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Physiological Indicators of Pathologic Video Game Use in Adolescence

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ABSTRACT

Purpose: Pathologic video game use (PVGU) has been associated with a host of negative psychological, physical, and social outcomes during adolescence; however, little research has examined physiological predictors of such use. The purpose of the study was to examine physiological predictors of the development of PVGU across adolescence.
Methods: The article involves a 1-year longitudinal study across midadolescence. Participants were 374 adolescents and their parents from a large metropolitan area in the Northwest United States. PVGU was assessed via questionnaire, as were a number of control variables. A number of physiological indicators including respiratory sinus arrhythmia (RSA) and galvanic skin conductance (indices of parasympathetic and sympathetic nervous system activity, respectively) were measured during baseline, a cognitively stimulating task (Rubik's cube), and a family problem-solving task.
Results: Less RSA withdrawal to a cognitively simulating task was related to greater pathologic video game symptoms, but less RSA withdrawal to a family problem-solving task was associated with the presence of pathologic video game symptoms ($p < .05$). For girls only, galvanic skin conductance activation during the family problem solving was related to greater pathologic video game symptoms ($p < .01$).
Conclusions: These findings suggest that adolescents who do not find cognitive tasks stimulating physiologically have a greater severity of PVGU. Additionally, adolescents who show physiological signs of stress in a family task were more likely to have PVGU symptoms and only girls have more severe PVGU levels. This study is the first to show that physiological indicators predict PVGU over time in adolescence and has important implications regarding the prevention and treatment of PVGU in adolescence.

IMPLICATIONS AND CONTRIBUTION

This is the first study to show that physiological indicators predict change in pathologic video game use over the course of adolescence. This study has important implications for the detection and treatment of pathologic video game use during adolescence.

In the past few years, there has been a marked increase in video game playing among children and adolescents [1]. Research indicates that, depending on game content, playing video games can have positive [2] or negative effects [3] on physical and mental health [4]. To date, most concerns about video games relate to aggression. However, in recent years, pathologic (or addictive) video game use (PVGU) has received increased research attention. Video game playing is termed "pathologic" when it "becomes dysfunctional, harming the individual's social, occupational, family, school, or psychological functioning" [5]. Social scientists are beginning to examine the

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possibility that PVGU could lead to dangerous psychological and physiological dependence similar to other types of addiction [5]. Although there are a number of studies examining predictors of PVGU, research has not yet examined whether physiology plays a role in the development of such use over time. Accordingly, the present study examines how physiological indicators predict PVGU.

The Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-V) has not yet declared PVGU a form of addiction [6], although it does list "internet gaming disorder" in the appendices as a condition worthy of more research. However, research has shown that physical and mental outcomes of PVGU show marked similarities to those of drug addicts [5–7]. For example, individuals showing PVGU report that video games dominate their life and playing video games results in a feeling of "high", feeling withdrawal symptoms when attempting to stop playing, feelings of tolerance, and showing conflict with family and friends, all characteristics of chemical addictions [5]. Concerning game play habits and daily life impact, 8.5%–11.9% [1,8] of video gamers exhibit congruence with addiction diagnostics [9]. PVGU has also been associated with aggression; impulsiveness; attention problems; depression; anxiety; social phobias; and disruptions in school, work, and social relationships [8,10,11]. In sum, these findings indicate that PVGU is problematic to overall physical and psychological health.

Physiology and pathologic video game use

Although studies have uncovered important antecedents of PVGU, there are some key deficiencies in the literature. The present study extends this research by examining the connection between adolescent physiology and PVGU, as certain physiological indicators regarding the autonomic nervous system can be reflective of many variables that may increase the likelihood of PVGU. Specifically, in this study, we examine the neurophysiology of the individual. Aspects of a person's neurophysiologic activity may be viewed as a foundational component of emotion, impulsivity, stress, cognition, self-regulation, and more. Problems with each of these have been viewed as risk factors of PVGU [7,8,12,13]; accordingly, an understanding of individual differences in neurophysiology may help us understand why PVGU develops among some individuals who play video games, but not the majority. Although this has received little attention in video game pathology literature, neurophysiology has explained various other problem behaviors in children and adolescents, such as externalizing behaviors, drug use, pathologic gambling, and sex addictions [14–18]. Additionally, research also shows that gender can moderate associations between neurophysiology and behavior, such as aggression, depression, and anxiety [19]. PVGU also tends to be much more common in boys than girls [8]. Accordingly, we extend the work of biological influences on PVGU by examining the neurophysiologic links and specifically examine gender as a moderator in these relationships.

An individual's nervous system consists of the brain, spinal cord, and peripheral nerves and has several branches, each with unique functions. One branch, the autonomic nervous system (ANS), controls the involuntary actions of the body and consists of two branches—the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS). Specifically, in this study, we examine PNS and SNS activity as they relate to the development of video game pathologies in a normative sample of adolescents. PNS activity increases the "rest-and-digest" state of the body and facilitates social engagement [16,18], whereas the SNS controls the "fight or flight" and inhibitory response, mobilizing the body to protect itself from danger [16].

One common measure of PNS activity is *vagal tone* or the activity of the vagus nerve. Vagal tone is measured by respiratory sinus arrhythmia (RSA) or spontaneous breathing which is controlled only by the PNS [15–20]. RSA is a well-validated and commonly used measure of vagal tone. According to polyvagal theory, the measurement of vagal tone gives valuable information regarding many psychosocial behaviors including emotion and stress regulation, which are common predictors of PVGU [20]. High resting levels of vagal tone indicate positive psychological health outcomes, whereas low baseline vagal tone typically shows the opposite [21]. When a person faces a novel task, moderate vagal withdrawal is expected and adaptive to orient the individual to the new task [22,23]. A number of studies suggest that blunted vagal withdrawal is related to substance use addiction [21,24], indicating that vagal tone may be a good predictor of PVGU as well.

Individual differences in SNS are also predictive of the development of psychopathologies. One of the most common measures of SNS activity is galvanic skin conductance (SC) [16,19]. Electrodes are placed on the hands, and the electrical conductance of the skin is measured. This conductance varies with the production of sweat which is only controlled by the SNS. Thus, SC has been validated and used frequently as a measure of SNS activity. Research literature shows that abnormally high SNS activity, measured by SC levels and higher SC reactivity to stress, is indicative of high anxiety and fear, as well as low emotion regulation [15,25,26], but abnormally high SNS activity has not yet been used as an indicator for possible PVGU. A number of studies find that higher levels of SC are related to substance use addiction [27] and gambling addiction [28]. Accordingly, we would expect high SC to also predict higher levels of PVGU across adolescence.

Hypotheses

On the basis of previous behavioral addiction literature, we predict that individual neurophysiology will predict the development of PVGU over time. Specifically, two hypotheses are predicted:

(1) Low baseline RSA levels and less vagal withdrawal will predict higher levels of PVGU over time.
(2) High SC levels at baseline and high SC reactivity will predict increased PVGU over time.

Importantly, we hypothesize these relationships after controlling for a number of key variables associated with PVGU, such as anxiety, self-esteem, externalizing behaviors, self-regulation, and demographic variables [5,8]. We also explore the possibility that these relationships are moderated by gender. Furthermore, we examine these predictors in both cognitive and socially challenging tasks, as described in the following. With no previous research in this area, we do not make specific hypotheses but examine moderators in an exploratory way.

Methods

Participants

Participant families for the Flourishing Families Study were selected from a city in the Northwestern United States and were interviewed during the first 8 months of 2007 for wave 1 and approximately 1 year apart for waves 2–6. The retention rate from wave 1 to wave 6 was 91%. Because PVGU was only measured in waves 5 and 6, we use these waves of data only in the present study.

For all variables except ANS data, missing data were minimal (<4%). At least some ANS data are available for 80% of the sample who participated in wave 5 (n = 374). For the present study, we only use those participants for whom at least some ANS data were obtained. All missing data were handled via multiple imputation as implemented in Mplus with 25 imputations. The final sample of participants involved 181 boys and 193 girls (*M* age, 15.29; standard deviation, 1.05; *range*, 13–18). Sixty-five percent identified as white/Caucasian, 13% as African-American, and 22% as other or mixed race. Thirty percent were from single-parent homes.

Measures

PVGU. As with several other PVGU studies, survey items were based on the DSM-IV criteria for pathologic gambling and adapted to apply to video games [5]. Children responded to 11 questions taken from a national video gaming study [4] regarding various aspects and impacts of their video gaming habits. An example included "In the past year, have you ever skipped sleep, eating, or bathing so that you could spend more time playing video games?" Responses varied between "yes," "no," and "sometimes," where "yes" and "sometimes" were considered evidence of pathologic symptomology. The number of video game symptoms was summed (with a range of 0–11 symptoms). This measure has shown good construct, convergent, and divergent validity in other studies [8,10]. Given this variable is a count and it has a preponderance of zeroes (~30%), a zero-inflated Poisson model is used. In these models, two outcomes of PVGU are specified: (1) whether the individual had any PVGU symptoms at all and (2) a severity index indicating the number of PVGU symptoms an individual reported.

Autonomic nervous system data collection

ANS data collection proceeded as follows: After electrodes were placed and after a period of acclimatization (approximately three minutes), a 3-minute baseline was taken. After the baseline, participants were given a 4 × 4 Rubik's Cube to solve for 3 minutes. Participants were told to complete the blue side of the Rubik's cube first and then complete the red side. As is typical for assessing ANS reactions to cognitively challenging tasks, the Rubik's Cube was novel and challenging for the vast majority of participants (cf. the star-tracing task) [29]. Indeed, only 10 participants completed a single side and none completed two.

Two other tasks not used in the current analyses were administered after the cube task. Following these two tasks, participants were instructed to sit still and relax for a 3-minute baseline before the problem-solving task. After this baseline, they were instructed to attempt to solve a family problem for 5 minutes. The family problem to discuss was selected earlier in the interview from a list of 28 typical family problems (e.g., finances, media, rules). For the problem-solving task, mothers, fathers, and children participated. This same problem-solving task was not administered to single parents, and these families are therefore removed from analyses using the problem-solving ANS variables. Reactivity to both the cube and problem-solving tasks are conceptualized as indicative of the adolescents' general stress reactivity to (respectively) cognitively and socially challenging tasks [30].

Respiratory sinus arrhythmia and galvanic skin conductance data acquisition and reduction. RSA and SC data were collected, extracted, and cleaned using MindWare data-capturing equipment and software (http://www.mindwaretech.com). Standard methods for acquiring RSA and SC, including electrode placement, were followed [31]. RSA was derived in accord with recommendations of the Society for Psychophysiological Research committee on Impedance Cardiography [32]. RSA and SC reactivity was obtained by subtracting baseline RSA and SC levels from levels during the cube and the problem-solving task.

Other controls

A number of other variables were added to the model as controls. Where possible, the following measures were specified as latent variables to remove measurement error. All fit the data well, indicating items are good indicators of the underlying constructs. To reduce shared method variance, child and parent reports are used where possible.

Demographics. All models controlled for the following: income, race (European-American, African-American, and other), family income, single-parent home, and child gender (0 = female, 1 = male).

Externalizing behaviors. Externalizing problem behavior was measured using parent report of child delinquency. Questions were adapted from the Child Behavior Checklist Youth Self Report, a questionnaire with high cross-culture reliability [33,34]. Responses ranged from 0 (not true) to 2 (often true), with high scores representing high levels of externalizing problem behavior. Cronbach alpha for this scale was .81. (Given issues of model identification, a latent variable is not created for this scale and typical method of summing items of this scale was used.)

Anxiety. Child anxiety was determined using a six-item subscale from the Spence Child Anxiety Inventory [35]. Children responded using a four-point Likert scale ranging from 0 (never) to 3 (always), with high scores reflecting high anxiety. Anxiety was created as a latent variable with acceptable model fit (root mean square error of approximation being somewhat high at .086, although the Confirmatory Fit Index (CFI) was very good at .990).

Emotion regulation. Emotional, behavioral, and cognitive regulation were assessed using both parent and child reports. Parents responded to a 12-item survey, whereas children responded to a similar 13-item survey—both scales measuring emotion, cognition, and behavior regulation [36]. Responses ranged from 1 (never true) to 4 (always true) with higher scores representing better emotion regulation after negative items. We also specified emotion regulation variables are latent constructs finding good model fit (root mean square error of approximation, .044; CFI, .992).

Child self-esteem. Self-esteem was measured using the Rosenberg Self-Esteem Scale [37]. Children responded to 10 items on a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree) regarding feelings about the self. Although it would have been ideal to create a latent variable of self-esteem, unresolvable modeling issues arose. As is common with this scale, items were therefore averaged with Cronbach alpha at .91.

Analysis plan

For RSA and SC, we fit a series of eight regression models. Given the count nature of the data and the preponderance of zeros (30% of participants reported no symptoms), the zero-inflated Poisson model was used. Thus, the model examines the relationship between neurophysiology and whether the adolescent had any symptoms and, for those who did have symptoms, how may symptoms they had (i.e., the "count" or "number" of symptoms).

An initial baseline model was fit including demographics and RSA or SC baseline levels (separate models were fit for RSA and SC). RSA or SC reactivity to the cube or problem-solving task was then added. Interactions between gender and baseline RSA and SC were then tested. Furthermore, interactions between gender and RSA and SC reactivity were tested. If interactions were not significant (neither predicting the presence nor number of symptoms), they were removed from the model. If no interactions were significant, then the baseline model is the final model.

Results

When examining significant effects of RSA and SC reactivity, it is important to note how the interpretation differs for these. Because, on average, vagal tone decreases to challenge, higher RSA reactivity values indicate little vagal withdrawal and lower values indicate greater withdrawal. However, because, on average, sympathetic activity *increases* in response to challenge, positive SC reactivity values indicate higher reactivity, whereas low values indicate little reactivity. Table 1 summarizes bivariate correlations for all study variables.

Baseline model

In the baseline RSA model, PVGU (presence and number of symptoms) at wave 5 significantly predicted the number of symptoms (β, .56; $p < .001$) and the presence of symptoms (β, .63; $p < .001$) at wave 6. For the number of symptoms, cognitive self-regulation and self-esteem were also significant predictors (β, −.28; $p < .01$; β, −.26; $p < .01$, respectively) such that greater cognitive self-regulation and self-esteem were associated with fewer symptoms over time. For the presence of symptoms, child anxiety was related to lower likelihood of having some symptoms rather than none (β, −.21; $p < .05$).

Parasympathetic baseline and reactivity

Table 2 contains parameter estimates for RSA baseline and reactivity models predicting the number of symptoms for the Rubik's cube task and the presence of symptoms for the problem-solving task. The table is divided into two parts, one for reactivity to the Rubik's cube task and its baseline and one for reactivity to the problem-solving task and its baseline. Baseline to neither the cube task nor problem-solving task was related to the presence or number of symptoms. However, less vagal withdrawal to the cube task was related to greater number of symptoms (Table 2; β, .19; $p < .05$). However, less vagal withdrawal to the problem-solving task was negatively related to the presence of symptoms (Table 2; β, −.20; $p < .05$). For simplicity in the table, we do not include nonsignificant results for physiological variables (presence of symptoms for Rubik's cube and number of symptoms for problem solving).

Sympathetic baseline and reactivity

Table 3 contains the parameter estimates for predictors of the number of symptoms. There were no significant SC predictors of the presence of symptoms; we therefore omit these tables although they are available on request. For the initial baseline and Rubik's cube models, no physiologic parameters were significant. However, the interaction between SC reactivity to the problem-solving task and gender was significantly related to the number of symptoms (β, −.42; $p < .01$). Figure 1 depicts this interaction. For boys, PVGU symptoms are relatively high and stable across high and low levels of SC reactivity. However, there is a substantial increase in girls' symptoms from low to high reactivity such that highly reactive girls are likely to have more symptoms than their less reactive counterparts.

Discussion

Physiological indicators predicted the development of PVGU over time, even after controlling for initial levels of PVGU and a number of other control variables, suggesting that physiology may play a key and unique role in the development of PVGU over adolescence. Specifically, these findings connect the physiological and psychological worlds of PVGU, suggesting that individual neurophysiology may be one important risk factor for the development of PVGU over time.

We found that less RSA withdrawal to the cognitively challenging task was associated with greater PVGU symptoms. These results are consistent with our predictions on the basis of previous behavioral addiction literature and indicate certain adolescents are not physiologically stimulated by certain tasks and may seek cognitive or social stimulation elsewhere, specifically in the video game world. This may, in part, be a physiological representation of sensation seeking, where individuals are motivated to seek out novel, intense, and complex situations, given that they find little stimulation in their everyday lives. Research shows that the link between video game addiction and sensation seeking is rather small, but significant; accordingly, our results may suggest a neurophysiological explanation for this link [38]. This being the case, one therapeutic approach to PVGU could be to encourage pathologic users to replace video game use with activities that are a cognitive challenge. Notably, whether adolescents are less stimulated by typical activities because of their gaming habits or they become pathologic users because they are not appropriately stimulated by normal activities is unclear. Research measuring vagal tone before and after the development of pathologic video gaming tendencies (perhaps, in early childhood) could provide more insight to these associations.

We also found that the presence of PVGU symptoms was associated with greater RSA withdrawal in the family problem task, indicating that children who may feel somewhat threatened during social tasks are more likely to seek out video games, perhaps as a coping mechanism. And, for girls, increased sympathetic activity during family problem-solving exercises (an even more clear indication of feeling of threat) suggests that an

Table 1
Bivariate correlations for all study variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. PVGU wave 6	—	.54***	−.01	.10	−.20*	−.07	.03	.13	−.15*	.10	.08	.11	.15*	−.26***	−.14+	−.07	.15*	.03	.02
2. PGVU wave 5	.46***	—	−.11	.04	−.20*	−.05	−.01	−.01	−.20*	.23**	.06	.15*	.22**	−.14*	.03	−.07	.03	.04	.04
3. RSA baseline	−.01	−.08	—	−.25***	.02	.01	.03	−.02	−.15*	−.12	−.04	−.08	−.04	.02	−.04	−.07	.05	−.02	.10
4. RSA Rubik's cube	.07	−.02	−.28***	—	−.07	.06	−.03	−.01	−.01	−.02	.12+	−.01	−.01	−.05	−.01	−.05	−.05	−.07	.01
5. RSA problem-solving task	−.21*	−.22*	−.05	−.05	—	.01	−.09	−.05	.03	−.05	.05	.06	−.13	.17+	.04	−.13	−.01	.08	−.02
6. SC baseline	.23**	.33***	−.01	.07	.13	—	.06	.01	−.14+	.19**	−.05	−.04	.05	−.09	.18*	.16*	−.24***	−.02	−.15*
7. SC Rubik's cube	−.01	.01	−.07	−.09	.07	−.38***	—	.24**	.05	−.07	.07	−.11	.01	−.13+	−.13+	−.08	−.08	.01	.07
8. SC problem-solving task	−.04	−.02	.12	.01	.16+	.01	.26**	—	.23*	.06	.11	.02	.11	−.05	.02	.05	−.02	−.14	.05
9. Age	.05	.12	−.13+	−.01	.06	.16*	−.01	−.04	—	−.02	.10	−.13+	−.10	.06	.05	−.01	.04	−.04	.04
10. Internalizing behaviors	.11	.09	−.06	.03	.09	.05	.07	.15	−.03	—	.05	.31***	.25***	−.07	.36***	.01	−.04	−.04	−.03
11. Externalizing behaviors	.02	.14+	−.10	.04	−.06	.09	.07	.08	.21**	.03	—	.32***	.17*	−.23**	−.10	−.32***	.22**	.06	.20
12. Emotional self-regulation	.02	.12	.02	.06	−.10	.04	−.09	−.02	.05	.37***	.27***	—	.49***	−.16*	.14*	.01**	.01**	.06	.11
13. Behavioral self-regulation	.04	.12	−.02	.03	−.03	−.06	.07	−.04	.01	.35***	.17*	.44***	—	−.33***	.13+	−.01	−.10	.08	.02
14. Cognitive self-regulation	−.17*	−.13+	.06	−.02	.09	−.04	.01	−.03	−.02	−.11	−.22**	−.06***	.02**	—	.11	.01	.12+	−.13+	−.03
15. Self-esteem	.01	.12	.11	.04	−.03	−.03	.06	.16+	.01	.26***	−.02	.35	.28***	.02	—	.15*	−.27***	−.01	−.11
16. Income	−.12	−.12	.11	−.06	−.03	−.10	.06	−.03	−.03	−.01	−.25***	−.10	.07	−.05	.05	—	−.47***	.02	−.59***
17.African-American	−.05	.03	−.01	−.02	−.09	−.09	−.06	.04	.04	−.03	.11	.16*	−.10	.21**	−.12	−.45***	—	−.23**	.28***
18. Other race	.10	.11	−.09	.05	−.04	.04	.01	.03	.03	.01	.04	.02	.12+	−.05	.05	−.14+	−.18*	—	.08
19. Single parent household	.09	.12	−.09	.05	−.24**	.11	.01	−.07	−.07	.03	.21**	−.03	−.10	−.08	−.06	−.60***	.29***	.09	—

Correlations for girls are above the diagonal and those for boys are below.
+$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.
PVGU = pathologic video game use; RSA = respiratory sinus arrhythmia; SC = galvanic skin conductance.

Table 2
Final models for RSA predicting the presence and number of video game addiction symptoms

	Number of video game addiction symptoms (wave 6); Rubik's cube model	Presence of video game addiction symptoms (wave 6); problem-solving model
Physiological variable		
RSA-baseline (before the task)	.18 (.10)†	−.01 (.08)†
RSA-reactivity	.19 (.08)*	−.20 (.08)*
Control variables		
VGA symptoms W5	.60 (.11)***	.63 (.11)***
Child age	.03 (.10)	−.02 (.10)
Child anxiety	.30 (.15)*	−.22 (.11)*
Child externalizing behaviors	−.10 (.12)	−.05 (.08)
Self-regulation: emotional	.01 (.13)	.11 (.16)
Self-regulation: behavioral	−.07 (.11)	.11 (.12)
Self-regulation: cognitive	−.27 (.09)**	.00 (.09)
Self-esteem	−.27 (.12)*	.09 (.08)
Income	−.24 (.14)†	.06 (.07)
African-American	.09 (.14)	.05 (.09)
Other race	.12 (.11)	−.04 (.10)
Single parent household	−.19 (.12)	
Child gender	.43 (.11)***	−.11 (.11)

Standardized betas (standard errors) are shown.
Only final models are shown. There were no significant interactions with gender; accordingly, these are not shown in the model. The presence of video game addiction symptoms showed no significant associations with the Rubik's cube model. Additionally, number of video game addiction symptoms showed no significant associations with the problem-solving task. Accordingly, for simplicity, these models are not shown in the table; however, they can be obtained by contacting the first author.
†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.
RSA = respiratory sinus arrhythmia; VGA, video game addiction.

underlying component in PVGU for girls may be stress management, particularly in a family setting. It is possible that some girls may be trying to escape dealing with family issues by turning to a virtual world in which they feel more control and less stress. Accordingly, stress management techniques could be another area by which PVGU could be approached and may be particularly beneficial for adolescent girls. Notably, this was not found for boys: it may be girls are more sensitive to networks and relationships and perhaps more prone to seek refuge through video games than boys.

This study has a number of important implications for the treatment of PVGU. Because ANS activity can be manipulated [39], exercises that increase parasympathetic tone by getting adolescents engaged in non−media-related activities and/or decrease sympathetic reactivity such as meditation could be implemented by adolescents to improve stress management and PVGU symptoms. Families with adolescents who exhibit PVGU could also be encouraged to participate in family counseling where healthy ways of dealing with family stress are discussed, with a focus on helping adolescents to remain calm in stressful situations and parents to remain nonthreatening in family interactions.

Finally, it may also be beneficial for pediatricians and health professionals to ask about video game use during routine physicals. The American Academy of Pediatrics' (AAP's) current recommendation for media use is to limit screen time for children aged more than 2 years to 2 hours/day [40]. In addition to this, physicians could ask screening questions to determine if children are at increased risk for PVGU and then ensure

Table 3
SC predicting number of video game addictions

	Number of video game addiction symptoms (wave 6)	
	Rubik's cube model	Problem-solving model
Physiological variables		
SC-baseline (before the task)	−.05 (.09)	−.17 (.12)
SC-reactivity	.29 (.17)†	.57 (.20)**
SC-reactivity problem solving × gender		−.42 (.13)**
Control variables		
VGA symptoms W5	.56 (.11)***	.44 (.13)***
Child age	−.00 (.11)	−.17 (.14)
Child anxiety	.31 (.14)*	.26 (.12)*
Child externalizing behaviors	−.13 (.13)	.18 (.13)
Self-regulation: emotional	.03 (.14)	−.21 (.16)
Self-regulation: behavioral	−.06 (.12)	.02 (.12)
Self-regulation: cognitive	−.28 (.09)**	−.09 (.10)
Self-esteem	−.25 (.12)*	−.14 (.13)
Income	−.28 (.16)†	−.17 (.11)†
African-American	.04 (.14)	.14 (.11)
Other race	.11 (.10)	.22 (.09)*
Single parent household	−.20 (.12)†	
Child gender	.49 (.11)***	.49 (.11)***

Standardized betas (standard errors) are shown.
Note: Only the final models and significant interactions with gender are shown. RSA = respiratory sinus arrhythmia; SC = galvanic skin conductance; VGA, video game addiction.
†$p < .10$, *$p < .05$, **$p < .01$; ***$p < .001$.

implementation of proper therapeutic interventions. Early intervention is preferred, as PVGU has been shown to be a long-term problem rather than just a phase [8]. This may help children avoid a host of negative behaviors associated with PVGU [5,8].

Although the study had many strengths including a longitudinal design, relatively large sample, and multiple reporters, there were a number of limitations. First, although we saw evidence of PVGU in the current sample, participants did not consist of a clinical sample. Furthermore, we measured an adolescent's physiological profile in general, as opposed to measuring it while they were playing video games. Although the latter would provide substantive information, the aim of the study was to examine how *general* physiologic functioning related to PVGU. Accordingly, future research could examine physiological predictors of PVGU while engaging in video game play.

In sum, this study is the first to show that physiological indicators predict PVGU over time in adolescence. These findings bring together the physiology and PVGU fields showing that physiology is important in our understanding PVGU development.

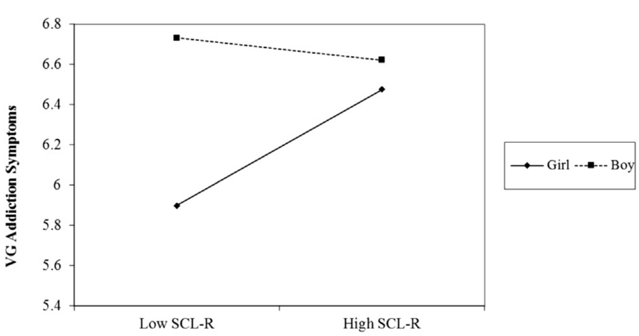

Figure 1. Interaction between SC-reactivity and child gender predicting video game addiction symptoms. SC = galvanic skin conductance; VG = video game.

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