective measures of screen time and media content exposure will be useful in future research.

The current study is the first to examine the role of adolescent physiological stress response in differentiating effects of amount and type (prosocial and aggressive content) of screen time on the development of internalizing and externalizing problems in adolescence. The present findings build on a burgeoning literature that highlights a need for a more nuanced examination of excessive media use on child development. To date, media use has primarily been hypothesized to impact development directly through effects on social learning [6], physical fitness [37], and cognitive development [38]. Although researchers are just beginning to parse effects of media content beyond overall exposure to media, few studies to date have incorporated the impact of individual differences within the child. Our findings suggest that understanding contextual effects of media require not only an understanding of the type and amount of media consumed by adolescents, but also the adolescent's psychophysiological profile. Overall, findings from the current study suggest that the purported negative effect of excessive screen time involving aggressive content on child development is not universal but rather depends on the child's dispositional physiological stress response.

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