Social Anxiety as a Moderator of the Association Between Autonomic Reactivity to Social Stress and Avoidant, Withdrawn, or Disengaged Responses

by

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A dissertation submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Auburn, Alabama
August 3, 2024

Keywords: Social anxiety, physiological reactivity, avoidance, disengagement, withdrawn behavior

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Abstract

Avoidant, withdrawn, and disengaged (AWD) responses orient a person away from a stressor or one's own thoughts, emotions, or physiological responses and high levels of AWD responses are associated with negative psychosocial outcomes across several life domains. One aspect of AWD responses that remains understudied is the role that physiological reactivity to stressful situations plays in shaping or driving AWD responses. Findings from the extant literature are mixed and it is hypothesized that associations between physiological reactivity and AWD responses may be moderated by social anxiety. Accordingly, the present study built on previous research by examining direct associations between measures of autonomic nervous system (ANS) reactivity to social stress and AWD responses as well as testing the potential moderating effect of two measures of social anxiety (i.e., global and context-specific). Participants were a community sample of fifth and sixth graders (M_{age} = 12.03). Early adolescents completed questionnaires assessing social anxiety and AWD responses, and their physiological reactivity and AWD responses were measured in the context of a peer-evaluative laboratory stress protocol. Teachers also completed questionnaires assessing early adolescents' withdrawn behavior. The present study found that measures of ANS reactivity to social stress were largely unrelated to AWD response measures. In addition, social anxiety moderated associations between ANS reactivity and AWD responses in some cases, such that ANS reactivity was either negatively associated with or unrelated to AWD responses among early adolescents who reported higher levels of social anxiety and positively associated with or unrelated to AWD responses among those who reported lower levels of social anxiety. If replicated, findings from the present study have significant clinical and intervention implications.

Acknowledgements

I would like to extend my sincere gratitude and appreciation to all of the wonderful people who supported me throughout my time as a graduate student at Auburn University and who helped me grow as a researcher, instructor, clinician, and person over the past ten years. This dissertation and the fulfillment of my PhD degree were made possible by my family, friends, colleagues, advisor, committee members, and academic mentors. I am incredibly fortunate to have had the opportunity to attend graduate school at Auburn University and often think about all of the small things that had to fall into place for me to end up in Auburn. For example, if not for my undergraduate professor, Dr. Sterling Wall, I would have never learned about Auburn University or Human Development and Family Science as a discipline, nor would I have met my wife with whom I recently had a child, earned a two master's degrees and a PhD, become a licensed Marriage and Family Therapist, or developed relationships with the friends and faculty members that ultimately changed my life.

It was through Dr. Wall's class that I met Dr. Scott Ketring and attended the National Conference for Family Relations during the year that Auburn University was hosting the conference. He quickly convinced me to apply to the PhD program in the HDFS department and later became my clinical supervisor, mentor, and a close friend and colleague. Dr. Ketring, it is hard to put into words just how profound an effect you have had on my life and how grateful I am to you for everything that you have done for me and for the MFT program at Auburn over the past ten years. You have played an invaluable role as the clinical supervisor of the MFT program and have done so much to shape the program and mentor students throughout your time at

Auburn. I'm not sure where I would be today without your support and guidance, and I look forward to our continued collaborations and future conversations.

In addition to being a mentor and supervisor, Dr. Ketring introduced me to the faculty member Auburn University who arguably played the largest role in my development and success in graduate school, Dr. Stephen Erath. I consider meeting Dr. Erath to be one of the most impactful events of my life as his guidance, mentorship, support, and friendship helped shape me into the person that I am today. Dr. Erath, you did an incredible job of preparing me for my future career in academia and taught me nearly all that I know about conducting research, mentoring students, and developing long-lasting collaborative relationships with others. Additionally, you helped me navigate a number of difficult periods in my life, celebrate my accomplishments, and forge a unique path through graduate school. You have always worked hard to ensure that I have everything that I need to be successful as a graduate student and you helped me to have a graduate school experience that was deeply fulfilling and meaningful. You are an incredible mentor, researcher, and friend and I'm excited to continue to collaborate with you on research endeavors for many years to come. I am incredibly grateful to you and will never be able to thank you enough for everything that you have done for me throughout my time at Auburn University.

Along with Dr. Ketring and Dr. Erath, I would be remise if I did not thank the faculty members who served on each of my committees over the past ten years and those who helped me obtain my license as an MFT. Dr. Mona El-Sheikh and Dr. Ben Hinnant have played particularly important roles in my development as a researcher as they served as committee members on all my major projects during graduate school. I published papers in collaboration with and received a tremendous amount of guidance, help, and impactful feedback from both Dr. El-Sheikh and Dr.

Hinnant. They have been fantastic mentors and have taught me so much about statistics, research methodology, psychophysiology, and research in general. Similarly, Dr. Brian Gillis and Dr. Wendy Troop-Gordan have provided valuable guidance, support, and mentorship as committee members on various projects. I had the pleasure of working with Dr. Troop-Gordon's Social Development lab and learned a great deal about collecting data in school environments. Dr. Troop-Gordon also provided very helpful advice and feedback when I found myself stuck while conducting analyses at several points during my graduate career and I am grateful for all her help and support. I am also extremely grateful to Dr. Gillis, who has played a special role in the lives of me and my family. Not only has Dr. Gillis been a close friend and colleague to me and my wife throughout our time at Auburn, he was also kind enough to officiate our wedding and we are so thankful for his friendship, love, and support. Likewise, I am thankful for the support of my clinical supervisors, Heather Novak and Caroline Maye, both of whom taught me so much about marriage and family therapy. I wouldn't be the MFT that I am today without you, and I sincerely appreciate all your guidance and mentorship. As with Dr. Ketring and Dr. Erath, I look forward to continued research collaborations with Dr. El-Sheikh, Dr. Hinnant, Dr. Troop-Gordon, and Dr. Gillis and hope to maintain lifelong connections with each of the faculty members and friends who have meant so much to me.

I would also like to thank the friends and family who provided me with so much love and support over the past ten years of graduate school. First and foremost, I want to thank my incredible wife, Carlie, who has been so supportive, caring, understanding, and flexible over the six years that we have been together. I am in awe of you and everything that you do, and I admire you and look up to you more than you will ever know. It takes a very special person to be able to put up with me and my ridiculous sense of humor on a day-to-day basis and I can never

thank you enough for loving me and being so patient with me, even during difficult periods of life and chaotic stretches of graduate school. You have always helped me to grow as a person while also loving and accepting the person that I am during each phase of our lives together. Additionally, you have been an amazing partner, friend, and teammate throughout the long process of finishing multiple graduate degrees and becoming a licensed MFT. I don't know what I'd do without you and I'm so thankful that my path in life led me to Auburn and to meeting you. We've started a family together and I'm so excited to watch all of us grow during this next chapter of our lives and to finally be able to start contributing to our family's finances a bit more. I'm also thankful for our child, Colson, who has made me feel so loved and fulfilled. Though you may not have been aware of the events that took place over the past year, you have been incredibly helpful during the final push to finish my PhD. I love being your dad and I'm already so proud of who you are and so excited to see what the future holds for you.

My immediate family has also been an invaluable source of support and encouragement over the past ten years and my journey through graduate school would have been much harder and lonelier without them in my life. Each of my siblings has been so supportive of me and of my academic pursuits and I wish I could see you all much more often. My parents have also provided me with so much love, support, and encouragement and have prepared me to navigate the world of academia from a very young age. Growing up around you, your colleagues, and your academic work has been extremely beneficial to me throughout graduate school and as I begin my own career. You have both helped me to see just how important and interesting academic research can be and I loved growing up in a world surrounded by smart people who are interested in making the world a better place, one project at a time. From dinnertime discussions about gene vectors and recombinant DNA, to summer breaks spent working in research corn

fields, your work and the passion that you have for learning about new and complicated topics has helped me develop a love for learning and teaching others.

Lastly, I would like to thank all the friends and colleagues with whom I interacted throughout my time at Auburn. I have met so many amazing people and maintained or developed many close friendships over the past ten years. I would especially like to extend my gratitude to Drew and Anastasia, Olivia and Adam, Gus, and Zeynep Su. Drew and Anastasia, you have been two of my closest friends for years and I miss you both every day. I'm so thankful for your willingness to come visit me all the way down in Alabama and for all your love, support, and friendship over the past ten years (and beyond). I'm glad that Carlie and I were able to meet Zaylee and we can't wait for both of you to meet Colson someday. Our phone calls, texts, and visits always mean the world to me, and I love looking back at pictures and revisiting memories that we made during our trips together. Olivia and Adam, you both are such amazing people, and you positively impact the lives of everyone with whom you come into contact. I admire both of you so much and want to thank you from the bottom of my heart for being there for me and being such great friends during our time together at Auburn. I had very mixed emotions when you graduated and moved away because I knew graduate school wouldn't feel the same without you but also felt so happy to see you guys move on to the next chapter of your life. I look forward to seeing you again in the future and wish you all the best in the world. Gus, you were my closest friend throughout all of childhood and adolescence and continue to be a very dear friend to me. Our lives have moved us to different locations and in different directions, but I've always valued your friendship so much. I hope that our families/spouses can all meet someday and I look forward to the next time we are able to see each other. Zeynep Su, although our friendship is relatively new, it has been really great getting to know you and interacting with you

during our time working in Dr. Erath’s lab. You are such a kind and warm-hearted person and I appreciate all of your help and support over the past few years. I’m excited to see where your future takes you.

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List of Abbreviations

ANS	Autonomic nervous system
AWD	Avoidant, withdrawn, and disengaged responses
BAS	Behavioral activation system
BIS	Behavioral inhibition system
CSSA	Context-specific social anxiety
DMSIP	Dual-mode social information processing
FFFS	Fight-flight-or-freeze system
FNE	Fear of negative evaluation
GSA	Global social anxiety
HPA	Hypothalamic -pituitary-adrenal (axis)
HR	Heart rate
HRR	Heart rate reactivity
PEP	Pre-ejection period
PEPR	Pre-ejection period reactivity
PNS	Parasympathetic nervous system
RSA	Respiratory sinus arrhythmia
RSAR	Respiratory sinus arrhythmia reactivity
SAM	Sympathetic-adrenal-medullary
SCL	Skin conductance level
SCLR	Skin conductance level reactivity
SNS	Sympathetic nervous system
TSST	Trier Social Stress Task

I. INTRODUCTION

Avoidant, withdrawn, and disengaged responses and outcomes

Avoidant, withdrawn, and disengaged (AWD) responses refer to cognitive or behavioral responses that orient a person away from a stressor or one's own thoughts, emotions, or physiological responses to a stressor (Compas et al., 2001; Rubin et al., 2009; 2010; Wiebe, 2013). Examples of AWD responses include – but are not limited to – avoidant or withdrawn behaviors in social situations (e.g., isolating oneself from peers or actively avoiding an anxiety-provoking social situation) as well as cognitive forms of avoidance or disengagement such as denial (e.g., pretending that a stressful event or situation isn't happening). In the context of acute stress, AWD responses may be protective or adaptive, such as when avoiding or withdrawing from a physically dangerous situation. However, generally high levels of AWD responses (i.e., AWD responses that are performed repeatedly or over long periods of time) are a core feature of several forms of psychopathology and are associated with negative psychosocial outcomes across several life domains (Aldao et al., 2010; Compas et al., 2017; Rubin et al., 2009; Rubin & Chronis-Tuscano, 2021; Schäfer et al., 2017).

Meta-analyses have found that AWD responses are positively associated with concurrent internalizing symptoms such as anxiety and depressive symptoms, disordered eating, and externalizing symptoms such as aggression, conduct problems, and substance use (Aldao et al., 2010; Compas et al., 2017; Schäfer et al., 2017). Compas et al. (2017) also found that measures of AWD responses were positively associated with longitudinal increases in internalizing symptoms but not with changes in externalizing symptoms over time. Similarly, in their reviews of the literature on social withdrawal in childhood and adolescence, Rubin et al. (2009) as well as Rubin and Chronis-Tuscano (2021) noted that socially withdrawn behaviors are concurrently and longitudinally associated with poorer peer relationships, lower social competence, more negative social and self-focused cognitions, increased loneliness, and increased internalizing symptoms such as anxiety and depressive symptoms. Accordingly, high levels of AWD responses appear to predict increased risk for a wide variety of negative psychosocial outcomes, and AWD responses may be particularly strongly associated with measures of internalizing symptoms such as anxiety and depressive symptoms. However, the underlying mechanisms that shape and drive AWD responses remain to be fully elucidated, highlighting the need for the present study.

What contributes to the development of AWD response tendencies?

Avoidance learning and outcomes associated with AWD responses have been thoroughly studied; however, there is still considerable debate about the underlying mechanisms that contribute to the development and maintenance of AWD response tendencies. One factor that is understudied yet theorized to play an important role in AWD responses is physiological reactivity to stressful or anxiety-provoking situations. In stressful contexts, increased physiological arousal mobilizes metabolic resources and enhances energy utilization to prepare a person for action, potentially in the form of defensive responses such as active avoidance (e.g., leaving or withdrawing from a stressful situation; Beauchaine, 2001; Gellner et al., 2021; Krypotos et al., 2015; Porges, 2001; 2007). Additionally, AWD responses offer a quick and efficient way to reduce arousal and may therefore be common among individuals who exhibit increases in physiological arousal in stressful or anxiety-provoking contexts and view this arousal as negative or unpleasant (Repetti, 1992). This may be especially true among socially anxious individuals, who are more likely to fear exhibiting heightened physiological arousal in social settings (e.g., through sweating or blushing), report negative interpretations of their physiological arousal (Anderson & Hope, 2009; Asbrand et al., 2020; Siess et al., 2014), and exhibit slower physiological recovery following exposure to stressors (Schmitz et al., 2011; 2013). Indeed, some have suggested that increases in physiological arousal may underlie or drive AWD responses among highly anxious individuals specifically (Gellner et al., 2021; Livermore et al., 2021).

Despite the arguments outlined above, there is a relative paucity of research examining associations between physiological arousal and AWD responses, and no study has examined measures of social anxiety as potential moderators of these associations. Relevant studies utilizing measures of the autonomic nervous system (ANS), which promotes rapid shifts in arousal and may facilitate AWD responses in stressful contexts (Beauchaine, 2001; Porges, 2001), are even more scarce, especially in late childhood and adolescence. Additionally, very few studies, if any, have utilized same- and cross-context assessments of physiological activity, AWD responses, and social anxiety as is the case in the present study. As a result, the nature of associations between measures of physiological arousal (e.g., ANS activity), AWD responses, and social anxiety remains unclear. Accordingly, the present study had two primary aims: (1) to examine associations between measures of ANS reactivity to social stress and AWD responses, and (2) to examine measures of social anxiety as potential moderators of these associations among a sample of early adolescents.

Responses to stress: Theoretical models relevant to the study of AWD responses

What little is known about associations between physiological arousal and AWD responses has largely been gleaned from theoretical models that describe links between stress-induced physiological reactivity and defensive responses, such as AWD responses. Theories of response coherence posit that physiological and cognitive-behavioral responses reflect two components of a broader emotion system that operate in a coordinated fashion and contribute to emotions such as anxiety or fear (Evers et al., 2014; Hollenstein & Lanteigne, 2014). According to response coherence models, physiological and cognitive-behavioral responses measured in the same context should be highly related to one another (i.e., exhibit coherence/concordance). For example, social anxiety elicited by a stressful or anxiety-provoking stimulus would theoretically involve a coordinated increase in physiological arousal, subjective reports of social anxiety or distress, and anxiety-related responses such as cognitive and behavioral forms of avoidance.

Related psychophysiological theories such as Polyvagal Theory (Porges, 2001; 2007) and Beauchaine's (2001) integrated model of ANS functioning also assert that physiological and cognitive-behavioral responses are related to one another. However, these theories differ from response coherence theories in that physiological responses to stressors are thought to underlie cognitive-behavioral responses as well as predict cognitive-behavioral responses and psychosocial outcomes more generally. Thus, whereas response coherence models describe in-the-moment interactions between different components of an emotion system, psychophysiological theories such as those developed by Porges (2001; 2007) and Beauchaine (2001) suggest that physiological responses to stressors drive and shape cognitive-behavioral responses and may be predictive of cognitive-behavioral response patterns across multiple contexts. For example, Polyvagal Theory (2001; 2007) posits that a reduction in parasympathetic nervous system activity (PNS; described in greater detail below) in response to social stressors facilitates real-time cognitive and behavioral engagement (e.g., problem-solving strategies or prosocial behaviors) and that lab-based measures of PNS reactivity to social stress may predict cognitive-behavioral response patterns and psychosocial outcomes in other contexts (e.g., reduced lab-based PNS reactivity is associated with higher levels of self-reported cognitive/academic problems and internalizing symptoms outside of the laboratory; Graziano & Derefinko, 2013).

The broader stress response literature outlines numerous neurobiological and physiological processes that facilitate cognitive and behavioral responses to stressful stimuli and prepare an individual to deal with the demands of challenging or stressful situations. Several brain regions are implicated in different forms of defensive responding such as freezing, active avoidance, and passive avoidance. Freezing is a reflexive action primarily driven by output from the central nucleus of the amygdala while active and passive avoidance behaviors are shaped, in part, by activity in the prefrontal cortex, septohippocampal system, and nucleus accumbens (Gray & McNaughton, 2000; LeDoux et al., 2017).

Despite differences in the neurological underpinnings of freezing, active avoidance, and passive avoidance, each type of AWD response involves activation of stress response systems, consisting of two primary components or phases: 1) a rapid response (on the order of milliseconds or seconds) that is mediated by the autonomic nervous system (ANS) and sympathetic-adrenal-medullar (SAM) axis and 2) a slower, more prolonged, and more pervasive response that is primarily mediated by the hypothalamic-pituitary-adrenal (HPA) axis and endocrine system (described in more detail in the following sections; Beauchaine, 2001; Godoy et al., 2018; Porges, 2001; 2007). These processes promote physiological changes throughout the body, such as increases in metabolism and energy utilization, immune system activation, and temporary suppression of digestive and reproductive systems (Godoy et al., 2018). While activation of the stress response is often discussed in the context of defensive responses such as fight-or-flight behaviors and AWD responses, it also facilitates approach behaviors and engaged responses in stressful or anxiety-provoking contexts (e.g., prosocial behaviors or problem-solving strategies; Beauchaine, 2001; Porges, 2001; 2007). Accordingly, the present study will examine multiple measures of physiological responses to stress as predictors of AWD responses, some of which are theoretically and conceptually linked to brain systems that underlie AWD responses.

Responses to stress: Neural, endocrine, and immune system correlates of AWD responses

The neural correlates of AWD responses have been the subject of considerable research and are relatively well-established (Gellner et al., 2021; Ike et al., 2020). In contrast, there has been somewhat limited research examining associations between measures of physiological responses in the body and AWD responses specifically. This is surprising given the extensive body of literature examining associations between physiological responses and internalizing symptoms such as depressive symptoms, anxiety, and somatic symptoms as well as prosocial and externalizing behaviors such as aggression, conduct problems, and substance use (Beauchaine et al., 2013; 2019; Fanti et al., 2019; Graziano & Derefinko, 2013; Hastings & Miller, 2014; Hinnant et al., 2016b; Murray-Close et al., 2014; Portnoy & Farrington, 2015). Although numerous studies have utilized measures of internalizing symptoms that include withdrawn behavior subscales (Beauchaine et al., 2019; Graziano & Derefinko, 2013), relatively few have examined physiological responses as predictors of AWD responses in and of themselves.

To date, existing studies on physiological functioning in the body and AWD responses have largely utilized measures of endocrine activity (e.g., cortisol) and inflammation (e.g., proinflammatory cytokines), which is perhaps unsurprising given the importance of endocrine and inflammatory processes in responding to stressors (Bellavance & Rivest, 2014). The HPA axis has been of particular interest to researchers studying stress-induced endocrine responses. As noted above, activation of the HPA axis occurs during the second phase of a stress response and leads to the release of glucocorticoids which promote downstream physiological stress responses such as the release of cortisol and norepinephrine (Karin et al., 2020). Acute activation of the HPA axis facilitates defensive responses to threats or stressors, such as AWD responses, while prolonged or excessive HPA axis activity can damage brain and bodily systems due, in part, to the proinflammatory effects of excessive glucocorticoid release and the interplay between endocrine and immune system activity (Bellavance & Rivest, 2014; McEwen & Rasgon, 2018). Studies examining associations between endocrine or immune system functioning and AWD responses have typically found that elevated endocrine and inflammatory responses to stressors are associated with higher levels of AWD responses (Blair et al., 2004; Buss et al., 2003; Eisenberger et al., 2017; Hassan & Schmidt, 2021; Roelofs et al., 2009; Sudhaus et al., 2015), though contrasting evidence exists (e.g., Cantave et al., 2019; Rudolph et al., 2018).

Responses to stress – The ANS and AWD responses

Another bioregulatory system that plays a critical role in facilitating responses to stressful events or situations is the autonomic nervous system (ANS). While endocrine and immune system responses are relatively slow and exert widespread effects throughout the brain and body (Godoy et al., 2018; Sapolsky, 2004), the ANS promotes rapid shifts in arousal (i.e., on the order of milliseconds or seconds) and has more targeted effects on specific effector organs (Beauchaine, 2001; Porges, 2001; 2007). Additionally, in contrast to neural, endocrine, and immune correlates of AWD responses, associations between measures of ANS activity and AWD responses have rarely been studied. However, several theoretical models emphasize the role of ANS activity in AWD responses and stress responses more generally (e.g., Beauchaine, 2001; Porges, 2001; 2007), highlighting the need for the present study.

The ANS consists of two main branches: the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS). The PNS is often referred to as the “rest and digest” or “feed and breed” system due to the dampening effect of the PNS on heart rate and the tendency for increased PNS activity to facilitate calmness and social engagement (Porges, 2001; 2007; 2021). The SNS, on the other hand, is more commonly associated with fight-or-flight behaviors and mobilization (Beauchaine, 2001; Porges, 2001; 2007). Rather than working in opposition to one another, the PNS and SNS serve complimentary roles and, ideally, operate in a synergistic fashion to promote rapid increases or decreases in arousal in response to changes in environmental demands.

The PNS exerts its influence on target organs via the tenth cranial nerve or “vagus nerve” (Porges, 2001; 2007). The vagus nerve provides PNS innervation to a wide variety of organs such as the heart, lungs, and most abdominal organs and it can be subdivided into two branches: 1) the older, or more phylogenetically ancient unmyelinated vagus nerve and 2) the newer, or more phylogenetically recent myelinated vagus nerve. The myelinated vagus may be unique to mammals and is believed to facilitate social engagement under relatively calm or non-threatening circumstances by inhibiting sympathetic influences on the heart and HPA-axis activity via the vagus nerve (also referred to as a “vagal brake” – Porges, 2001; 2007; 2021; see Grossman, 2023 for a contrasting view on the evolutionary biology of the vagus nerve). PNS influence on the heart is commonly measured via respiratory sinus arrhythmia (RSA), which reflects high frequency heart rate variations during the respiratory cycle (Porges, 2001; 2007). Under moderately challenging circumstances, a decrease in vagal influence on the heart – also known as vagal withdrawal – promotes increases in arousal, attention, and engagement with one’s environment. When decreased PNS input (i.e., vagal withdrawal) is insufficient to deal with the demands of a situation, the SNS may become increasingly active and facilitate mobilization or inhibition (depending on the circumstances). Increases in SNS activity may also promote fight-or-flight behaviors in particularly challenging or threatening contexts. Psychophysiological theories such as Polyvagal Theory (Porges, 2001; 2007) and Beauchaine's (2001) integrated model of ANS functioning suggest that AWD responses are largely driven by stress-induced increases in arousal that are primarily mediated by the SNS but may also involve coordinated reductions in PNS activity (i.e., vagal withdrawal).

Two well-validated measures of SNS activity are skin conductance levels (SCL), also referred to as electrodermal activity, and pre-ejection period (PEP). SCL is a measure of eccrine sweat gland activity reflected in changes in electrical conductivity across the surface of the skin (Zisner & Beauchaine, 2016). Eccrine sweat glands are primarily located on the palms of a person's hands and the soles of their feet. They are exclusively innervated by the SNS and, as a result, respond strongly to emotionally-salient stimuli. This contrasts with apocrine sweat glands, which are more heavily distributed throughout other parts of the body and are not strongly influenced by emotional responses (Zisner & Beauchaine, 2016). Higher basal SCL and SCL reactivity (i.e., changes in SCL from a baseline period to a stress period; SCLR) is believed to reflect increased levels of anxious arousal or inhibitory control efforts, whereas lower basal SCL or SCLR may reflect fearlessness, impulsivity, or a lack of engagement in challenging or stressful circumstances (Sheppes et al., 2009; Zisner & Beauchaine, 2016).

PEP is a less commonly used measure of SNS activity, though researchers have grown increasingly interested in PEP reactivity (PEPR) as a measure of reward responding in recent years (e.g., Ahles et al., 2017). PEP is defined as the length of time between the start of the QRS complex (i.e., the electrical signal that initiates each contraction of the heart) and the opening of the aortic valve, and indexes the contractile force of the left ventricle of heart. PEP is distinct from other cardiac measures such as RSA, as evidenced by the fact that PEP is unchanged by vagal blockade (Newlin & Levenson, 1979). While basal PEP is influenced by a variety of ANS, central nervous system (CNS), and hormonal inputs, PEPR is almost exclusively determined by β-adrenergic influences on the heart (Zisner & Beauchaine, 2016). Accordingly, higher PEPR (i.e., a *shortening* of PEP from baseline to a task or challenge) reflects an increase in β-adrenergic influences on the heart and more SNS activation in response to a task or challenge while lower PEPR (i.e., a lack of change in PEP or a *lengthening* of PEP) reflects no change or a decrease in β-adrenergic activity. PEPR may also be a viable index of the amount of effort that participants exert during laboratory tasks such that higher PEPR reflects more effort and potentially higher levels of active coping during challenging or stressful tasks (Kelsey, 2012). Additionally, PEPR can serve as a measure of mesolimbic dopaminergic activity and approach behavior activity under carefully controlled conditions (e.g., when measured in response to a monetary incentive task; Zisner & Beauchaine, 2016).

Although SCL and PEP are both measures of SNS activity, they are theorized to reflect activity in different underlying motivational systems in the brain. While SCL has been conceptualized as a measure of behavioral inhibition system (BIS) activity, PEP may serve as a measure of behavioral activation system (BAS) activity under reward conditions (Beauchaine, 2001; Zisner & Beauchaine, 2016). The BIS and BAS are two of the three motivational systems described by Gray and McNaughton (2000), with the other system – the fight-flight-or-freeze system (FFFS) – exerting its influence on ANS activity via the vagus nerve and other physiological systems (e.g., endocrine; Beauchaine, 2001; Beauchaine et al., 2001). The FFFS and BIS underlie active (e.g., escape behaviors or behavioral withdrawal from a stressful situation) and passive forms of avoidance and AWD responses (e.g., cognitive avoidance, denial), respectively. As a result, SCL and SCLR are presumably the measures of ANS activity that would be most strongly associated with AWD responses. PEPR in response to stressors rather than rewards or incentive tasks may also be associated with AWD responses given that it is a reliable measure of β-adrenergic influence on the heart and that increased β-adrenergic activity is associated with anxiety-like symptoms and behaviors such as avoidance (hence the use of so-called "beta-blockers" to treat anxiety disorders; Williams et al., 2017). However, studies examining PEPR in response to social stress tasks are scarce and thus it is difficult to draw firm conclusions about the nature of associations between PEPR and measures of AWD responses.

In addition to measures such as RSA/RSAR, SCL/SCLR, and PEP/PEPR which reflect activity within specific physiological systems (PNS and SNS, respectively), ANS activity and overall arousal can be assessed through more general measures such as heart rate (HR) and heart rate reactivity (HRR). Cardiac activity is subject to a wide range of influences (e.g., PNS activity, SNS activity, and hormonal inputs) and thus cannot be used as a measure of the relative activation of specific components of the ANS (Zisner & Beauchaine, 2016). However, HR and HRR have demonstrated their utility in previous studies on trait anxiety and externalizing behaviors such as conduct problems in children and adolescents (described below) and are included in the present study. Additionally, the types of SNS-mediated increases in arousal that are thought to underlie AWD responses (i.e., arousal driven by FFFS and/or BIS activity) would likely involve corresponding increases in HR to stressors (i.e., elevated HRR) and would be relevant to the study of the physiology of AWD responses. However, given that overall arousal and PNS activity are influenced by the BAS, BIS, and FFFS, physiological measures such as

HR, HRR, RSA, and RSAR may not be significant predictors of specific cognitive or behavioral responses to stress.

Direct associations between measures of ANS reactivity to stress and AWD responses among children and adolescents

Theories of psychophysiological functioning support the notion that stress-induced increases in arousal may facilitate and promote AWD responses, particularly if the arousal is driven by SNS activity elicited by activation of the FFFS and/or BIS (Beauchaine, 2001; Porges, 2001; 2007). This pattern of arousal may involve decreases in RSA (i.e., vagal withdrawal), increases in SCL, increases in HR, and a potential shortening of PEP (i.e., increases in β-adrenergic SNS activity) in response to stressful or anxiety-provoking situations. While there is some empirical evidence that higher ANS reactivity to stressors, and SNS reactivity in particular, is associated with AWD responses among children and adolescents, findings across studies are mixed and inconsistent.

Respiratory sinus arrhythmia reactivity (RSAR)

Previous research has shown that RSAR to social stress (Erath & Tu, 2014; Kaeppler & Erath, 2017; Paysnick & Burt, 2015; Poole & Schmidt, 2023) and reward (Brenner et al., 2005) tasks is generally unrelated to measures of AWD responses among children and adolescents. For example, Erath and Tu (2014) and Kaeppler and Erath (2017) examined the physiological and coping responses of early adolescents (N = 123, M_{age} = 12.0 years). RSAR was measured in response to a peer-evaluative social stress task, and participants completed measures of real-time coping (i.e., coping responses used during the lab protocol) as well as coping with peer victimization. Both studies found that RSAR was not significantly associated with measures of real-time disengaged coping with peer-evaluative stress or disengaged coping with peer victimization. Similarly, Paysneck and Burt (2015) found that RSAR to a social competence interview, in which participants were asked to recount a recent stressful life experience, was not associated with a global measure of non-productive coping (e.g., wishful thinking, ignore the problem, self-blame) among adolescents (N = 66, M_{age} = 16.6 years). Poole and Schmidt (2023) also found that RSAR to a speech task was not associated with observed behavioral expressions of avoidance/inhibition among children (N = 152, M_{age} = 7.82 years).

In contrast to the aforementioned findings, there is some evidence that RSAR is negatively associated with AWD responses among children and adolescents. For example, Blair et al. (2004) found that RSAR to a cognitive task was negatively associated with parent-reported BIS scores (i.e., withdrawn and avoidant behaviors) among children 3-5 years of age (N = 170). In a related study, Myruski & Dennis-Tiwary (2021) studied the physiological and attentional responses of children ages 5-9 (N = 97) and found that RSAR to a waiting task was negatively associated with attentional avoidance strategies such as passive distraction and gaze aversion during a delay of gratification task. These results suggest that higher RSAR to cognitive and anticipatory (e.g., waiting task) tasks may be more adaptive and associated with fewer AWD responses than lower RSAR. However, most existing evidence from studies on RSAR and AWD responses suggests that RSAR to social stressors specifically is unrelated to measures of AWD responses among children and adolescents.

Skin conductance level reactivity (SCLR)

Theoretically, SCLR is the measure of ANS functioning that should be most strongly associated with AWD responses given that SCLR is conceptualized as a measure of BIS-mediated SNS activity. Several studies have found that SCLR is positively associated with measures of AWD responses among children and adolescents (Cummings et al., 2007; Paysnick

& Burt, 2015) or have observed larger skin conductance responses (i.e., greater response amplitude) among inhibited children relative to their less-inhibited counterparts (Scarpa et al., 1997). For example, a study by Paysnick and Burt (2015) examined associations between SCLR to a social competence interview (i.e., recounting a recent interpersonal stressor) and a measure of coping that included productive (e.g., problem-solving) and non-productive (e.g., wishful thinking, ignore the problem, keep to self) scales among adolescents (N = 66, M_{age} = 16.6 years). They found that SCLR to the social competence interview was positively associated with non-productive coping and unrelated to productive coping. In a related longitudinal study, Cummings et al. (2007) examined associations between SCLR to two stress tasks (i.e., an inter-adult argument and a problem-solving task) and parent-reported measures of children's social problems (i.e., social withdrawal and social skill deficits) over a two-year period (N = 157, T1 M_{age} = 9.3 years; T2 M_{age} = 11.5 years). Cummings et al. (2007) found that SCLR to an inter-parental argument at T1 was positively associated with mother-reported social problems two years later (T2). Thus, heightened SCLR to social stressors may underlie concurrent AWD responses as well as contribute to increases in AWD responses over time.

In contrast to the findings outlined above, some studies have reported negative or non-significant associations between SCLR and measures of AWD responses among children and adolescents (Erath & Tu, 2014; Kaeppler & Erath, 2017). For example, Erath and Tu (2014) and Kaeppler and Erath (2017) found that SCLR to a peer-evaluative stress task was negatively associated with disengaged coping with peer victimization and unrelated to a measure of real-time coping with peer-evaluative stress among early adolescents (N = 123, M_{age} = 12.0 years). Accordingly, although there is some evidence to support the notion SCLR to social stress tasks is positively associated with measures of AWD responses, contrasting evidence also exists.

Pre-ejection period reactivity (PEPR)

Studies examining associations between PEPR and AWD responses specifically are extremely scarce. This is particularly true with regards to studies that use child or adolescent samples. The overwhelming majority of studies using PEPR have measured PEPR in response to reward tasks or have examined associations between PEPR to stress or challenge tasks and internalizing symptoms, externalizing behaviors, or substance use. While reduced or blunted PEPR to reward tasks is related to a lack of physiological engagement with rewards and associated with externalizing problems, substance use, and depressive symptoms among children, adolescents, and young adults (Ahles et al., 2017; Brenner et al., 2005; Brenner & Beauchaine, 2011; Chen & French, 2024; Hinnant et al., 2016a; Hinnant et al., 2016b; Hinnant et al., 2022), the extent to which PEPR is associated with AWD responses or cognitive and behavioral engagement (e.g., prosocial behaviors, problem-solving coping responses) remains unclear.

Two existing studies have examined associations between PEPR and a measure of AWD responses or cognitive/behavioral engagement (which is essentially the opposite of AWD responses), though only one of these studies utilized a child or adolescent sample. Brenner et al. (2005) examined associations between PEPR to a reward task and self-reported BIS activity among undergraduate students (N = 65) and found that PEPR was unrelated to self-reported BIS activity. Additionally, Christensen et al. (2017) examined associations between PEPR to the TSST and a measure of habitual cognitive reappraisal (e.g., positive refocusing and reappraisal) among adolescents ages 13-17 (N = 169). This way of measuring cognitive reappraisal can, in some ways, be thought of as the inverse to cognitive forms of AWD responses (e.g., cognitive avoidance). Christensen et al. (2017) found that PEPR to the TSST was positively associated with cognitive reappraisal, which suggests that elevated PEPR may be associated with engaged cognitive and behavioral responses rather than AWD responses. However, these results have not been replicated and additional research will be necessary before firm conclusions can be drawn from the literature about the nature of associations between PEPR and AWD responses specifically.

Heart rate reactivity (HRR)

To our knowledge, no existing study has examined associations between HRR and measures of AWD responses among children or adolescents. As a result, hypotheses about associations between HRR and measures of AWD responses in the present study were derived from related research utilizing young adult samples. These studies have produced mixed results, which is perhaps unsurprising given that HR and HRR are influenced by a variety of physiological processes and brain systems (e.g., PNS, SNS, BAS, BIS, and FFFS activity; Zisner & Beauchaine, 2016). Findings from several studies using young adult samples support the notion that general increases in arousal in response to stressors facilitate and potentially underlie AWD responses. For example, Connor-Smith and Compas (2004) found that HRR to a social feedback task (i.e., the Thematic Apperception Test) was positively associated with disengaged coping responses to interpersonal stress among undergraduate students (N = 68, M_{age} = 18.5 years). In a related study, Sözer et al. (2023) found that HRR to the TSST was positively associated with self-reported BIS scores among undergraduate students (N = 61, M_{age} = 20.2 years). Thus, an increase in HR in response to social stress tasks may be associated with higher levels of AWD responses.

In contrast to the aforementioned findings, several studies have reported no association between HRR and measures of AWD responses among young adults. For example, Schwerdtfeger et al. (2006) found that HRR to a public speaking task was not significantly associated with avoidant coping among undergraduate students (*N* = 85; M_{age} = 23.1 years). Similarly, Ginty et al. (2021) found that HRR to an acute psychological stress task (Paced Auditory Serial Addition Test) was not significantly associated with a measure of PTSD avoidance symptoms among adults (*N* = 120, M_{age} = 21.5 years). Two studies have also reported negative associations between HRR and measures of AWD responses, further complicating the interpretation of findings across studies. Ginty et al. (2020) found that HRR to an acute psychological stress task (Paced Auditory Serial Addition Test) was negatively associated with behavioral disengagement as measured by the Brief Coping Orientation to Problems Experienced Scale (Carver, 1997) among young adults (*N* = 452, M_{age} = 19.5 years). Likewise, Sloan (2004) found that HRR to a film viewing task (i.e., viewing films that represented pleasant, unpleasant, and neutral emotions) was negatively associated with experiential avoidance among young adults (*N* = 62, M_{age} = 19.0 years).

As a whole, findings from studies examining associations between HRR and AWD responses among young adults appear mixed and inconsistent. However, upon closer inspection, a trend seems to emerge wherein studies that examine HRR to social stressors tend to report a positive association between HRR and AWD responses or no association, whereas studies that examine HRR to psychological stressors or emotion-induction tasks tend to report a negative association between HRR and AWD responses or no association. Accordingly, given that a social stress task is utilized in the present study, a reasonable hypothesis would be that HRR to the peer-evaluative stress task will be positively associated with each measure of AWD responses, though the associations may be relatively weak and inconsistent across measures. In addition, it should be noted that findings from studies using young adult samples may not generalize to children and adolescents. As a result, hypotheses derived from these studies may be more tenuous than other hypotheses about the nature of associations between specific measures of ANS reactivity and AWD responses.

Social anxiety as a moderator of the association between ANS reactivity and AWD responses among children and adolescents: Theoretical background

Overall, findings from studies examining associations between measures of autonomic reactivity and AWD responses are mixed. Inconsistencies across studies may be partially explained by the influence of moderating variables that impact the degree to which measures of ANS reactivity and AWD responses are associated with one another. One such variable that may influence associations between measures of autonomic reactivity and AWD responses is an individual's level of social anxiety (measured in the laboratory or using questionnaires or observational methods). Indeed, some have argued that physiological reactivity and AWD responses may be particularly strongly associated with one another among anxious individuals (Gellner et al., 2021; Livermore et al., 2021), such that there is a stronger association between measures of physiological reactivity and AWD responses at higher levels of anxiety (including social anxiety) relative to lower levels of anxiety. Although there is some evidence that associations between measures of physiological reactivity to social stress and social behavior are stronger at higher levels of social anxiety relative to lower levels among early adolescents (e.g., Kaeppler & Erath, 2017), no study has examined measures of social anxiety as potential moderators of the association between physiological reactivity and AWD responses specifically.

Multiple factors may explain the potential moderating influence of social anxiety on associations between measures of autonomic reactivity to stressors and AWD responses among children and adolescents in particular. For example, socially anxious children and adolescents report more negative interpretations of internal physiological sensations than their less anxious counterparts and may view increases in physiological arousal as a sign that something is wrong or that they are under threat (Anderson & Hope, 2009; Asbrand et al., 2020; see Siess et al., 2014 for a brief overview). Children and adolescents with higher levels of social anxiety also tend to choose coping strategies or behavioral responses based on their physiological and emotional state, as opposed to the specific demands of a given situation (Vasey & Daleiden, 1996). Moreover, socially anxious children and adolescents have been shown to exhibit slower physiological recovery following exposure to stressors in some studies (Schmitz et al., 2011; 2013) which may prompt them to use AWD responses to quickly reduce their arousal. Similarly, children and adolescents with higher levels of social anxiety may have a harder time "overriding" or regulating their physiological and emotional responses to stressors using top-down regulatory processes, given that anxious youth often report or exhibit poorer executive functioning and emotion regulation relative to less anxious youth (see Cisler et al., 2010 and Zainal & Newman, 2022 for reviews). As a result, the physiological responses of socially anxious children and adolescents may be more tightly coupled to their coping or behavioral responses, compared to less anxious youth.

The dual-mode social information processing (dmSIP; Verhoef et al., 2022) model provides a useful framework for an exploration into the potential moderating influence of social anxiety on the association between ANS reactivity and AWD responses. The dmSIP model describes two different modes of processing that shape cognitive and behavioral responses to changes in one's environment: (1) an automatic mode and (2) a reflective mode. In the dmSIP model, the automatic mode of processing is theorized to be the primary driver of cognitive and behavioral responses in non-stressful or highly stressful contexts (i.e., at the more extreme ends of a stress continuum) while the reflective mode dictates responses in moderately stressful contexts. For example, in moderately stimulating and stressful environments, a person's behavior would largely be driven by the reflective mode of processing, which helps them think through their options and make relatively well-thought-out decisions about how they want to respond based on situational cues. However, if the environment is not stressful and elicits hypoarousal/hyper-reactivity or becomes highly stressful and elicits hyperarousal/hyper-reactivity, that person would operate from an automatic mode of processing. Behavioral responses in automatic mode stem from a "database of automatic contingencies" (Verhoef et al., 2022, p. 44), which facilitates quick, reflexive responses based on an initial appraisal of the situation without complete or continuous consideration for situational cues.

Importantly, the dmSIP model proposes that an "arousal-based switch" is responsible for switching between modes of processing along a U-shaped curve, such that the automatic mode of processing will be used when arousal levels are either low or high and the reflective mode of processing will be used when a person is moderately aroused or at an optimal level of arousal. This is similar to the Yerkes-Dodson law of arousal, which states that optimal performance on a task is most likely to occur when arousal is at a moderate level, and that performance and functioning would be impaired to some degree when levels of arousal are either too low or too high (Cohen, 2011). The activity of the arousal-based switch in the dmSIP model is also influenced by a variety of other factors such as emotional dispositions (e.g., emotional hyperreactivity), motivational dispositions (e.g., hypersensitivity to punishment or threat cues), executive functioning (e.g., poor emotion regulation), and internal state (e.g., feeling stressed, hungry, tired, etc.). Although the dmSIP model was originally applied to aggressive children and adolescents, it is equally applicable to children and adolescents with elevated levels of social anxiety.

In the original description of the dmSIP model, Verhoef et al. (2022) presented evidence that children's proactive aggressive behavior often (though not always) occurs when they are in an automatic mode of processing that is triggered by physiological hypo-reactivity to stressors, blunted emotional responses, insensitivity to punishments and rewards, a lack of emotion regulation or problem-solving, and/or internal physiological factors such as stress, frustration, or fatigue. Similarly, the AWD responses that are particularly common among socially anxious children and adolescents may also be more likely to occur when these individuals are in an automatic mode of processing. However, in the case of socially anxious youth (as opposed to aggressive children), the automatic mode of processing and resulting AWD responses may be triggered by hypersensitivity to punishments or threat cues (including a negative interpretation of their own physiological arousal), a lack of emotion regulation or problem-solving, and/or internal factors such as stress or fatigue. In contrast, children or adolescents who are less socially anxious may be less likely to shift into an automatic mode of processing as their level of physiological arousal increases or decreases given that they are less sensitive to punishments or threat cues, more likely to exhibit emotion regulation and problem-solving skills, and may be more capable of overcoming or regulating potentially problematic internal states. Thus, the dmSIP model may help to explain the moderating effect of social anxiety on the association between ANS reactivity to stress and AWD responses among children and adolescents.

Social anxiety as a moderator of the association between ANS reactivity and AWD responses: Empirical evidence

To date, no study has examined social anxiety as a moderator of the association between any measure of physiological reactivity and AWD responses among children or adolescents. In addition, no existing study has examined social anxiety as a moderator of associations between measures of ANS reactivity specifically and AWD responses among individuals of any age. However, findings from several studies utilizing related measures and/or adult samples provide partial support for the moderation hypothesis described above. For example, Roelofs et al. (2009) found that increased cortisol reactivity to the Trier Social Stress Task (TSST) was associated with increased avoidance tendencies toward social threat stimuli among adults with Social Anxiety Disorder (SAD; n = 18) but not among individuals with PTSD (n = 17) or healthy controls (n = 22). Similarly, van Peer et al. (2007) found that cortisol administration resulted in an increase in avoidant responses during an approach-avoidance task for college-aged students who reported high BIS scores (n = 20) but not among individuals who reported low BIS scores (n = 20). In this study, self-reported BIS was used as a measure threat sensitivity, and individuals who reported high BIS scores reported significantly higher levels of trait anxiety, social anxiety, and harm avoidance than individuals who reported low BIS scores. While van Peer et al. (2007) did not examine physiological reactivity per se, their findings partially support the hypothesis that anxiety moderates the association between physiological reactivity to stress and AWD responses.

In a related study by Pineles et al. (2011), avoidant coping moderated the association between HRR to a monologue about a recent traumatic event (T1) and PTSD symptoms three months later (T2) among adults (N = 55; M_{age} = 29.2 years). More specifically, T1 HRR was positively associated with T2 PTSD symptoms among individuals who reported higher levels of avoidant coping but not among those who reported lower levels of avoidant coping. When examining the figure illustrating the results described by Pineles et al. (2011), it appears that T1 HRR would also be positively associated with avoidant coping for individuals with higher levels of T2 PTSD symptoms but not for those with lower levels of PTSD symptoms if the moderating and outcome variables were switched in their analytic models. Similarly, a study by Fortunato et al. (2013) found that children who reported higher levels of internalizing symptoms (i.e., anxiety and depressive symptoms) exhibited higher levels of RSAR during withdrawal-based (i.e., fear and sadness) but not approach-based (i.e., happiness and anger) emotion inductions relative to children who reported lower levels of internalizing symptoms. However, the results reported by Pineles et al. (2011) and Fortunato et al. (2013) should be interpreted cautiously given that neither study utilized a measure of social anxiety specifically and that both studies examined analytic models that differ from the model that will be tested in the present study. In addition, Fortunato et al. (2013) examined physiological reactivity to an emotion-induction task that had withdrawal-based and approach-based components but did not utilize a measure of AWD responses specifically.

Despite the relative paucity of studies, numerous interventions and skills training programs have seemingly embraced the idea that high levels of physiological reactivity to stressors may be problematic and more likely to drive maladaptive responses (such as AWD responses) among socially anxious individuals. This is evidenced by the emphasis that is often placed on awareness of physiological signals and arousal reduction techniques. For example, evidence-based children's programs such as the Fun FRIENDS curriculum (Barret, 2007a; 2007b), Coping Cat online training program (Flannery-Schroeder & Kendall, 1996), and neurofeedback videogame intervention MindLight (Schoneveld et al., 2016) emphasize the use of relaxation techniques aimed at increasing active coping (e.g., problem-solving) and reducing anxiety. Fun FRIENDS in particular teaches children “relaxation techniques to relax the body and mind during stressful situations,” “self-awareness of body clues,” in addition to other strategies or techniques (see https://friendsresilience.org/funfriends for a full description of key aspects of the program). Similarly, Coping Cat’s Child Anxiety Tales program has a module that teaches children how to use relaxation techniques (see https://www.copingcatparents.com/Child_Anxiety_Tales for a full description). Accordingly, it will be important to further clarify the extent to which physiological reactivity to stressors is associated with AWD responses, as well as the extent to which measures of social anxiety moderate this association.

The present study

The aims of the present study were to examine associations between measures of ANS reactivity to a social stress task and AWD responses, as well as measures of social anxiety as potential moderators of these associations among a sample of early adolescents. AWD responses are associated with a host of negative psychosocial outcomes (Aldao et al., 2010; Compas et al., 2017; Rubin et al., 2009, 2010; Schäfer et al., 2017) and are theorized to be shaped, in part, by stress-induced increases in physiological arousal (Beauchaine, 2001; Porges, 2001, 2007). In addition, associations between measures of physiological reactivity to stressors and AWD responses may be particularly strong among highly anxious individuals, including socially anxious youth (Gellner et al., 2021; Livermore et al., 2021). However, previous studies examining associations between measures of physiological reactivity to stressors and AWD responses have produced mixed results and social anxiety has yet to be examined as a moderator of these associations.

The present study advances the existing literature in several ways. First, it is the only study to examine four well-validated measures of ANS functioning (i.e., RSAR, SCLR, PEPR, and HRR to a social-evaluative stress task) as predictors of AWD responses. In addition, the present study included self-report, teacher-report, and observational measures of AWD responses which, along with the four measures of ANS activity, constitute a comprehensive examination of associations between measures of ANS activity and AWD responses. Likewise, the present study utilized multi-method data across predictors (i.e., objective physiological data), moderators (i.e., self-reports of social anxiety), and outcomes (i.e., teacher-reports, observational data, and self-reports of AWD responses) which may increase the reliability of findings by reducing or eliminating common informant variance.

This study is also the first to examine social anxiety as a potential moderator of associations between measures of physiological reactivity and AWD responses and utilized two measures of social anxiety to investigate whether moderating effects differ as a function of the type of social anxiety that is measured. More specifically, the present study included measures of context-specific, real-time social anxiety and global social anxiety (see Methods section for more detailed information about each measure). Context-specific social anxiety reflects the levels of anxiety that participants experienced during the peer-evaluative stress task, and it was measured in the same context as participants' physiological responses to social stress. In contrast, global measures of social anxiety assessed participants' anxiety levels across time and across a variety of social contexts and situations. Thus, although the two measures of social anxiety used in the present study are somewhat interrelated, both measures provide unique value and might moderate associations between measures of ANS reactivity and AWD responses in different ways.

Examining associations between measures of physiological reactivity, AWD responses, and social anxiety within the same context is another unique feature of the present study. We examined associations between measures of physiological reactivity to a social stress task, AWD responses exhibited during the social stress task or reported immediately after (i.e., observational and real-time measures), and social anxiety experienced during the social stress task. Same-context assessment is important, as inconsistencies observed across previous studies examining measures of physiological reactivity and AWD responses may be due, in part, to the tendency for researchers to measure physiology and AWD responses in different contexts (e.g., physiological measures in the laboratory and global measures of AWD responses outside of the laboratory).

The present study also examined measures of physiological reactivity to social stress, AWD responses to social situations, and social anxiety (including social anxiety) during a developmental period in which social stressors are particularly salient and social anxiety symptoms tend to peak (Beidel, 2007). Studies examining associations between measures of physiological reactivity and AWD responses in childhood and adolescence are especially uncommon, further highlighting the value of the present study. Similarly, no other study has examined social anxiety as a moderator of associations between measures of ANS reactivity and AWD responses among individuals of any age. Thus, the present study addressed numerous gaps in the literature on physiological reactivity to stress, AWD responses, and social anxiety.

Study objectives and hypotheses

The first objective of the present study was to examine direct associations between four measures of ANS reactivity to a peer-evaluative stress task and AWD responses. Given the relative scarcity and inconsistency of findings from previous studies on ANS functioning and AWD responses, we were only able to develop hypotheses for three out of the four measures of

ANS reactivity. We hypothesized that **(H1)** SCLR would be positively associated with all measures of AWD responses given the theoretical and empirical support for the notion that increases in BIS-mediated sympathetic arousal underlie AWD responses, (**H2)** HRR would be positively associated with all measures of AWD responses, and **(H3)** RSAR would be unrelated to all measures of AWD responses. To our knowledge, no other study has examined associations between PEPR and measures of AWD responses, which makes it difficult to generate hypotheses about the nature of these associations. PEPR to social stress tasks is an index of SNS activity much like SCLR and may be positively related to AWD responses as well **(H4)**. However, this hypothesis is speculative and, as a result, analyses involving PEPR were considered exploratory.

The second objective of the present study was to examine measures of social anxiety as potential moderators of associations between measures of ANS reactivity to social stress and AWD responses. Based on results from a limited set of previous studies (Fortunato et al., 2013; Pineles et al., 2011; Roelofs et al., 2009; van Peer et al., 2007), we hypothesized that social anxiety would moderate the association between specific measures of ANS reactivity to social stress and AWD responses. More specifically, we hypothesized that SNS (i.e., SCLR; **H5**) and general ANS (i.e., HRR; **H6**) reactivity to social stress would be more strongly positively associated with AWD responses among early adolescents who reported higher levels of social anxiety relative to early adolescents who reported lower levels of social anxiety. Interactions involving RSAR and PEPR were considered exploratory given the evidence that RSAR is generally unrelated to AWD responses as well as the lack of relevant studies involving PEPR. However, given that PEPR to social stressors is an index of SNS activity and β-adrenergic influences on the heart, PEPR may also be positively associated with AWD responses among early adolescents who report higher levels of social anxiety and weakly associated with or unrelated to AWD responses among early adolescents who report lower levels of social anxiety (similar to SCLR). Context-specific and global measures of social anxiety were tested as moderators in separate analyses to explore possible differences.

II. METHODS

Participants

One hundred-twenty-three (123) fifth and sixth graders (M_{age} = 12.03 years, *SD* = 0.64) and one parent per early adolescent (82% biological mothers, 67% married) participated in the present study. The sample of early adolescents consisted of 50% males and 58.5% European Americans, 35% African Americans, and 6.5% of other ethnicities. The most commonly-reported annual family income was between $35,001 and $50,000; 21% reported an income of less than $20,000, and 24% reported an income of more than $75,000. Overall, there was very little missing data in the present study aside from measures of ANS reactivity, real-time disengaged coping, and teacher-reported withdrawn behavior (see Table 2 for descriptive statistics).

Teacher reports were obtained for 81% of participants and approximately 25% of participants were missing data on at least one physiological parameter (though very few were missing data on multiple physiological measures and there is very little missing data for each measure of ANS reactivity; see Table 2). There were no significant differences between participants with and without data on all physiological parameters with regards to sex, income, or either measure of anxiety (i.e., context-specific anxiety and global social anxiety). However, participants with missing data on at least one measure of ANS reactivity were more likely to be African American, $t(121) = 2.80$, $p = 0.006$, and younger in age, $t(121) = -2.22$, $p = 0.028$, than participants who were not missing any physiological data. Similarly, there were no significant differences between participants with and without real-time disengaged coping data (described below) with regards to race/ethnicity, age, income, or either measure of anxiety, though participants without real-time disengaged coping response data were more likely to be boys, $t(121) = -2.13$, $p = 0.035$. Lastly, there were no significant differences between participants with and without teacher data with regards to sex, age, or either measure of social anxiety. However, participants without teacher data were more likely to be African American, $t(121) = 3.51$, $p < 0.001$, and from lower income households, $t(117) = -2.64$, $p = 0.009$.

Procedures

Participants were recruited in two cohorts separated by one year through flyers sent home with fifth and sixth graders at five elementary schools in the southeastern United States. Parents who expressed interest were provided with information about the study, including details of the lab protocol, and were contacted via telephone to schedule a visit to the laboratory. Early adolescents and their parents completed the laboratory protocol and assessments during the summer and teachers completed questionnaires near the end of the school year. The lab visit lasted roughly two hours, and parents and early adolescents were each compensated with $60 for their participation. After a brief introduction and consent procedures, parents completed questionnaires and early adolescents participated in lab activities while their physiological responses were monitored and recorded. Following the lab activities, early adolescents were debriefed and given a break before completing questionnaires. All study procedures were approved by the University Institutional Review Board.

The lab protocol included two social stress components: a peer evaluation task and a peer rebuff period. After acclimating to the physiological data collection equipment and completing a 3-minute baseline period, early adolescents responded to several interview questions (e.g., “How difficult do you expect the conversation activity to be?"). Next, they were asked to lead a 3-min conversation with a same-sex adult research assistant as if they were meeting an unfamiliar, same-age peer for the first time. As part of the instructions, early adolescents were told that they could ask questions about the research assistant, talk about themselves, or talk about anything else that they wanted to. They were also told that the conversation would be viewed via one-way Skype (an internet-based video-chat program) by three same-age, same-sex peer judges, who were actually fictitious. Early adolescents were informed that the peer judges would decide how well they performed in the conversation activity compared to two other participants the peer judges had allegedly watched via Skype. The peer evaluation period refers to the 3-minute conversation activity.

Following the peer evaluation period, early adolescents responded to several interview questions about the conversation activity and were told that they would soon receive a response from the peer judges via Skype indicating whom the peer judges chose as the best performers. Three minutes after early adolescents completed the post-conversation interview questions, they received a text message via Skype, ostensibly from the peer judges, indicating that the peer judges chose the other two participants as the best performers in the conversation activity. Participants were told that the peer judges sometimes change their minds and that they would be given an opportunity to try to change the peer judges' opinions by speaking directly to them through Skype. The peer rebuff period refers to the 3-minute period following the feedback from the peer judges, during which participants considered their potential response to the peer judges. The social stress protocol was ended following the peer rebuff period and several interview questions, and participants were carefully debriefed using a process debriefing procedure. More specifically, early adolescents were led to their own conclusion that the peer judges were fictitious, and the purpose of the study and reasons for deception were discussed with participants.

Measures

Physiological Assessments

RSA, SCL, PEP, and HR were measured continuously in 1-minute intervals during acclimation (5 minutes), resting baseline (3 minutes), speaking baseline (reading aloud with a research assistant; 3 minutes), peer evaluation (3 minutes), waiting (3 minutes), peer rebuff (3 minutes), and recovery (3 minutes) periods. Physiological measures were not collected for three participants during the peer evaluation period because they chose not to participate in the peer stress procedures, or their uncomfortable appearance led us to forego the peer evaluation and/or rebuff period(s). A taped loop in the electrode lead cables was used to limit movement artifacts for all physiological data collection.

ANS Reactivity

Respiratory Sinus Arrhythmia Reactivity (RSAR) and Heart Rate Reactivity (HRR). RSA and HR data acquisition followed standard guidelines using a MindWare data acquisition system (MindWare Technologies, Inc., Gahanna, OH). Electrocardiography (ECG) data, including RSA and HR, were collected through disposable Ag-AgCl electrodes (1½" foam sensor, 7% chloride gel) placed on early adolescents' right clavicle and left and right rib by a same-sex research assistant. RSA scores were quantified using the spectral analysis method (Berntson et al., 1997) with MindWare HRV analysis software and expressed in units of $\ln(ms^2)$. The very few artifacts that were detected were corrected manually using standard procedures (Berntson et al., 1997). RSA data were not collected for 3 participants who chose not to participate in the peer stress procedures or whose discomfort led us to forego the peer-evaluative stress task while HR data were not included for five participants. RSAR and HRR refer to residualized change scores from the pre-task period to the peer evaluation period. The residualized change score is the residual of the regression of RSA during the peer evaluation period on pre-task RSA (or HR during the peer evaluation period on pre-task HR). In the present study, RSA residualized change scores were multiplied by -1, such that higher RSAR scores indicate greater reductions in RSA (i.e., greater vagal withdrawal) from the pre-task period to the peer evaluation period.

Skin Conductance Level Reactivity (SCLR). SCL data acquisition also followed standard guidelines using a MindWare data acquisition system and MindWare EDA analysis software (MindWare Technologies). SCL (units = microsiemens or μS) was measured with two disposable Ag-AgCl electrodes (1½” x 1” foam, 0 % chloride gel) placed on the palm of the preadolescent’s non-dominant hand. SCL data were not included for twelve participants due to measurement artifacts. SCLR was computed as the residualized change score from the pre-task period to the peer evaluation period, such that higher SCLR scores indicate greater increases in SCL from the pre-task period to the peer evaluation period.

Pre-Ejection Period Reactivity (PEPR). PEP was derived from cardiac data using a modified lead-II configuration (Berntson et al., 1997) and thoracic impedance data using a four-spot impedance configuration (Berntson & Cacioppo, 2004). These data were collected using Ag-AgCl electrodes (1½” foam, 7% chloride gel; MindWare Technologies, Inc., Gahanna, OH). To measure cardiac data, electrodes were placed on the right clavicle and left and right ribs. Thoracic impedance was measured using electrodes placed at the apex and base of the thorax and dual electrodes were placed on the back, approximately 1 ½ inches above and below the thorax electrodes. Data were quantified using MindWare IMP analysis software and measured in milliseconds (ms). PEP data were not included for eight participants due to measurement artifacts. To account for initial (i.e., pre-task) values when examining reactivity, PEPR was computed as the residualized change score from the pre-task period to the peer evaluation period. In the present study, PEPR values were multiplied by -1, such that higher PEPR scores indicate a greater shortening of PEP (i.e., an increase in SNS activity and β-adrenergic influences on the heart) while lower PEPR scores indicate a lengthening of PEP (i.e., a decrease in SNS activity and β-adrenergic influences on the heart) in response to the peer evaluation period.

Social Anxiety

Context-Specific Social Anxiety (CSSA). Context-specific social anxiety was assessed with a composite of two items from the peer evaluation task. Participants were asked to rate their anxiety on a five-point scale (1 = *not at all* to 5 = *very much*) before and after the peer evaluation task (e.g., "How nervous or anxious are you about the conversation activity?" and "How nervous or anxious were you during the activity?"). The two items were moderately correlated ($r = 0.58$, $p < 0.001$) and were averaged to create a measure of lab-based, context-specific social anxiety.

Global Social Anxiety (GSA). Early adolescents completed the eighteen-item Social Anxiety Scale for Adolescents (SAS-A; La Greca & Lopez, 1998). Items were rated on a five-point scale (1 = *not at all*, 5 = *all the time*; e.g., "I worry about what others think of me"; "I feel shy even with peers I know very well") and internal consistency of the SAS-A was good ($\alpha = 0.92$).

AWD Responses – Avoidant and Withdrawn Behavior

Observed Social Disengagement. Early adolescents' social engagement during the peer evaluation task was assessed using observational ratings developed in a previous study (Erath et al., 2007). Ratings of social engagement were based on demonstration of attention (e.g., eye contact when listening), demonstration of interest (e.g., follow-up questions), flexible responding based on the apparent desire of the conversation partner (e.g., allowing the RA to complete statements), and validation of the conversation partner (e.g., providing validating non-verbal and verbal feedback). Social engagement was rated on a five-point scale (1 = *not at all*, 5 = *very much*) by trained graduate students who were unaware of early adolescents' levels of anxiety. Coders were trained using practice tapes until they achieved an inter-rater reliability of .70 on each item. Fifty-five percent of tapes were double coded, and inconsistent ratings were resolved by consensus. Inter-rater reliability was high (ICC = .84). To better represent the types of AWD responses examined in the present study, ratings of early adolescents' social engagement were reverse-coded, such that higher scores reflect higher levels of observed social disengagement during the peer-evaluative stress task. Accordingly, the reverse-coded ratings are henceforth referred to as observed social disengagement.

Teacher-Reported Withdrawn Behavior. Teachers completed the eight-item Withdrawn/Depressed subscale of the Teacher Report Form (TRF; e.g., "Withdrawn, doesn't get involved with others"; Achenbach, 1991). Items were rated on a three-point scale (0 = *not true* to 2 = *very true*) and a mean score was calculated for each participant using the five items from the TRF that specifically assess withdrawn behavior (i.e., "would rather be alone than with others," "refuses to talk," "secretive, keeps things to self," "too shy or timid," and "withdrawn, doesn't get involved with others") whereas the three items assessing depressive symptoms or behaviors were excluded (i.e., "there is very little he/she enjoys," "underactive, slow moving, or lacks energy," and "unhappy, sad, or depressed"). Internal consistency was good across the five items assessing withdrawn behavior (α = .82).

AWD Responses – Disengaged Coping

Coping with Peer-Evaluative Stress in Real-Time. Real-time coping with peer-evaluative stress was assessed with early adolescents' open-ended responses to questions that immediately followed the peer evaluation and peer rebuff periods. After the peer evaluation period, participants were asked, "Having a conversation with someone you don't know, while being judged by peers, can be challenging—how did you cope with this situation?" Following their initial response, participants were asked, "Did you use any other coping strategies to make yourself feel better or to help you get through the conversation activity?" Similarly, after the peer rebuff period, participants were asked, "Not being chosen by peers can be challenging—how did you cope with this situation?" This was followed by the question, "Did you use any other coping strategies to make yourself feel better or to help you plan your response to the peer judges?" After extensive training in the coding of coping responses, the principal investigator and trained doctoral students coded disengaged coping responses (e.g., didn't think about the peer judges, thought about something else; $\kappa = 0.89$). All discrepant codes were resolved by consensus. A combined mean score was calculated to capture early adolescents' real-time disengaged coping responses across the peer evaluation and peer rebuff periods. Coping responses based on the context-specific measure used in the present study predict improved academic outcomes across the transition to middle school (Erath et al., 2016) and are associated with concurrent teacher-reported and observed social skills as well as peer-reported victimization (Erath et al., 2007).

Voluntary Disengaged Coping. Early adolescents completed the peer stress version of the Responses to Stress Questionnaire (RSQ; Connor-Smith et al., 2000), which assesses coping responses to stressful situations in peer contexts. The RSQ is comprised of a list of items about what people might think, feel, or do in stressful situations such as arguments or disagreements between peers (e.g., "I try to stay away from people and things that make me feel upset or remind me of the stressful aspects of problems with other kids.") and participants are asked to use a four-point scale (1 = *not at all*, 4 = *a lot*) to rate how much they do or feel these things in response to peer stressors. The RSQ includes voluntary and involuntary coping factors. The voluntary coping factor includes the following scales: primary control, secondary control, and disengagement. The involuntary coping factor includes engagement and disengagement scales. Given our focus on AWD responses, only the voluntary disengagement coping scale was used in the present study (consisting of denial, avoidance, and wishful thinking subscales). The voluntary disengagement scale demonstrated acceptable reliability ($\alpha = .76$).

Demographic Variables

Race/ethnicity, grade level, and sex were represented by dichotomous variables (non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1; male = 0, female = 1, respectively), and parents reported annual household income on a 6-point scale (1 = *less than $10,000* to 6 = *more than $75,000*).

Plan of Analysis

Regression analyses were conducted using MPlus (Muthén & Muthén, 2012) to test independent associations linking each of the four measures of ANS reactivity with each measure of AWD responses. Interactive effects were also explored by examining measures of social anxiety as potential moderators of associations between measures of ANS reactivity and AWD responses. Continuous control and predictor variables were mean-centered, and the following demographic variables were included in analyses if they were associated with predictor and outcome variables: sex, ethnicity (non-African American vs. African American), grade, and household income. Missing data were handled using maximum likelihood with robust standard errors (MLR) estimation, which accounts for non-normally distributed data when estimating model parameters. Sensitivity analyses with winsorized variables were conducted for variables with significant outliers (+/-3Ds), and variables with a skewness statistic greater than +/-2 were transformed.

All regression analyses were conducted in a stepwise fashion (see Table 2). In the first step of analysis, we examined the main effects of primary predictor variables (i.e., control variables, ANS reactivity variables, and measures of social anxiety) on AWD responses. Next, we examined models that included interactions between ANS reactivity variables (e.g., RSAR) and one measure of social anxiety (e.g., context-specific social anxiety) at a time (see Table 1 for a list of all primary variables used in analyses). Three sets of analyses were conducted to reduce the number of overall analyses while also limiting overlap between conceptually related variables (e.g., to avoid inclusion of two SNS measures in the same analysis): (1) analyses of models including both RSAR and SCLR, (2) analyses of models including both RSAR and PEPR, and (3) analyses of models including HRR. If an interaction emerged as significant, simple intercepts and slopes were computed according to standard procedures for interaction effects (Dearing & Hamilton, 2006). Slopes represent associations between a given measure of ANS reactivity (e.g., RSAR) and a measure of AWD responses at higher (+1 SD) and lower (-1 SD) levels of a specific measure of social anxiety (e.g., context-specific social anxiety). Regions of significance were also calculated for significant interactions to determine the level of social anxiety at which the association between a given measure of ANS reactivity and AWD responses becomes significant (Lazar & Zerbe, 2011).

III. RESULTS

Preliminary Analyses

Descriptive statistics and correlations are shown in Table 2. On average, participants exhibited decreases in RSA (i.e., vagal withdrawal; $t_{119} = -7.21$, $p < .001$) and PEP (i.e., a shortening of PEP which indicates an increase in β-adrenergic activity; $t_{112} = -3.87$, $p < .001$) as well as increases in SCL ($t_{107} = 15.55$, $p < .001$) and HR ($t_{114} = 8.28$, $p < .001$) in response to the peer-evaluative stress task. Several ANS reactivity scores and three teacher-reported withdrawn behavior values were considered outliers based on their deviation from the mean (+/-3 SDs, see Table 2; RSAR – one outlier, SCLR – one outlier, PEPR – two outliers, HRR – three outliers). No other outliers were observed among the remaining moderator and outcome variables. Skewness statistics for all variables were within the range of +/-2 that is generally considered acceptable for regression analyses (Field, 2009; George & Mallery, 2010; Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006) and no transformations were performed. However, sensitivity analyses were conducted with outliers re-coded to the next highest value within the cutoff of +/-3SDs. Results did not differ from those observed in the original regression analyses; thus, the original values were used in the analyses presented below.

Bivariate analyses indicated that ANS reactivity variables and context-specific social anxiety were not significantly associated with any of the AWD variables examined in the present study. Global social anxiety was positively associated with observed social disengagement and voluntary disengaged coping responses but not teacher-reported withdrawn behavior or real-time disengaged coping responses. Context-specific social anxiety and global social anxiety were not significantly associated with one another, and the only significant correlations that emerged between the four AWD response variables were positive correlations between observed social disengagement and teacher-reported withdrawn behavior ($r = .29$) as well as voluntary disengaged coping responses ($r = .25$). Demographic variables were also largely unrelated to measures of AWD responses. However, income was negatively associated with observed social disengagement while race/ethnicity was positively associated with observed social disengagement, such that participants from less affluent families and White children exhibited higher levels of observed social disengagement during the peer-evaluative stress task. Income was also negatively associated with voluntary disengaged coping responses, such that individuals from less affluent homes tended to report higher levels of voluntary disengaged responses.

Regression Analyses Examining Autonomic Variables as Predictors of AWD Responses

Main Effects

Models with RSAR, SCLR. Regression coefficients for models that include RSAR and SCLR can be found in Tables 3 and 4. Findings were consistent across context-specific social anxiety and global social anxiety models except where noted. Income was negatively associated with observed social disengagement and voluntary disengaged coping responses, such that children from less affluent families exhibited higher levels of observed social disengagement during the peer-evaluative stress task and reported higher levels of voluntary disengaged coping responses. In addition, SCLR was positively associated with real-time disengaged coping responses at a non-significant trend-level, such that children who exhibited higher SCLR in response to the peer-evaluative stress task reported higher levels of real-time disengaged coping responses. Lastly, global social anxiety was positively associated with observed social disengagement and voluntary disengaged coping responses, such that children who reported higher levels of global social anxiety exhibited higher levels of observed social disengagement and reported higher levels of voluntary disengaged coping responses.

Models with RSAR, PEPR. Regression coefficients for models that include RSAR and PEPR can be found in Tables 5 and 6. Findings were consistent across context-specific social anxiety and global social anxiety models except where noted. Like the RSAR/SCLR models, income was negatively associated with observed social disengagement and negatively associated with voluntary disengaged coping responses, such that children from less affluent families exhibited higher levels of observed social disengagement during the peer-evaluative stress task and reported higher levels of voluntary disengaged coping responses. In addition, PEPR was negatively associated with observed social disengagement, such that children who exhibited lower PEPR in response to the peer-evaluative stress task (i.e., a lengthening of PEP which reflects a decrease in SNS activity and β-adrenergic influence on the heart) exhibited higher levels of observed social disengagement. Lastly, similar to the RSAR/SCLR models, global social anxiety was positively associated with observed social disengagement and voluntary disengaged coping responses, such that children who reported higher levels of global social anxiety exhibited higher levels of observed social disengagement and reported higher levels of voluntary disengaged coping responses.

Models with HRR. Regression coefficients for models that include HRR can be found in Tables 7 and 8. Findings were consistent across context-specific social anxiety and global social anxiety models except where noted. Again, income was negatively associated with observed social disengagement and voluntary disengaged coping responses. In addition, HRR was negatively associated with real-time disengaged coping responses at a non-significant trend level, such that children who exhibited lower HRR in response to the peer-evaluative stress task exhibited higher levels of real-time disengaged coping responses. Lastly, similar to the models above, global social anxiety was positively associated with observed social disengagement and voluntary disengaged coping responses, such that children who reported higher levels of global social anxiety exhibited higher levels of observed social disengagement and reported higher levels of voluntary disengaged coping responses.

Interactions

Models with RSAR, SCLR, and Context-Specific Social Anxiety. The interaction between SCLR and context-specific social anxiety was a non-significant trend-level predictor of observed social disengagement (β = -.17, *B* = -0.06, *SE* = 0.04, *p* = .099; Figure 1), such that SCLR was negatively associated with observed social disengagement at a non-significant trend level at higher levels of context-specific social anxiety (*B* = -0.11, *SE* = 0.07, *p* = .099) but not at lower levels of context-specific social anxiety. Regions of significance (ROS) analyses revealed that there were no realistic lower or upper values (i.e., values within the range of possible scores on a given measure) of context-specific social anxiety at which the association between SCLR and observed social disengagement became significant. The interaction between SCLR and context-specific social anxiety explained 2.5% of the variance in observed social disengagement above and beyond main effects (ΔR^2 = .025), indicating a small effect size (Cohen, 1988).

Additionally, the interaction between SCLR and context-specific social anxiety was a non-significant trend-level predictor of teacher reported withdrawn behavior (β = -.19, *B* = -0.02, *SE* = 0.01, *p* = .080; Figure 2), such that SCLR was negatively associated with teacher-reported withdrawn behavior a non-significant trend level at higher levels of context-specific social anxiety (*B* = -0.04, *SE* = 0.02, *p* = .060) but not at lower levels of context-specific social anxiety. ROS analyses revealed that there were no realistic lower or upper values of context-specific social anxiety at which the association between SCLR and teacher-reported withdrawn behavior became significant. The interaction between RSAR and context-specific social anxiety was also a significant predictor of teacher-reported withdrawn behavior (β = -.26, *B* = -0.12, *SE* = 0.05, *p* = .010; Figure 3), such that RSAR was positively associated with teacher-reported withdrawn behavior at lower levels of context-specific social anxiety (*B* = 0.18, *SE* = 0.08, *p* = .022) but not at higher levels of context-specific social anxiety. ROS analyses indicated that the association between RSAR and teacher-reported withdrawn behavior was significantly positive at context-specific social anxiety scores below 2.12 (-0.6 SDs) and significantly negative at scores above 4.50 (+1.6 SDs; see Figure 4). The two aforementioned interactions explained a cumulative 7.7% of the variance in teacher-reported withdrawn behavior above and beyond main effects (ΔR^2 = .077), indicating a medium effect size (Cohen, 1988).

Lastly, the interaction between SCLR and context-specific social anxiety was a significant predictor of real-time disengaged coping responses (β = -.22, *B* = -0.04, *SE* = 0.02, *p* = .021; Figure 5), such that SCLR was positively associated with real-time disengaged coping responses at lower levels of context-specific social anxiety (*B* = 0.07, *SE* = 0.02, *p* = .002) but not at higher levels of context-specific social anxiety. ROS analyses revealed that the association between SCLR and teacher-reported withdrawn behavior was significantly positive at context-specific social anxiety scores below 2.48 (-0.3 SDs; see Figure 6). This interaction accounted for 4.9% of the variance in real-time disengaged coping above and beyond main effects (ΔR^2 = .049), indicating a small-to-medium effect size (Cohen, 1988).

Models with RSAR, SCLR, and Global Social Anxiety. The interaction between SCLR and global social anxiety was a significant predictor of observed social disengagement (β = .18, *B* = 0.09, *SE* = 0.04, *p* = .048; Figure 7), such that SCLR was negatively associated with observed social disengagement at a non-significant trend level at lower levels of global social anxiety (*B* = -0.08, *SE* = 0.05, *p* = .095) but not at higher levels of global social anxiety. ROS analyses revealed that there were no realistic lower or upper values of global social anxiety at which the association between SCLR and observed social disengagement became significant.

This interaction explained 3.5% of the variance in observed social disengagement above and beyond main effects (ΔR^2 = .035), indicating a small-to-medium effect size (Cohen, 1988).

Furthermore, the interaction between RSAR and global social anxiety was a significant predictor of real-time disengaged coping responses (β = -.27, *B* = -0.28, *SE* = 0.10, *p* = .007; Figure 8), such that RSAR was negatively associated with real-time disengaged coping responses at higher levels of global social anxiety (*B* = -0.31, *SE* = 0.11, *p* = .004) but not at higher levels of global social anxiety. ROS analyses indicated that the association between RSAR and real-time disengaged coping responses was significantly negative at global social anxiety scores above 2.61 (+0.3 SDs; see Figure 9). This interaction explained 6.3% of the variance in real-time disengaged coping responses above and beyond main effects (ΔR^2 = .063), indicating a medium effect size (Cohen, 1988).

Models with RSAR, PEPR, and Context-Specific Social Anxiety. Similar to the RSAR/SCLR models, the interaction between RSAR and context-specific social anxiety was a significant predictor of teacher-reported withdrawn behavior (β = -.20, *B* = -0.09, *SE* = 0.05, *p* = .041; Figure 10), such that RSAR was positively associated with teacher-reported withdrawn behavior at lower levels of context-specific social anxiety (*B* = 0.16, *SE* = 0.08, *p* = .049) but not at higher levels of context-specific social anxiety. ROS analyses indicated that the association between RSAR and teacher-reported withdrawn behavior was significantly negative at context-specific social anxiety scores below 1.61 (-1 SD; see Figure 11). This interaction accounted for 4.2% of the variance in teacher-reported withdrawn behavior above and beyond main effects (ΔR^2 = .042), indicating a small-to-medium effect size (Cohen, 1988). No other significant or trend-level interactions emerged.

Models with RSAR, PEPR, and Global Social Anxiety. Consistent with the RSAR/SCLR models, the interaction between RSAR and global social anxiety was a significant predictor of real-time disengaged coping responses (β = -.31, *B* = -0.32, *SE* = 0.11, *p* = .002; Figure 12), such that RSAR was negatively associated with real-time disengaged coping responses at higher levels of global social anxiety (*B* = -0.33, *SE* = 0.11, *p* = .002) and positively associated with real-time disengaged coping responses at a non-significant trend level at lower levels of global social anxiety (*B* = 0.19, *SE* = 0.12, *p* = .099). ROS analyses indicated that the association between RSAR and teacher-reported withdrawn behavior was significantly positive at global social anxiety scores below 1.29 (-1.4 SDs) and significantly negative at scores above 2.64 (+0.3 SDs; see Figure 13). This interaction accounted for 8.0% of the variance in teacher-reported withdrawn behavior above and beyond main effects (ΔR^2 = .080), indicating a medium effect size (Cohen, 1988). No other significant or trend-level interactions emerged.

Models with HRR and Context-Specific Social Anxiety. The interaction between HRR and context-specific social anxiety was a non-significant trend-level predictor of teacher-reported withdrawn behavior (β = -.18, *B* = -0.01, *SE* = 0.01, *p* = .070; Figure 14), such that HRR was negatively associated with teacher-reported withdrawn behavior at a non-significant trend level at higher levels of context-specific social anxiety (*B* = -0.01, *SE* = 0.01, *p* = .084) but not at lower levels of context-specific social anxiety. ROS analyses revealed that there were no realistic lower or upper values of context-specific social anxiety at which the association between HRR and teacher-reported withdrawn behavior became significant. This interaction accounted for 3.1% of the variance in teacher-reported withdrawn behavior above and beyond main effects (ΔR^2 = .031), indicating a small-to-medium effect size (Cohen, 1988).

Additionally, the interaction between HRR and context-specific social anxiety was a significant predictor of voluntary disengaged coping responses (β = -.18, *B* = -0.01, *SE* = 0.01, *p* = .070; Figure 15), such that HRR was positively associated with voluntary disengaged coping responses at a non-significant trend level at lower levels of context-specific social anxiety (*B* = 0.02, *SE* = 0.01, *p* = .077) but not at higher levels of context-specific social anxiety. ROS analyses revealed that there were no realistic lower or upper values of context-specific social anxiety at which the association between HRR and voluntary disengaged coping responses became significant. This interaction accounted for 3.1% of the variance in voluntary disengaged coping responses above and beyond main effects (ΔR^2 = .031), indicating small-to-medium effect sizes (Cohen, 1988).

Models with HRR and Global Social Anxiety. The interaction between HRR and global social anxiety was a significant predictor of real-time disengaged coping responses (β = -.21, *B* = -0.03, *SE* = 0.01, *p* = .038; Figure 16), such that HRR was negatively associated with real-time disengaged coping responses at higher levels of global social anxiety (*B* = -0.04, *SE* = 0.01, *p* = .006) but not at lower levels of global anxiety. ROS analyses indicated that the association between HRR and real-time disengaged coping responses was significantly negative at global social anxiety scores above 2.35 (+/-0 SDs; see Figure 17). This interaction explained 3.7% of the variance in real-time disengaged coping responses above and beyond main effects (ΔR^2 = .037), indicating a small-to-medium effect size (Cohen, 1988). No other significant or trend-level interactions were observed.

Supplemental Analyses – Fear of Negative Evaluation Subscale and ANS as the Moderator

Additional analyses were conducted to examine potential differences in interactive effects when the "fear of negative evaluation" (FNE) subscale from the Social Anxiety Scale for

Adolescents (SAS-A) was used in place of the full SAS-A as a measure of global social anxiety in interaction analyses. The two other subscales from the SAS-A – social distress/avoidance in novel situations and social distress/avoidance in general – both include items that assess avoidant behaviors or responses that may overlap with the types of AWD responses that were examined as outcome variables in the present study. As such, exploratory analyses were conducted to determine if the observed pattern of interactive effects changed when social distress and avoidance items were omitted. The resulting findings were similar to those observed in the original analyses utilizing the full SAS-A. The only observed difference was that the interaction between HRR and global social anxiety emerged as a significant predictor of voluntary disengaged responses when the FNE subscale was used. The overall pattern of results from this set of supplemental analyses was consistent with the pattern of interactions described in previous sections. Detailed information about these supplemental analyses can be found in Appendix A. To fully describe interactions between ANS and anxiety variables, we also tested associations between the social anxiety variable initially designated as the moderator and AWD response variables at higher and lower levels of the ANS reactivity variable initially designated as the predictor (i.e., analyses where predictor and moderator variables were switched; Roisman et al., 2012) when significant social anxiety x ANS interactions emerged. Results led to interpretations similar to the interpretation of main results (discussed below) and information about these analyses can be found in Appendix B.

IV. DISCUSSION

High levels of AWD responses are associated with negative psychosocial outcomes across several life domains (Aldao et al., 2010; Compas et al., 2017; Rubin et al., 2009; Rubin & Chronis-Tuscano, 2021; Schäfer et al., 2017) and physiological reactivity to stressors is theorized to play a role in the development and maintenance of AWD response tendencies (Beauchaine, 2001; Gellner et al., 2021; Krypotos et al., 2015; Porges, 2001; 2007). The connection between physiological reactivity and AWD responses may be especially strong for socially anxious individuals (Gellner et al., 2021; Livermore et al., 2021), who are more likely to fear exhibiting heightened physiological arousal in social settings (e.g., through sweating or blushing), report negative interpretations of their physiological arousal (Anderson & Hope, 2009; Asbrand et al., 2020; Siess et al., 2014), and exhibit slower physiological recovery following exposure to stressors (Schmitz et al., 2011; 2013). However, relatively few existing studies have examined associations between measures of physiological reactivity and AWD responses, and even fewer have examined measures of social anxiety as potential moderators of these associations. Moreover, studies utilizing measures of ANS reactivity or child/adolescent samples are scarce. Accordingly, the present study sought to build on previous research in two main ways: 1) by examining associations between measures of ANS reactivity to social stress and AWD responses and 2) by examining social anxiety as a potential moderator of these associations.

While a number of existing studies have examined associations between measures of physiological reactivity and AWD responses, very few, if any, have explicitly attempted to answer the question of whether physiological reactivity underlies AWD responses specifically. As previously noted, this is surprising given the prevalence of studies examining associations between physiological responses and internalizing symptoms as well as prosocial and externalizing behaviors (Beauchaine et al., 2013; 2019; Fanti et al., 2019; Graziano & Derefinko, 2013; Hastings & Miller, 2014; Hinnant et al., 2016b; Murray-Close et al., 2014; Portnoy & Farrington, 2015). The present study sought to address this gap in the literature by examining associations between four commonly-used measures of ANS reactivity to a peer-evaluative stress task and four measures of AWD responses. Furthermore, the present study extended existing research by testing whether associations between measures of ANS reactivity and AWD responses vary as a function of early adolescents' social anxiety symptoms. To our knowledge, the present study is the first to examine social anxiety as a potential moderator of these associations and our results are likely to inform future theoretical work and intervention efforts if replicated.

Overall, support for hypotheses about direct associations between measures of ANS reactivity and AWD responses was mixed and inconsistent. As described in previous sections, findings from the extant literature suggest that SCLR and HRR to social stress may be positively associated with AWD responses, though contrasting evidence also exists, and no previous study has examined associations between HRR and AWD responses among children or adolescents. Additionally, previous studies have found that RSAR is generally unrelated to measures of AWD responses among children and adolescents, while studies of PEPR as a predictor of AWD responses among participants of any age are extremely scarce. Accordingly, we hypothesized that SCLR (hypothesis 1) and HRR (hypothesis 2) would be positively associated with all measures of AWD responses while RSAR would be unrelated to all AWD response measures (hypothesis 3).

In the present study, SCLR was positively associated with real-time disengaged coping responses at a non-significant trend level while HRR was negatively associated with real-time disengaged coping responses at a non-significant trend level. This suggests that BIS-mediated increases in SNS arousal (reflected by higher levels of SCLR) and lower overall increases in arousal (i.e., lower HRR) in response to social stress may underlie specific AWD responses measured in the same context as physiological arousal. However, SCLR and HRR to social stress appear to be unrelated to observed behavior in a laboratory context as well as global measures of AWD responses (i.e., measures that assess AWD responses outside of the laboratory environment). Thus, support for hypothesis 1 is limited while results from the present study either do not support hypothesis 2 or contrast with the hypothesis.

As expected according to hypothesis 3, RSAR was unrelated to all measures of AWD responses. Lastly, while analyses involving PEPR were considered exploratory, we found that PEPR was negatively associated with observed social disengagement. This suggests that a lack of β-adrenergic activity (and potentially low BAS activity) in response to social stressors may drive real-time social disengagement by undermining early adolescents' ability or motivation to actively engage with and respond to the social stressor. Accordingly, ANS reactivity to social stress appears to be largely unrelated to measures of AWD responses and, contrary to hypotheses, lower ANS reactivity may actually underlie higher levels of AWD responses in some cases.

Intriguingly, we found that significant and trend-level associations between measures of ANS reactivity and AWD responses only emerged in models using laboratory-based assessments of AWD responses (i.e., observed social disengagement and real-time disengaged coping). Indeed, coherence between ANS reactivity and AWD response variables appeared to be stronger when ANS and AWD responses were measured in the same context as opposed to across contexts, consistent with response coherence models of emotion (Evers et al., 2014; Hollenstein & Lanteigne, 2014). However, these findings were relatively sparse and measures of ANS reactivity were largely unrelated to AWD response measures highlighting the importance of studies examining moderating variables such as measures of social anxiety.

While results from the present study differed to some degree across interactive analyses, a detectable pattern of interactions emerged. Contrary to hypotheses, we found that associations between ANS reactivity and AWD response variables were either negative or non-significant at higher levels of social anxiety and positive or non-significant at lower levels of social anxiety. For example, in Figure 7, the association between RSAR and teacher-reported withdrawn behavior is positive at lower levels of context-specific social anxiety and non-significant at higher levels of context-specific social anxiety. Similarly, in Figure 8, the association between RSAR and real-time disengaged coping responses is negative at higher levels of global social anxiety and positive (at a non-significant trend level) at lower levels of global social anxiety.

Findings from the present study suggest that higher levels of ANS reactivity to peer-evaluative stress may actually be protective or adaptive for early adolescents who report higher levels of social anxiety insofar as higher ANS reactivity is related to lower levels of AWD responses in some cases. In contrast, higher levels of ANS reactivity may be relatively maladaptive and promote or facilitate AWD responses among early adolescents who report lower levels of social anxiety. These findings are somewhat surprising, given the evidence and arguments outlined in psychophysiological theories such as those developed by Porges (2001; 2007) and Beauchaine (2001). These theories posit that increased physiological arousal, particularly SNS-mediated arousal, in response to social stressors facilitates defensive responses such as avoidance and other AWD responses. In addition, the design and aims of a variety of intervention programs for anxious youth (including socially anxious youth) appear to be based, in part, on the assumption that higher levels of physiological reactivity to social stress are particularly maladaptive or problematic for anxious youth and that children and teens can reduce their anxiety symptoms and anxiety-related behaviors (e.g., avoidance) by down-regulating their physiological reactivity to social stressors. While this assumption is not explicitly stated in most intervention programs or curricula, the emphasis placed on awareness of physiological signals and arousal reduction techniques suggests an underlying belief or assumption that physiological reactivity is maladaptive for anxious/socially anxious youth.

Furthermore, while the present study found a number of significant or trend-level interactions and a relatively consistent overall pattern of effects, social anxiety did not moderate associations between measures of ANS reactivity and AWD responses in the majority of models. Additionally, ROS analyses revealed that only a subset of conditional slopes from interaction models became significantly positive or negative within the range of realistic values on a given measure of social anxiety. These results further challenge the notion that physiological reactivity plays a particularly important role in driving or shaping AWD responses among socially anxious children and teens. Overall, it appears that the association between ANS reactivity to peer-evaluative stress and AWD responses varies as a function of early adolescents' social anxiety symptoms only in some cases, and, when it does vary, ANS reactivity is either negatively associated with or unrelated to AWD responses among early adolescents who report higher levels of social anxiety.

Although the findings described above are contrary to our hypotheses, there are a variety of plausible explanations for the results. For example, socially anxious youth and their less anxious counterparts likely have different default, automatic, or habitual responses to social stressors and the extent to which autonomic reactivity underlies AWD responses may depend, to some degree, on a person's default or habitual way of responding to social stressors. This is supported by evidence that AWD responses such as avoidance often become the default behavioral pattern for socially anxious individuals in stressful contexts or social situations (see

Arnaudova et al., 2017 and Ball & Gunaydin, 2022 for reviews). These default or habitual response patterns may be shaped or driven by numerous factors such as the tendency for socially anxious individuals to appraise neutral and negative situations as more threatening than their non-anxious counterparts and to display increased automatic avoidance tendencies (i.e., the unconscious priming of avoidant responses; Arnaudova et al., 2017; Ball & Gunaydin, 2022). In addition, socially anxious individuals have a harder time regulating avoidance behaviors due to reduced or dysfunctional activity in brain regions associated with top-down control (i.e., regulation of attention, emotion, and behavior; Arnaudova et al., 2017). The combination of increased threat appraisal, increased automatic avoidance tendencies, and reduced regulation of avoidance behaviors may promote frequent, repetitive, and chronic use of AWD responses, ultimately leading to the development of a default or habitual pattern of behaviors that consists primarily of AWD responses.

Further evidence for the notion that socially anxious and non-anxious youth differ in their default or habitual responses to social stressors can be found in the DSM-V (American Psychiatric Association, 2013). Avoidance of social situations is part of the diagnostic criteria for Social Anxiety Disorder which suggests that many individuals with clinical levels of social anxiety habitually avoid anxiety-producing social situations, even if it interferes with their functioning (e.g., at work, with friends). Findings from the present study also support the idea that socially anxious youth tend to respond to social stress with AWD responses, as global social anxiety was positively associated with observed social disengagement (r = .21) and voluntary disengaged coping responses (r = .50).

In contrast to their socially anxious counterparts, non-anxious youth may exhibit a default pattern of responses to social situations that consists of relatively active and engaged responses (e.g., problem-solving, prosocial behavior, frequent interactions with others). This is not to say that socially anxious youth are incapable of utilizing these types of responses or that non-anxious individuals never avoid social situations; rather, the evidence suggests that the tendency of socially anxious youth is to avoid or withdraw from social situations (i.e., exhibit or utilize more AWD responses) while the tendency of non-anxious youth is to engage with others to a greater degree than their socially anxious peers (Aldao et al., 2010; Compas et al., 2017; Schäfer et al., 2017). Social interaction and connection with others are fundamental human needs and motivations (Baumeister & Leary, 1995). As such, it can be argued that the overarching default pattern of responses for humans in non-threatening social situations is to engage with others rather than avoid or withdraw from them or from the situation altogether. However, individual differences in the ways in which people interpret neutral and negative situations, react to possible threats or stressors at an automatic or unconscious level (potentially including physiological reactivity), and regulate their attention, emotion, and behaviors – among many other contributing factors – shape the way in which this overarching default pattern of responses manifests on a person-by-person basis. For example, the default pattern of responses for a person with a predisposition towards increased threat appraisal, increased automatic avoidance tendencies, and reduced regulation of avoidance behaviors is likely to shift from a pattern of engaging with others and approaching social situations to a pattern of cautiously entering into and navigating social situations as well as potentially avoiding or withdrawing from interactions with others.

Findings from the present study are more interpretable when default responses are considered in conjunction with the dual mode social information processing (dmSIP) model. As described in previous sections, the dmSIP posits that cognitive and behavioral responses are dictated by two different modes of processing: an automatic mode and a reflective mode. The automatic mode utilizes a database of contingencies drawn from previous experiences to facilitate quick, reflexive responses to a situation based on a brief yet incomplete appraisal of the situation (a low-resolution picture of the situation; Verhoef et al., 2022). In contrast, the reflective mode facilitates a deeper and more comprehensive appraisal of a given situation and helps a person think through their options and make an informed decision about how they should respond. In the dmSIP model, physiological arousal/reactivity serves as the mechanism by which a person switches between automatic and reflective modes of processing, such that the automatic mode typically dictates cognitive and behavioral responses in non-stressful or highly stressful contexts (which may elicit hypo-arousal/hypo-reactivity and hyper-arousal/hyper-reactivity, respectively) and the reflective mode dictates responses in moderately stressful contexts.

When applied to the present study, the dmSIP model suggests that socially anxious early adolescents who exhibit low or blunted ANS reactivity to social stressors may be operating from an automatic mode of processing. This mode of processing would likely facilitate or promote higher levels of AWD responses given that AWD responses are often the default or automatic pattern of responding for socially anxious individuals. However, higher levels of ANS reactivity may shift socially anxious individuals out of an automatic mode of processing and into a reflective mode of processing, allowing them to consider cognitive and behavioral responses that differ from their default pattern of AWD responses (e.g., engaged or problem-focused responses). This helps to explain why, in some cases, ANS reactivity was negatively associated with AWD responses among early adolescents who reported higher levels of social anxiety in the present study.

The dmSIP and the notion of default behavioral patterns also apply to findings from the present study involving early adolescents who reported lower levels of social anxiety. In contrast to their highly anxious counterparts, the default or automatic pattern of responding for individuals who report lower levels of social anxiety likely involves relatively low levels of AWD responses and higher levels of engaged responses (e.g., problem-solving, emotion-regulation, cognitive restructuring; Aldao et al., 2010). As such, the cognitive-behavioral responses of non-anxious early adolescents who exhibit lower ANS reactivity to social stressors may be driven by an automatic mode of processing that promotes relatively engaged responses as opposed to AWD responses. However, as ANS reactivity levels increase, these individuals may also shift into a reflective mode of processing that helps them to consider cognitive and behavioral responses that differ from their default or habitual responses. In addition, the heightened arousal and reflective mode of processing may prompt non-anxious early adolescents to attend to potential threat cues in their social environment (e.g., cues that may indicate the potential for social exclusion, rejection, or victimization) that they may not process or attend to when operating from an automatic mode of processing. This may contribute to a broadening of the types of responses that are utilized by non-anxious early adolescents, such that these individuals report or exhibit higher levels of AWD responses as well as engaged responses. These ideas are consistent with the findings that measures of ANS reactivity and AWD responses were positively associated, in some cases, among early adolescents who reported lower levels of social anxiety in the present study.

Strengths, Limitations, and Future Directions

The present study has multiple strengths and unique contributions to the existing literature as well as several potential limitations. A key strength is the multimethod and multi-measure design which allowed for a detailed examination of associations between measures of ANS reactivity, social anxiety, and AWD responses within and across contexts. The present study utilized physiological, observational, self-report, and teacher-report measures, some of which assessed early adolescents' responses or behaviors in a laboratory context (i.e., ANS reactivity, observed social disengagement, self-reported disengaged responses, and self-reported context-specific social anxiety) while others assessed responses or behaviors outside of the laboratory (i.e., teacher-reported withdrawn behavior at school, self-reported voluntary disengaged coping responses to peer stress, and global social anxiety). As a result, we were able to test whether direct associations and interactive effects differed when physiological, emotional, and cognitive-behavioral responses were assessed in the same context (e.g., the association between SCLR and observed social disengagement moderated by context-specific social anxiety) or across contexts (e.g., the association between SCLR and teacher-reported withdrawn behavior moderated by global social anxiety).

While the present study offers a relatively comprehensive examination of associations between measures of ANS reactivity, social anxiety, and AWD responses, there are several promising avenues for future research that should also be explored. First, the role of cognitive variables in predicting and shaping AWD responses is unclear and specific cognitive variables may be stronger or more consistent predictors of AWD responses than measures of physiological reactivity. For example, increased threat appraisal is associated with higher levels of avoidance and is speculated to play a role in the development of persistent or excessive avoidance among individuals with clinical levels of anxiety (Ball & Gunaydin, 2022). As such, an important future direction will be to continue to build on existing research by examining associations between various cognitive measures (e.g., threat appraisal) and measures of AWD responses. Furthermore, studies with larger sample sizes may have sufficient power to test three-way interactions between physiological reactivity, cognitive variables, and social anxiety as predictors of AWD responses. Previous research has found evidence for subgroups of socially anxious youth (Gazelle, 2008; Kaeppler & Erath, 2017) and it is possible that heightened physiological reactivity to social stress only predicts higher levels of AWD responses among socially anxious youth who exhibit increased threat appraisal, for example. While the present study found that higher levels of ANS reactivity were protective or adaptive for socially anxious youth in some cases, this effect may be further qualified by cognitive variables that were not assessed in this study.

Another important future direction will be to test associations between measures of physiological reactivity not utilized in the present study and AWD responses to social stress, as well as to examine whether these associations are moderated by measures of social anxiety or anxiety more broadly. We were able to test associations between four well-validated measures of ANS reactivity to social stress and four measures of AWD responses. However, there are other psychophysiological measures that would provide an interesting test of study hypotheses if used in place of measures of ANS reactivity. For example, salivary alpha amylase and cortisol samples can be used to assess different parts of the human stress response: namely, sympathetic-adrenal-medullar (SAM) axis activity (which is involved in the initial phase of the stress response) and hypothalamic-pituitary-adrenal (HPA) axis activity (which is involved in the slower secondary phase of the stress response), respectively (Beauchaine, 2001; Godoy et al., 2018; Porges, 2001; 2007). By measuring SAM and HPA axis responses to social stress, potentially in conjunction with measures of ANS reactivity, future studies will be able to test whether the pattern of effects differs across psychophysiological measures or across different phases of the human stress response (i.e., the initial phase and the secondary phase). While more immediate and rapid physiological responses to stressors may be protective or adaptive among socially anxious individuals in some cases, slower and longer-lasting physiological responses such as those triggered by the HPA axis may influence AWD responses in unique ways as HPA axis activity and cortisol exert effects on neurobiological systems and behavioral responses that differ from those produced by SAM axis and ANS activity (Godoy et al., 2018).

It is also important to note that the physiological responses elicited by the peer-evaluative stress task used in the present study may differ from the responses elicited by more threatening or anxiety-provoking social stressors as well as non-social stress tasks such as mental arithmetic tasks. For example, while early adolescents exhibited moderate-to-high levels of physiological reactivity to our peer-evaluative stress task, other tasks such as the TSST may elicit larger or more extreme physiological responses which may be related to AWD responses in unique ways. Consistent with the dual-mode SIP model described above, associations between physiological arousal or reactivity and AWD responses may prove to be nonlinear and these nonlinear associations may also differ as a function of early adolescents' levels of social anxiety. Accordingly, future research should incorporate analyses examining nonlinear effects of physiological arousal and/or reactivity on AWD responses.

Measures of baseline or anticipatory arousal would also be relevant to the study of AWD responses, as there is evidence that altered baseline ANS activity (e.g., reduced resting RSA) is associated with poorer regulation of emotions and behavior (Beauchaine, 2015) as well as social anxiety symptoms (Siess et al., 2014). Likewise, the effects of physiological reactivity to social stress on AWD responses may be conditional upon baseline levels of arousal. As such, an intriguing line of future research would involve the examination of associations between measures of psychophysiological activity that reflect different phases of the overall stress response (potentially assessed during a laboratory protocol that includes a variety of different types of stressors), cognitive variables such as threat appraisal, measures of social anxiety, and AWD responses. This would allow for a particularly thorough examination of direct associations and interactions between several types of variables that are theorized to underlie and influence AWD responses.

While the present study advanced the existing literature in a variety of ways, there are several limitations that future research may be able to address. First, analyses in the present study were cross-sectional and conclusions about the direction of associations and/or causality cannot be made. Although there is a strong conceptual argument for the direction of effects described in the present study, it is also possible that AWD responses shape physiological responses to social stressors or that associations between measures of physiological reactivity and AWD responses are reciprocal. For example, AWD responses may reduce physiological arousal among highly anxious youth as they are able to avoid or withdraw from anxiety-provoking stressors that may have elicited high levels of anticipatory arousal (Repetti, 1992). In contrast, less anxious youth might experience more distress and less relief upon using AWD responses, thereby increasing physiological arousal, given that they are less likely to be anxious about the stressor in the first place. Accordingly, intensive longitudinal studies will be needed to clarify the nature of associations between measures of ANS reactivity, social anxiety, and AWD responses as well as the role that ANS reactivity and social anxiety play in the development of AWD responses over time.

Second, given that the term "AWD responses" refers to a range of interrelated yet distinct cognitive-behavioral responses, the present study likely did not fully capture or measure all types and/or aspects of AWD responses. Indeed, while the present study utilized four reliable measures of AWD responses that cut across contexts, there are myriad assessments that would be relevant to future studies examining AWD responses. For example, future studies utilizing measures of experiential avoidance (e.g., the Acceptance and Fusion Questionnaire for Youth; Greco et al., 2008) or measures that examine unique aspects of avoidance/AWD responses (e.g., the Multidimensional Experiential Avoidance Questionnaire which assesses behavioral avoidance, distress aversion, procrastination, distraction and suppression, repression and denial, and distress endurance; Gámez et al., 2011) would be highly informative and would help to further elucidate the ways in which physiological responses underlie and shape AWD responses.

The present study also included data from a community sample and findings may not generalize to early adolescents with clinical levels of social anxiety. However, mean global social anxiety scores in the present study (as measured by the SAS-A) were slightly higher than mean scores reported in previous studies that utilized data from community samples (e.g., Epkins, 2002; Flanagan et al., 2008; Inderbitzen-Nolan & Walters, 2000; Morris & Masia, 1998). In addition, 29.5% of early adolescents in the present study reported global social anxiety scores above the suggested clinical threshold of 50 on the SAS-A which is used to identify children and adolescents who are likely to develop clinically significant levels of social anxiety (Olivares et al., 2002). Thus, a wide range of social anxiety levels are represented in the present study which increases confidence in the generalizability of our findings.

Lastly, teachers' ratings of early adolescents' withdrawn behaviors were only obtained for approximately 80% of the sample in the present study thereby reducing analytic power. However, significant results emerged across several sets of analyses which indicates that the sample provided sufficient power to detect small-to-medium effects. Additionally, future studies may wish to utilize parent or peer ratings of early adolescents' withdrawn behaviors as well as teacher, parent, or peer ratings of various other types of AWD responses (e.g., experiential avoidance, task avoidance, social avoidance, etc.).

Clinical Implications

To our knowledge, the present study is one of the first to explicitly test whether physiological reactivity to social stress underlies AWD responses among early adolescents and to examine measures of social anxiety as potential moderators of the association between physiological reactivity and AWD responses. If findings from the present study are replicated, they may inform clinical and intervention efforts. As previously mentioned, numerous intervention programs and curricula designed to help anxious children and teens teach youth to be more aware of physiological signals and emphasize the use of arousal reduction techniques as a means of reducing anxiety symptoms and anxiety-related behaviors (e.g., avoidance). This includes well-known and widely used, evidence-based programs and curricula such as the Fun FRIENDS curriculum (Barret, 2007a; 2007b), Coping Cat online training program (Flannery-Schroeder & Kendall, 1996), and the neurofeedback videogame intervention MindLight (Schoneveld et al., 2016). However, findings from the present study do not support the notion that higher levels of arousal and physiological reactivity to stressors are problematic for socially anxious youth (insofar as higher physiological reactivity increases anxiety-related behaviors and AWD responses). In fact, results seem to suggest that higher levels of physiological reactivity to social stress may actually be adaptive and protective for socially anxious youth in some cases. Thus, the emphasis on reducing physiological reactivity to social stressors, particularly among socially anxious youth, may be somewhat unwarranted and potentially even counterproductive.

Findings from the present study also challenge the notion that higher levels of arousal and physiological reactivity interfere with optimal social performance in stressful contexts and promote maladaptive responses such as AWD responses among socially anxious youth (Stein, 2004). Furthermore, previous studies have found that higher levels of ANS reactivity may facilitate lower levels of problematic behaviors for early adolescents who report high levels of social anxiety or social stress (e.g., peer victimization), while lower levels of reactivity may contribute to poorer socioemotional functioning (e.g., Erath et al., 2018; Gregson et al., 2014; Kaeppler & Erath, 2017). This suggests that higher levels of physiological reactivity, at least within the ANS, may be adaptive and improve socioemotional functioning by supporting reflective processing, particularly among youth who report high levels of social anxiety or social stress.

Ultimately, intervention programs and curricula as well as other treatments for socially anxious youth may benefit from a change in the way in which physiological arousal/reactivity is viewed. While attempts to regulate anticipatory arousal *prior to* entering an anxiety-provoking social situation may prove to be helpful in reducing social anxiety and decreasing avoidance of the situation, there is good reason to believe that attempts to regulate arousal and attend to physiological signals *while actively navigating* a social situation may undermine social functioning and promote AWD responses. For example, our findings suggest that attempts to regulate aspects of arousal related to ANS measures included in the present study (e.g., heart rate) are unlikely to improve reflective processing or adaptive engagement for socially anxious youth. Cognitive models of social anxiety also posit that socially anxious individuals tend to shift their attention away from others and towards their own physiological sensations, emotions, and cognitions in anxiety-provoking situations (Clark & Wells, 1995; Rapee & Heimberg, 1997). In addition, attentional control – which includes the ability to shift one's attention between internal and external cues – is an important executive function that is often reduced in socially anxious individuals (Eysenck et al., 2007).

Interventions and treatments that teach socially anxious youth to pay attention to physiological sensations and attempt to regulate their arousal *while actively navigating* an anxiety-provoking situation may inadvertently reinforce the tendency for socially anxious youth to attend to themselves rather than attending to and engaging with others. Likewise, these interventions may teach socially anxious youth to reduce the relatively high levels of physiological reactivity that the present study and previous studies have found to be adaptive for youth who report higher levels of social anxiety or social stress. Thus, instead of teaching socially anxious children and teens to attend to bodily signals and regulate their arousal in anxiety-provoking situations, intervention programs and curricula may be better served teaching socially anxious youth how to shift their focus away from themselves and their arousal in social situations and towards external cues that help them engage with others or with the task at hand. However, future research will be needed before firm conclusions can be drawn about the role of physiological arousal or reactivity in driving or shaping AWD responses among both socially anxious and non-anxious youth.

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Table 1

Primary variables included in analyses (not including control variables)

Predictors	**Moderators**	**Outcomes**
RSAR	Context-specific social anxiety	Observed social disengagement
SCLR	Global social anxiety	Teacher-reported withdrawn behavior
PEPR	*Fear of negative evaluation	Real-time disengaged coping responses
HRR		Voluntary disengaged coping responses

Note: RSAR = respiratory sinus arrhythmia reactivity to the peer-evaluative stress task (units = ln[ms^2]), SCLR = skin conductance level reactivity to the peer-evaluative stress task (units = μS), PEPR = pre-ejection period reactivity to the peer-evaluative stress task (unit = ms), and HRR = heart rate reactivity to the peer-evaluative stress task (unit = bpm). *Analyses including fear of negative evaluation as a moderator are included in Appendix A.

Table 2

Descriptive statistics and correlations between study variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Sex	-														
2. Race	.06	-													
3. Age	-.07	-.46**	-												
4. Income	.02	-.52**	.25**	-											
5. RSAR	.23*	-.12	.12	.25**	-										
6. SCLR	-.17^{+}	-.31**	.03	.18^{+}	-.03	-									
7. PEPR	.20*	.13	-.13	-.09	.14	-.19^{+}	-								
8. HRR	.15	-.17^{+}	.23*	.23*	.71**	-.04	.29**	-							
9. CSSA	.12	.17^{+}	.07	-.02	.15^{+}	-.01	.09	.13	-						
10. GSA	.19*	.07	-.17^{+}	-.17^{+}	-.17^{+}	-.07	.05	-.09	.13	-					
11. FNE	.14	-.06	-.10	-.11	-.16^{+}	.03	.03	-.03	.10	.92**	-				
12. SocD	-.15	.19*	-.02	-.27**	-.06	-.11	-.15	-.03	-.09	.21*	.15^{+}	-			
13. Withd	-.16	-.04	.06	-.06	.03	-.08	-.08	-.07	-.05	.04	.01	.29**	-		
14. RTdis	-.14	-.03	.09	-.02	-.12	.19^{+}	-.15	-.17^{+}	.00	-.01	.05	-.03	-.05	-	
15. VDis	.11	.13	-.15	-.24**	-.13	-.11	.06	-.03	-.08	.50**	.40**	.25**	.01	-.13	-
Mean	50%	35%	.61	4.13	.00	.00	.00	.00	2.77	2.38	2.23	2.85	.25	.39	2.23
SD	.50	.48	.49	1.55	.77	3.09	6.73	7.37	1.12	.81	.95	1.19	.39	.62	.51
Skew	.02	.64	-.46	-.45	.46	.70	1.64	.99	.40	.35	.63	.10	1.97	1.34	.00
N	123	123	123	119	119	108	113	115	120	122	122	115	99	112	122

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = ln[ms^2]); SCLR = skin conductance level reactivity (units = μS); PEPR = pre-ejection period reactivity (unit = ms); HRR = heart rate reactivity (unit = bpm); CSSA = context-specific social anxiety; GSA = global social anxiety; FNE = fear of negative evaluation subscale from the Social Anxiety Scale for Adolescents; SocD = observed social disengagement during the peer evaluation period; Withd = teacher-reported withdrawn behavior; RTdis = real-time disengaged coping responses; VDis = voluntary disengaged coping responses as measured by the Responses to Stress Questionnaire (RSQ); $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

Table 3

Regression analyses examining associations between respiratory sinus arrhythmia reactivity, skin conductance level reactivity, and AWD outcome variables moderated by context-specific social anxiety and global social anxiety

	Observed social disengagement				**Teacher-reported withdrawn behavior**			
	CSSA		**GSA**		**CSSA**		**GSA**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-.21 (.07)	-.27**	-.18 (.07)	-.24*	-	-	-	-
RSAR	.03 (.15)	.02	.03 (.14)	.02	.02 (.05)	.04	.02 (.05)	.03
SCLR	-.02 (.04)	-.05	-.02 (.04)	-.05	-.01 (.01)	-.07	-.01 (.01)	-.07
Anxiety	-.10 (.10)	-.10	.26 (.13)	.18*	-.02 (.04)	-.06	.02 (.05)	.04
	R^2 = 8.4%		R^2 = 10.7%		R^2 = 1.0%		R^2 = 0.8%	
Interactions								
RSAR x Anxiety	-.08 (.14)	-.06	-.07 (.20)	-.04	-.12 (.05)	-.26*	-.02 (.07)	-.04
SCLR x Anxiety	-.06 (.04)	-.17$^+$	.09 (.04)	.18*	-.02 (.01)$^+$	-.19$^+$	.00 (.02)	-.02
	ΔR^2 = 2.5%		ΔR^2 = 3.5%		ΔR^2 = 7.7%		ΔR^2 = 0.2%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = ln[ms^2]); SCLR = skin conductance level reactivity (units = μS); CSSA = context-specific social anxiety; GSA = global social anxiety; $^+p < .10$, $*p < .05$, $**p < .01$

Table 4

Regression analyses examining associations between respiratory sinus arrhythmia reactivity, skin conductance level reactivity, and AWD outcome variables moderated by context-specific social anxiety and global social anxiety

	Real-time disengaged coping responses				**Voluntary disengaged coping responses**			
	CSSA		**GSA**		**CSSA**		**GSA**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-	-	-	-	-.07 (.03)	-.22*	-.05 (.03)	$-.16^{+}$
RSAR	-.10 (.07)	-.12	-.10 (.07)	-.12	-.04 (.06)	-.06	-.01 (.05)	-.01
SCLR	.04 (.02)	$.18^{+}$	.04 (.02)	$.18^{+}$	-.01 (.02)	-.07	-.01 (.01)	-.05
Anxiety	.01 (.05)	.02	-.01 (.07)	-.01	-.04 (.04)	-.08	.29 (.05)	.46***
	R^2 = 4.8%		R^2 = 4.7%		R^2 = 7.7%		R^2 = 27.4%	
Interactions								
RSAR x Anxiety	.03 (.07)	.04	-.28 (.10)	-.27**	-.04 (.06)	-.06	-.05 (.07)	-.05
SCLR x Anxiety	-.04 (.02)	-.22*	-.01 (.02)	-.03	.02 (.02)	.12	.02 (.02)	.09
	ΔR^2 = 4.9%		ΔR^2 = 6.3%		ΔR^2 = 1.8%		ΔR^2 = 0.9%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = $\ln[ms^2]$); SCLR = skin conductance level reactivity (units = μS); CSSA = context-specific social anxiety; GSA = global social anxiety; $^{+}p < .10$, $*p < .05$, $**p < .01$

Table 5

Regression analyses examining associations between respiratory sinus arrhythmia reactivity, pre-ejection period reactivity, and AWD outcome variables moderated by context-specific social anxiety and global social anxiety

	Observed social disengagement				**Teacher-reported withdrawn behavior**			
	CSSA		**GSA**		**CSSA**		**GSA**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-.23 (.07)	-.30**	-.21 (.07)	-.27**	-	-	-	-
RSAR	.08 (.15)	.05	.09 (.14)	.06	.03 (.05)	.06	.03 (.05)	.06
PEPR	-.03 (.02)	-.18*	-.03 (.02)	-.19*	-.01 (.01)	-.09	-.01 (.01)	-.10
Anxiety	-.10 (.10)	-.09	.28 (.13)	.19*	-.02 (.04)	-.05	.03 (.05)	.06
	R^2 = 11.4%		R^2 = 14.0%		R^2 = 1.2%		R^2 = 1.4%	
Interactions								
RSAR x Anxiety	-.02 (.14)	-.02	-.15 (.20)	-.08	-.09 (.05)	-.20*	-.05 (.07)	-.08
PEPR x Anxiety	.00 (.01)	.01	-.00 (.02)	-.01	.00 (.01)	-.06	.00 (.01)	-.01
	ΔR^2 = 0.0%		ΔR^2 = 0.6%		ΔR^2 = 4.2%		ΔR^2 = 0.4%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = ln[ms^2]); PEPR = pre-ejection period reactivity (unit = ms); CSSA = context-specific social anxiety; GSA = global social anxiety; $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

Table 6

Regression analyses examining associations between respiratory sinus arrhythmia reactivity, pre-ejection period reactivity, and AWD outcome variables moderated by context-specific social anxiety and global social anxiety

	Real-time disengaged coping responses				**Voluntary disengaged coping responses**			
	CSSA		**GSA**		**CSSA**		**GSA**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-	-	-	-	-.07 (.03)	-.23*	-.05 (.03)	-.16^{+}
RSAR	-.09 (.08)	-.11	-.09 (.08)	-.11	-.04 (.06)	-.06	-.01 (.05)	-.01
PEPR	-.01 (.01)	.13	-.01 (.01)	-.13	.00 (.01)	.06	.00 (.01)	.03
Anxiety	.01 (.05)	.03	-.02 (.07)	-.02	-.04 (.04)	-.09	.30 (.05)	.47***
	R^2 = 3.1%		R^2 = 3.1%		R^2 = 7.3%		R^2 = 27.2%	
Interactions								
RSAR x Anxiety	.06 (.07)	.09	-.32 (.11)	-.31**	-.05 (.06)	-.09	-.04 (.08)	-.05
PEPR x Anxiety	.00 (.01)	-.04	.00 (.01)	-.01	.01 (.01)	.08	.01 (.01)	.06
	ΔR^2 = 0.9%		ΔR^2 = 8.0%		ΔR^2 = 1.4%		ΔR^2 = 0.6%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = ln[ms^2]); PEPR = pre-ejection period reactivity (unit = ms); CSSA = context-specific social anxiety; GSA = global social anxiety; $^{+}p < .10$, $*p < .05$, $**p < .01$

Table 7

Regression analyses examining associations between heart rate reactivity and AWD outcome variables moderated by context-specific social anxiety and global social anxiety

	Observed social disengagement				**Teacher-reported withdrawn behavior**			
	CSSA		**GSA**		**CSSA**		**GSA**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-.22 (.07)	-.28**	-.20 (.07)	-.25**	-	-	-	-
HRR	.01 (.02)	.05	.01 (.02)	.05	.00 (.01)	-.07	.00 (.01)	-.07
Anxiety	-.11 (.10)	-.10	.26 (.13)	.18*	-.02 (.04)	-.04	.01 (.05)	.03
	R^2 = 8.5%		R^2 = 10.7%		R^2 = 0.7%		R^2 = 0.5%	
Interactions								
HRR x Anxiety	-.02 (.01)	-.11	-.01 (.02)	-.02	-.01 (.01)	$-.18^{+}$	.00 (.01)	-.04
	ΔR^2 = 1.1%		ΔR^2 = 0.0%		ΔR^2 = 3.1%		ΔR^2 = 0.2%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); HRR = heart rate reactivity (unit = bpm); CSSA = context-specific social anxiety; GSA = global social anxiety; $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

Table 8

Regression analyses examining associations between heart rate reactivity variables and AWD outcomes moderated by context-specific social anxiety and global social anxiety

	Real-time disengaged coping responses				**Voluntary disengaged coping responses**			
	CSSA		**GSA**		**CSSA**		**GSA**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-	-	-	-	-.08 (.03)	-.25**	-.06 (.03)	-.17*
HRR	-.01 (.01)	$-.16^{+}$	-.01 (.01)	$-.17^{+}$	.00 (.01)	.04	.00 (.01)	.05
Anxiety	.01 (.05)	.02	-.02 (.07)	-.03	-.04 (.04)	-.09	.30 (.05)	.47***
	R^2 = 2.6%		R^2 = 2.7%		R^2 = 6.7%		R^2 = 27.3%	
Interactions								
HRR x Anxiety	.00 (.01)	.00	-.03 (.01)	-.21*	-.01 (.01)	-.18*	-.01 (.01)	-.13
	ΔR^2 = 0.0%		ΔR^2 = 3.7%		ΔR^2 = 3.1%		ΔR^2 = 1.5%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); HRR = heart rate reactivity (unit = bpm); CSSA = context-specific social anxiety; GSA = global social anxiety; $^{+}p < .10$, $*p < .05$, $**p < .01$

Table 9

Regression analyses examining associations between respiratory sinus arrhythmia reactivity, skin conductance level reactivity, and AWD outcome variables moderated by SAS-A fear of negative evaluation subscale (FNE)

	Observed social disengagement		**Teacher-reported withdrawn behavior**		**Real-time disengaged coping responses**		**Voluntary disengaged coping responses**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-.19 (.07)	-.25**	-	-	-	-	-.06 (.03)	-.18*
RSAR	.02 (.14)	.01	.01 (.05)	.03	-.09 (.07)	-.11	-.01 (.06)	-.02
SCLR	-.02 (.04)	-.06	-.01 (.01)	-.07	.04 (.02)	.18^{+}	-.02 (.02)	-.09
FNE	.18 (.12)	.14	.01 (.04)	.02	.02 (.06)	.03	.21 (.05)	.38***
	R^2 = 9.6%		R^2 = 0.6%		R^2 = 4.9%		R^2 = 21.0%	
Interactions								
RSAR x FNE	-.13 (.16)	-.08	-.03 (.06)	-.05	-.20 (.09)	-.23*	-.06 (.06)	-.09
SCLR x FNE	.08 (.04)	.19*	.00 (.01)	.02	-.01 (.02)	-.04	.02 (.02)	.11
	ΔR^2 = 4.2%		ΔR^2 = 0.3%		ΔR^2 = 5.1%		ΔR^2 = 1.7%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = ln[ms^2]); SCLR = skin conductance level reactivity (units = μS); FNE = fear of negative evaluation subscale from the Social Anxiety Scale for Adolescents; $^{+}p < .10$, $*p < .05$, $**p < .01$

Table 10

Regression analyses examining associations between respiratory sinus arrhythmia reactivity, pre-ejection period reactivity, and AWD outcome variables moderated by SAS-A fear of negative evaluation subscale (FNE)

	Observed social disengagement		**Teacher-reported withdrawn behavior**		**Real-time disengaged coping responses**		**Voluntary disengaged coping responses**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-.22 (.07)	-.29**	-	-	-	-	-.06 (.03)	-.19*
RSAR	.08 (.14)	.05	.03 (.05)	.06	-.08 (.08)	-.10	-.01 (.06)	-.02
PEPR	-.03 (.02)	-.19*	-.01 (.01)	-.10	-.01 (.01)	-.13	.00 (.01)	.04
FNE	.18 (.11)	.14	.01 (.04)	.03	.02 (.06)	.03	.20 (.05)	.38***
	R^2 = 12.6%		R^2 = 1.1%		R^2 = 3.2%		R^2 = 20.3%	
Interactions								
RSAR x FNE	-.20 (.17)	-.12	-.04 (.06)	-.08	-.24 (.09)	-.28**	-.06 (.06)	-.08
PEPR x FNE	-.01 (.01)	-.03	.00 (.01)	.03	.00 (.01)	-.01	.00 (.01)	.00
	ΔR^2 = 1.4%		ΔR^2 = 0.6%		ΔR^2 = 6.6%		ΔR^2 = 0.5%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); RSAR = respiratory sinus arrhythmia reactivity (units = ln[ms^2]); PEPR = pre-ejection period reactivity (unit = ms); FNE = fear of negative evaluation subscale from the Social Anxiety Scale for Adolescents;
$^+p < .10$, $*p < .05$, $**p < .01$

Table 11

Regression analyses examining associations between heart rate reactivity and AWD outcome variables moderated by SAS-A fear of negative evaluation subscale (FNE)

	Observed social disengagement		**Teacher-reported withdrawn behavior**		**Real-time disengaged coping responses**		**Voluntary disengaged coping responses**	
Main effects								
Sex	-	-	-	-	-	-	-	-
Race	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-
Income	-.21 (.07)	-.27**	-	-	-	-	-.07 (.03)	-.20*
HRR	.01 (.02)	.04	.00 (.01)	-.07	-.01 (.01)	$-.16^{+}$	.00 (.01)	.03
FNE	.17 (.12)	.13	.00 (.04)	.00	.02 (.06)	.04	.21 (.04)	.38***
	R^2 = 9.4%		R^2 = 0.5%		R^2 = 2.7%		R^2 = 20.1%	
Interactions								
HRR x FNE	-.01 (.02)	-.04	.00 (.01)	-.06	-.02 (.01)	-.19*	-.02 (.01)	-.20*
	ΔR^2 = 0.1%		ΔR^2 = 0.3%		ΔR^2 = 3.3%		ΔR^2 = 3.6%	

Note: Sex, race/ethnicity, and age are dichotomous variables (Male = 0, Female = 1; non-African American = 0, African American = 1; 5th grade = 0, 6th grade = 1, respectively); HRR = heart rate reactivity (unit = bpm); FNE = fear of negative evaluation subscale from the Social Anxiety Scale for Adolescents; $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

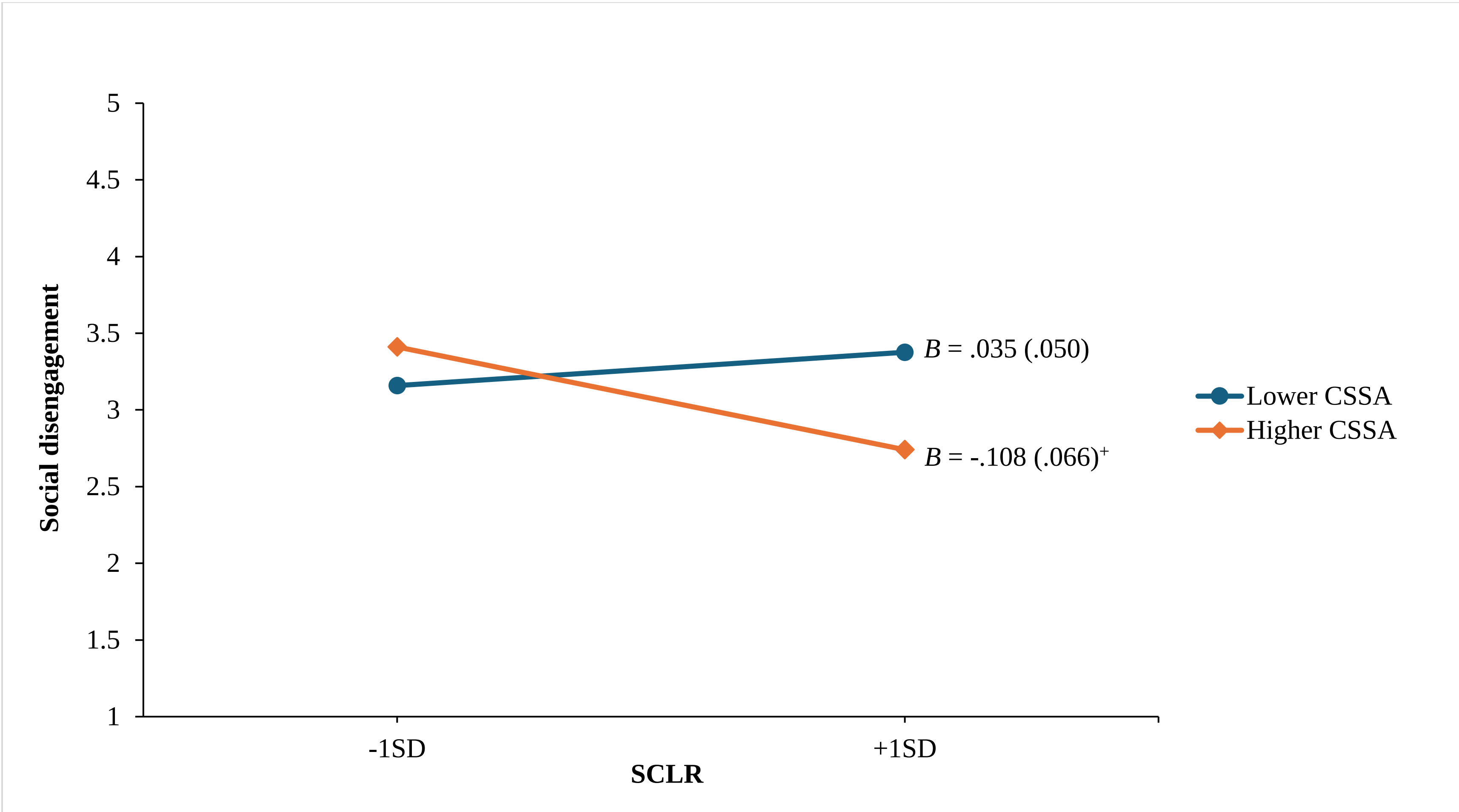

Figure 1. The association between skin conductance level reactivity (SCLR) and observed social disengagement moderated by context-specific social anxiety (CSSA). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

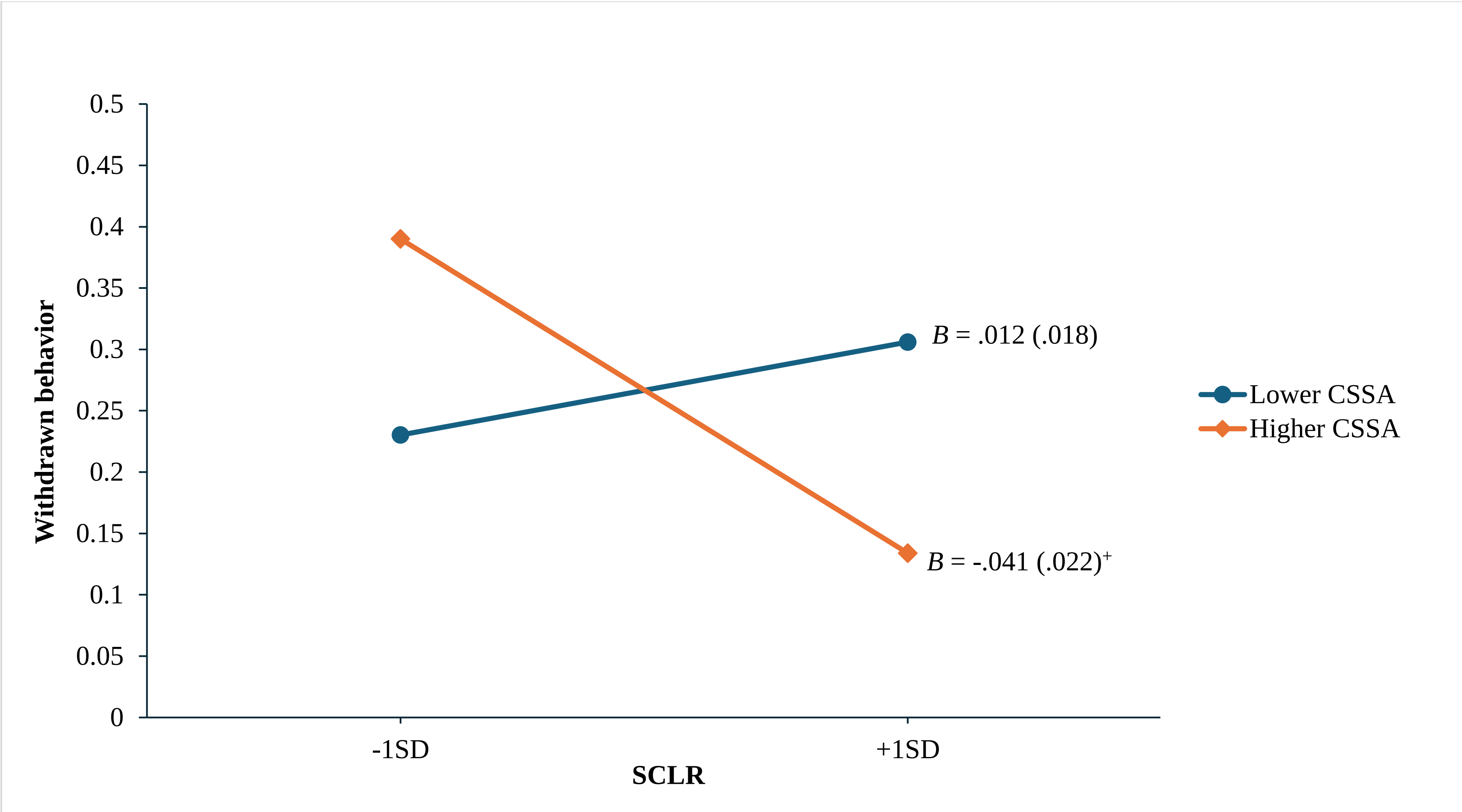

Figure 2. The association between skin conductance level reactivity (SCLR) and teacher-reported withdrawn behavior moderated by context-specific social anxiety (CSSA). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

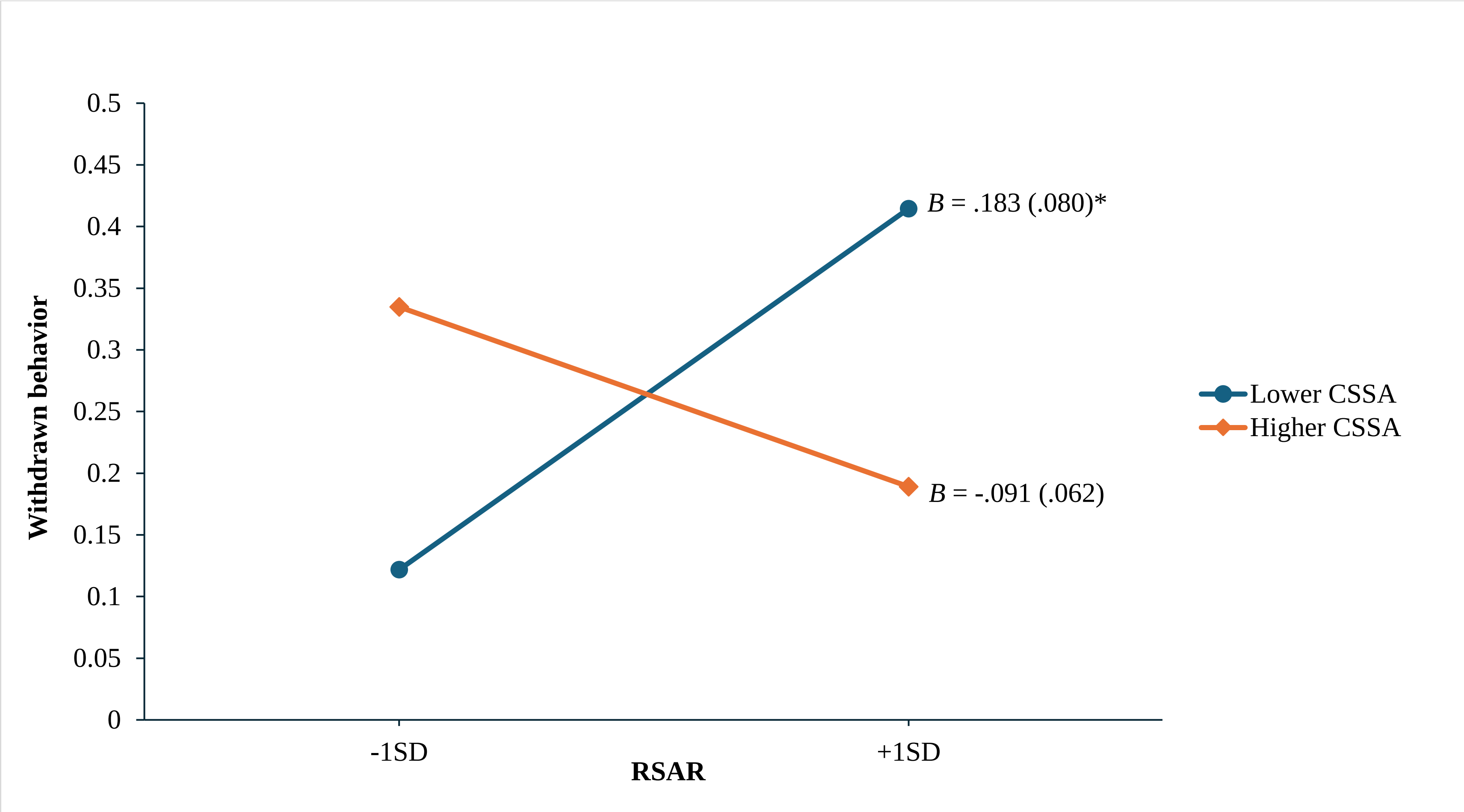

Figure 3. The association between respiratory sinus arrhythmia reactivity (RSAR) and teacher-reported withdrawn behavior moderated by context-specific social anxiety (CSSA) – From the set of models with RSAR and SCLR. $^{+}p < .10$, $*p < .05$, $**p < .01$

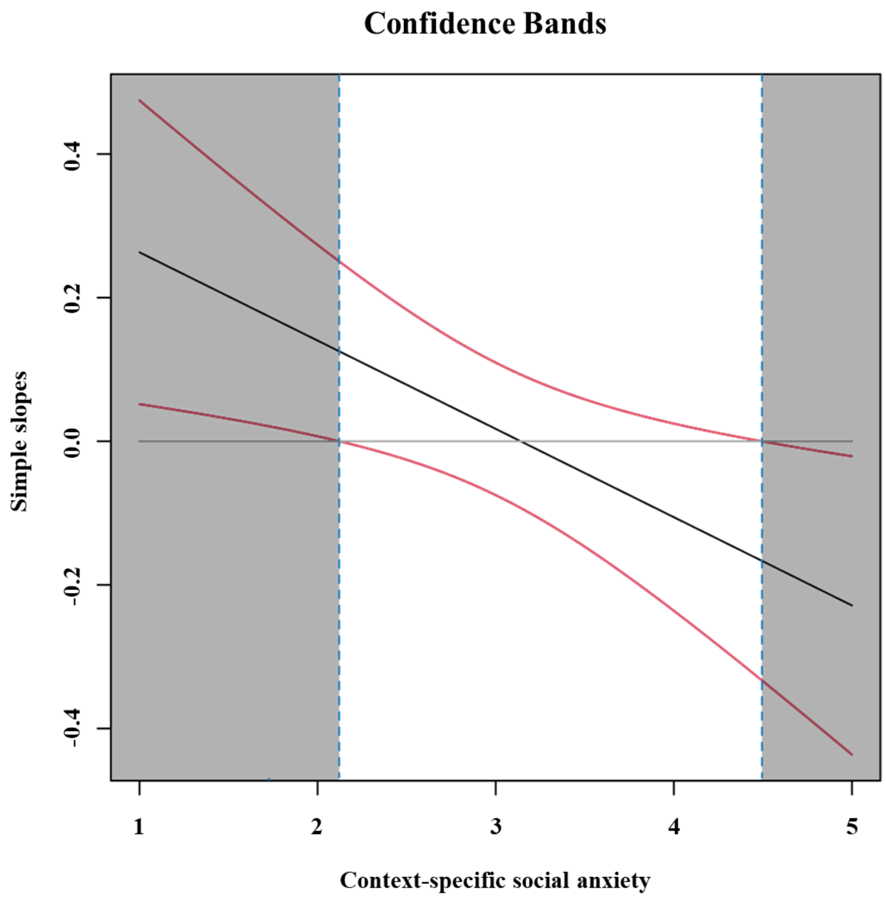

Figure 4. Regions of significance for the interaction between respiratory sinus arrhythmia reactivity (RSAR) and context-specific social anxiety (CSSA) as a predictor of teacher-reported withdrawn behavior. The association between RSAR and teacher-reported withdrawn behavior was significantly positive at context-specific social anxiety scores below 2.12 (-0.6 SDs) and significantly negative at scores above 4.50 (+1.6 SDs).

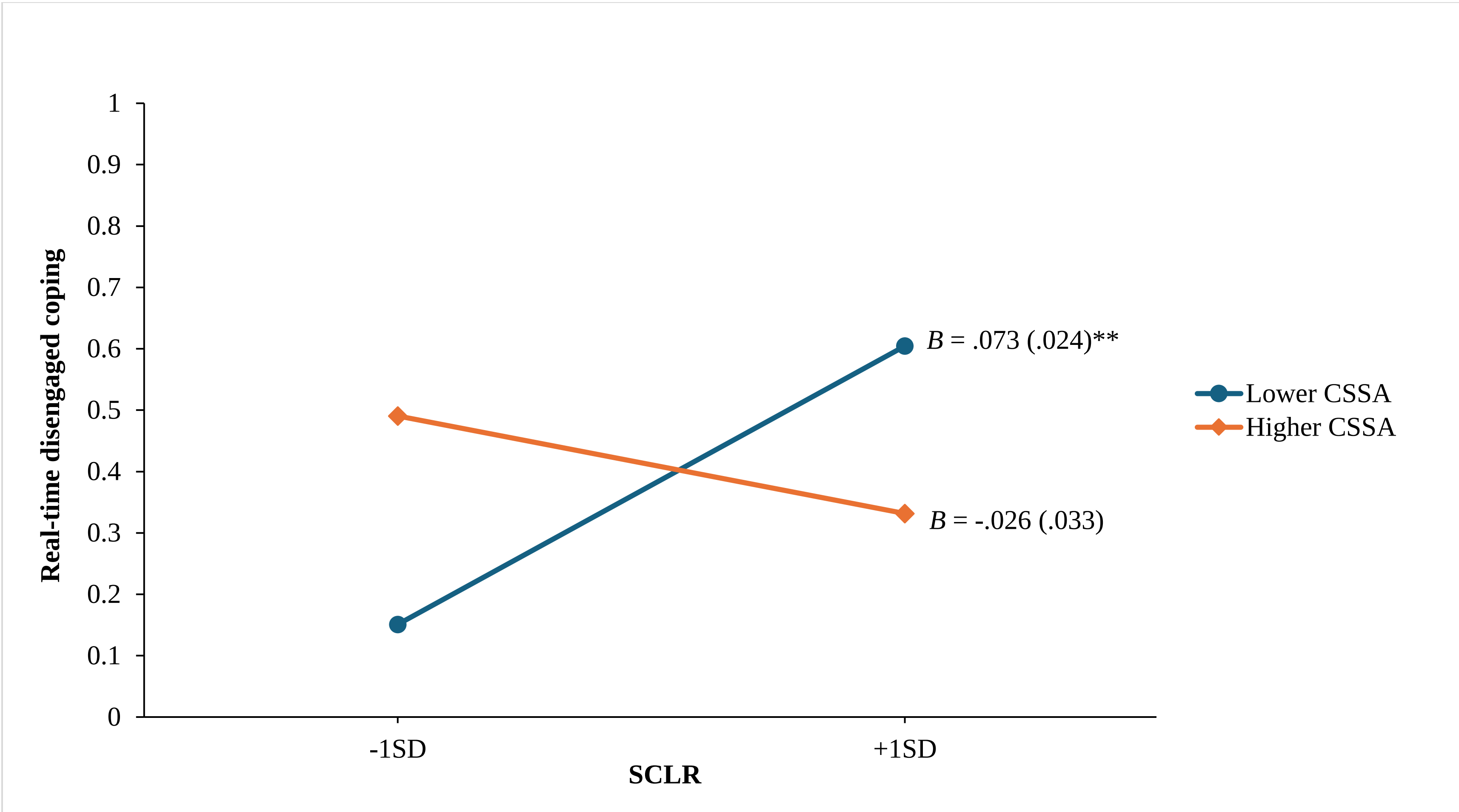

Figure 5. The association between skin conductance level reactivity (SCLR) and real-time disengaged coping responses moderated by context-specific social anxiety (CSSA). $^{+}p < .10$, $*p < .05$, $**p < .01$

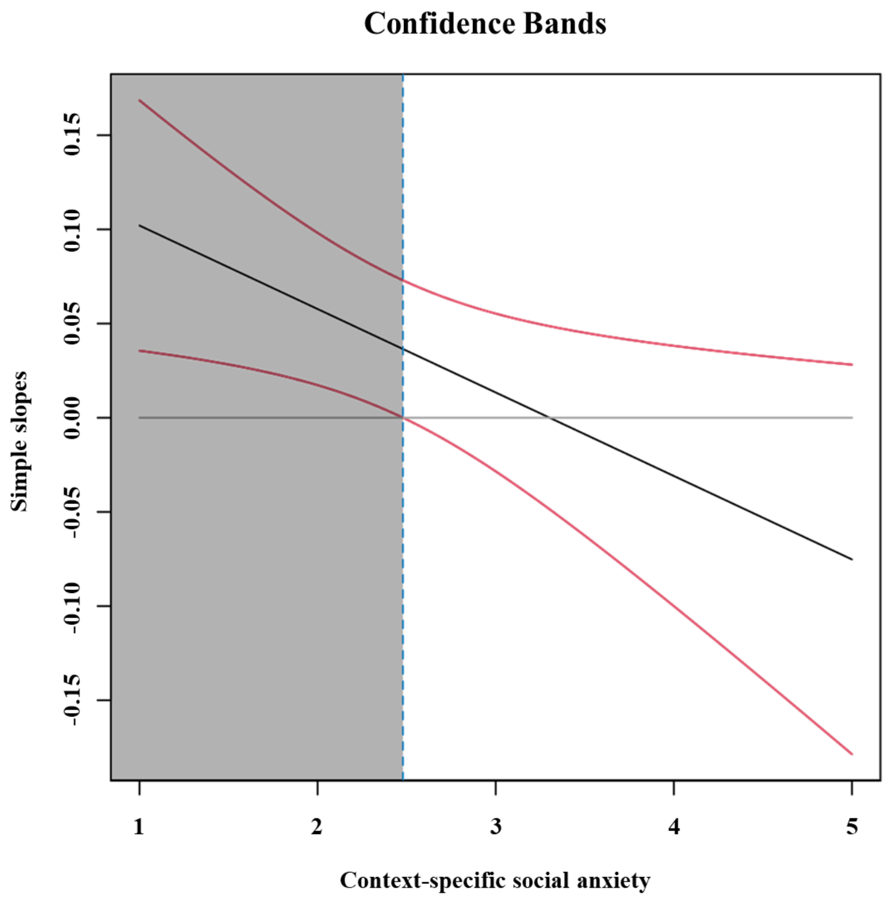

Figure 6. Regions of significance for the interaction between skin conductance level reactivity (SCLR) and context-specific social anxiety (CSSA) as a predictor of real-time disengaged coping responses. The association between SCLR and real-time disengaged coping responses was significantly positive at context-specific social anxiety scores below 2.48 (-0.3 SDs).

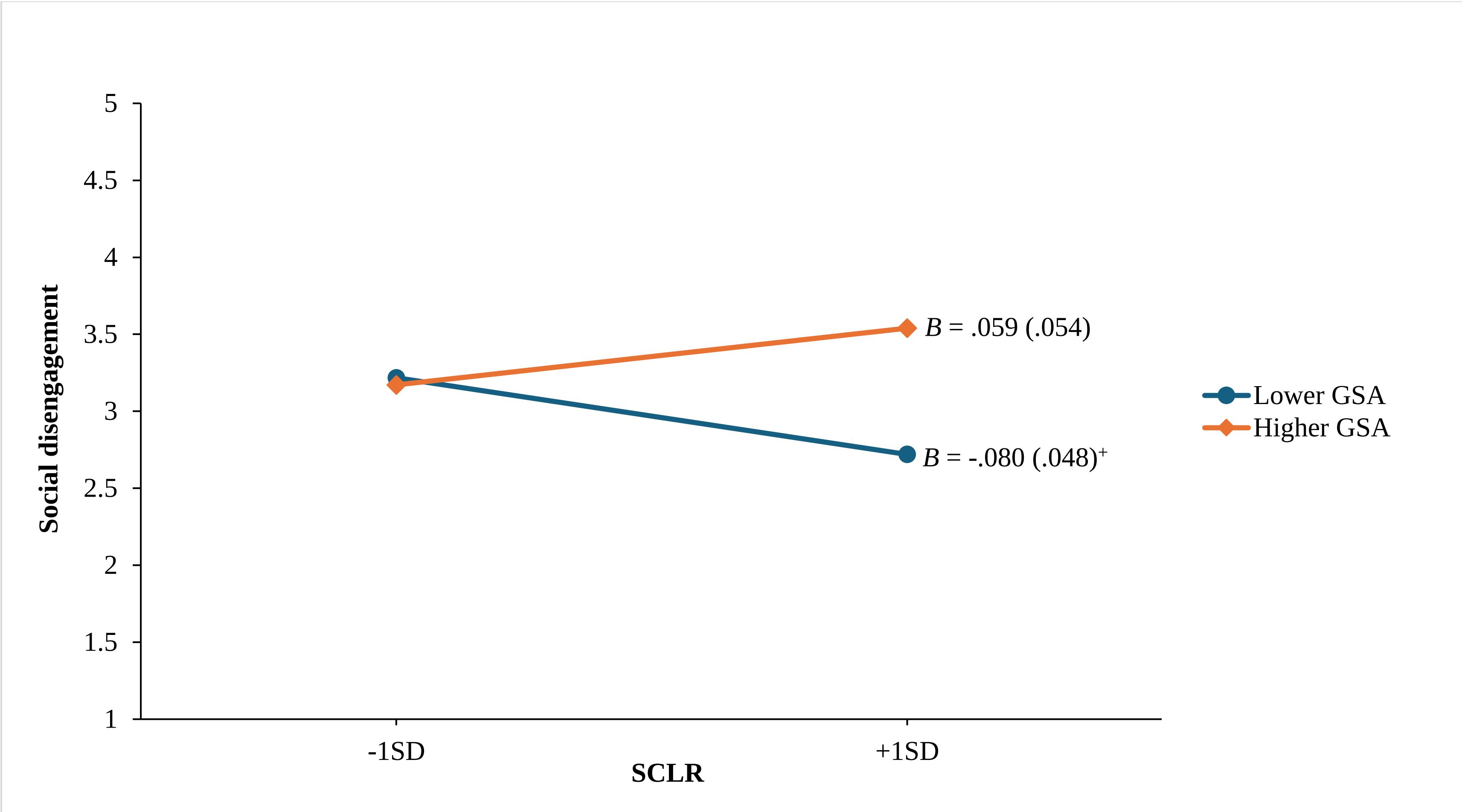

Figure 7. The association between skin conductance level reactivity (SCLR) and observed social disengagement moderated by global social anxiety (GSA). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

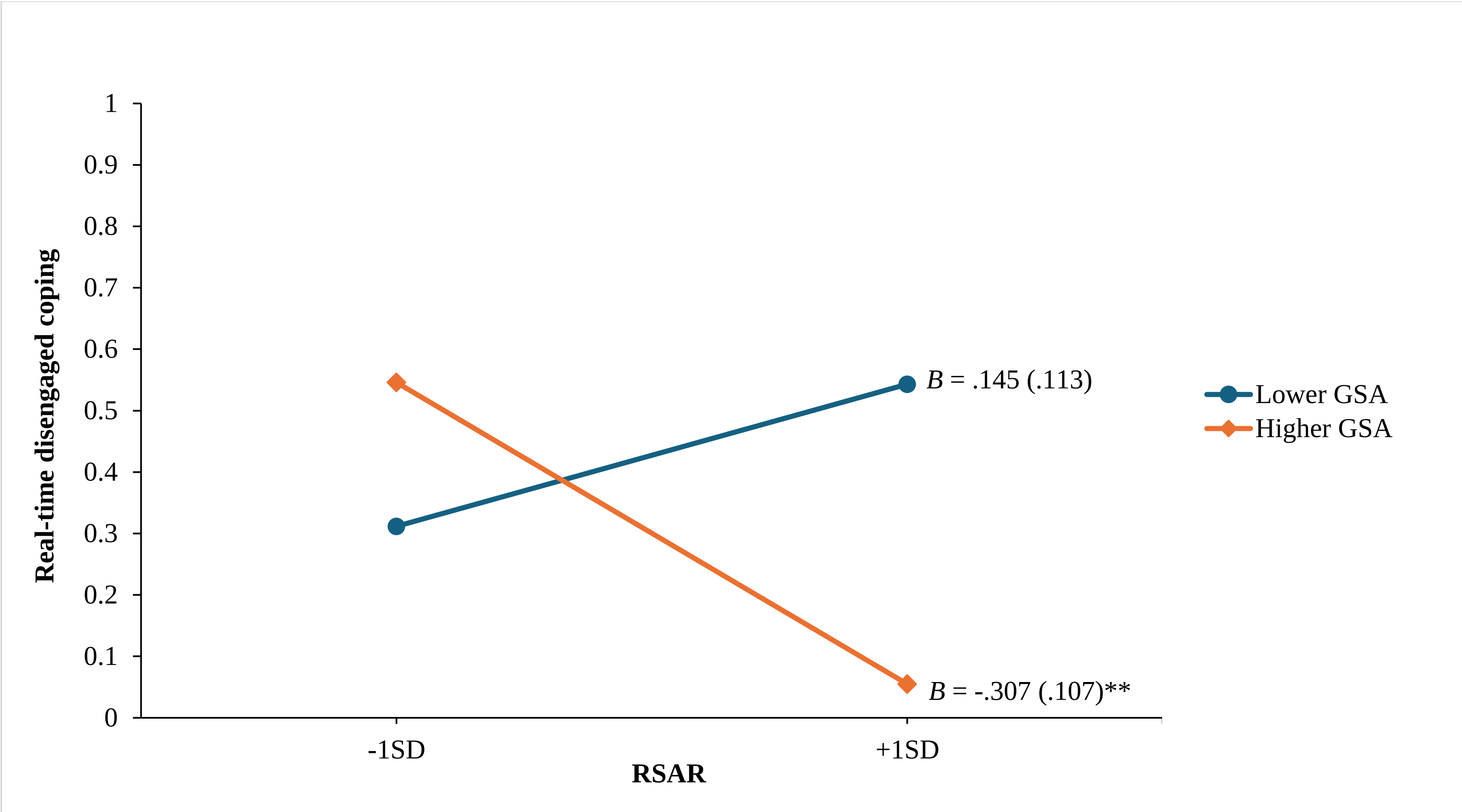

Figure 8. The association between respiratory sinus arrhythmia reactivity (RSAR) and real-time disengaged coping responses moderated by global social anxiety (GSA) – From the set of models with RSAR and SCLR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

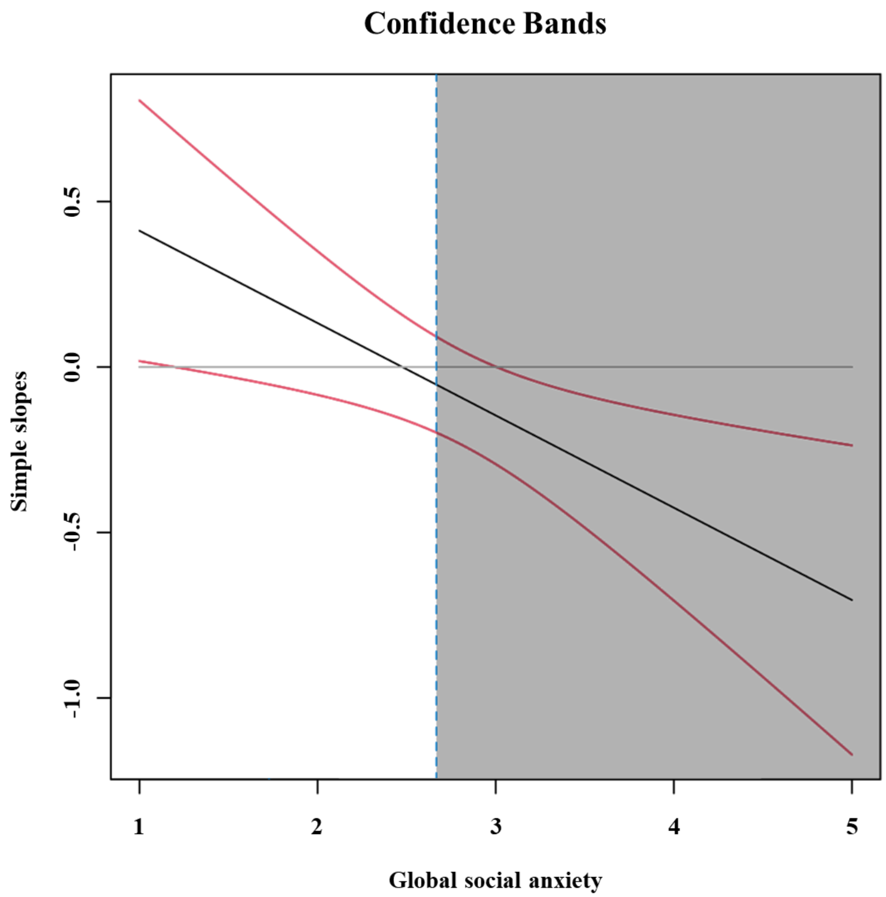

Figure 9. Regions of significance for the interaction between respiratory sinus arrhythmia reactivity (RSAR) and global social anxiety (GSA) as a predictor of real-time disengaged coping responses. The association between RSAR and real-time disengaged coping responses was significantly negative at global social anxiety scores above 2.61 (+0.3 SDs).

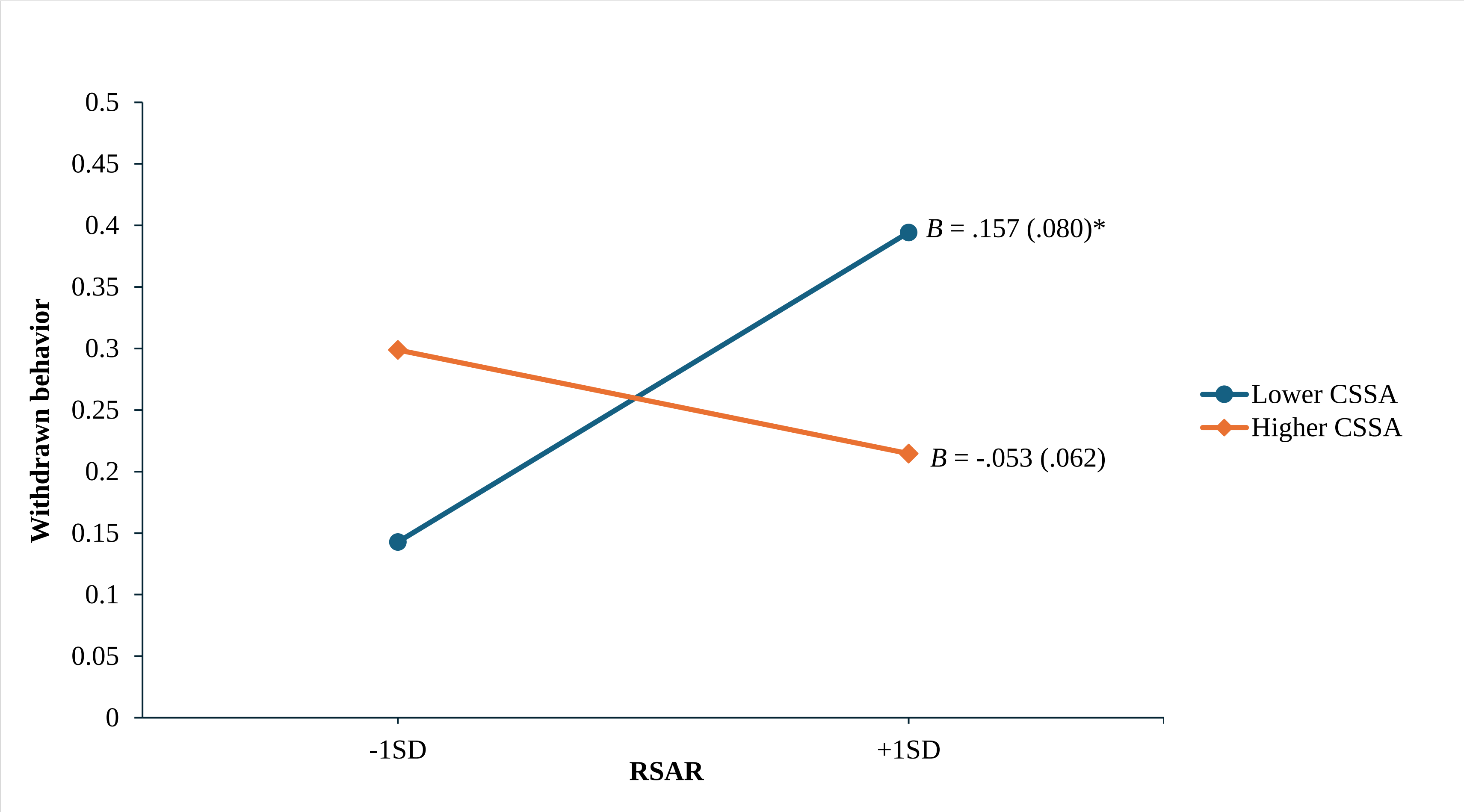

Figure 10. The association between respiratory sinus arrhythmia reactivity (RSAR) and teacher-reported withdrawn behavior moderated by context-specific social anxiety (CSSA) – From the set of models with RSAR and PEPR. $^{+}p < .10$, $*p < .05$, $**p < .01$

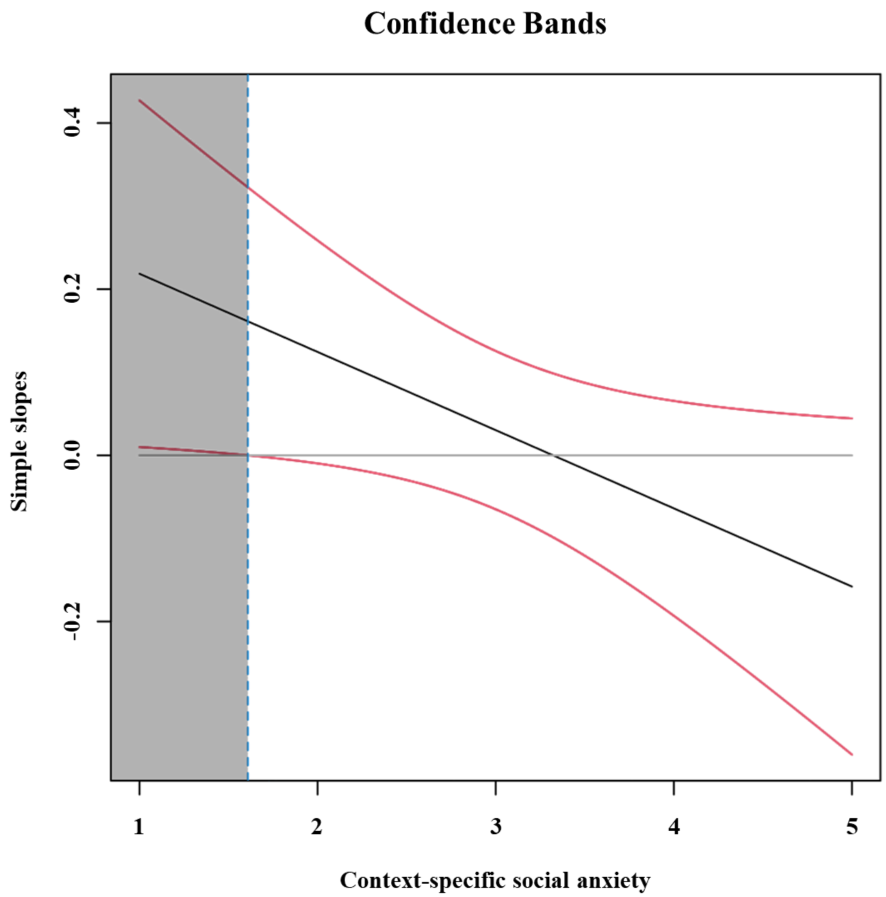

Figure 11. Regions of significance for the interaction between respiratory sinus arrhythmia reactivity (RSAR) and context-specific social anxiety (CSSA) as a predictor of teacher-reported withdrawn behavior. The association between RSAR and teacher-reported withdrawn behavior was significantly negative at context-specific social anxiety scores below 1.61 (-1 SD).

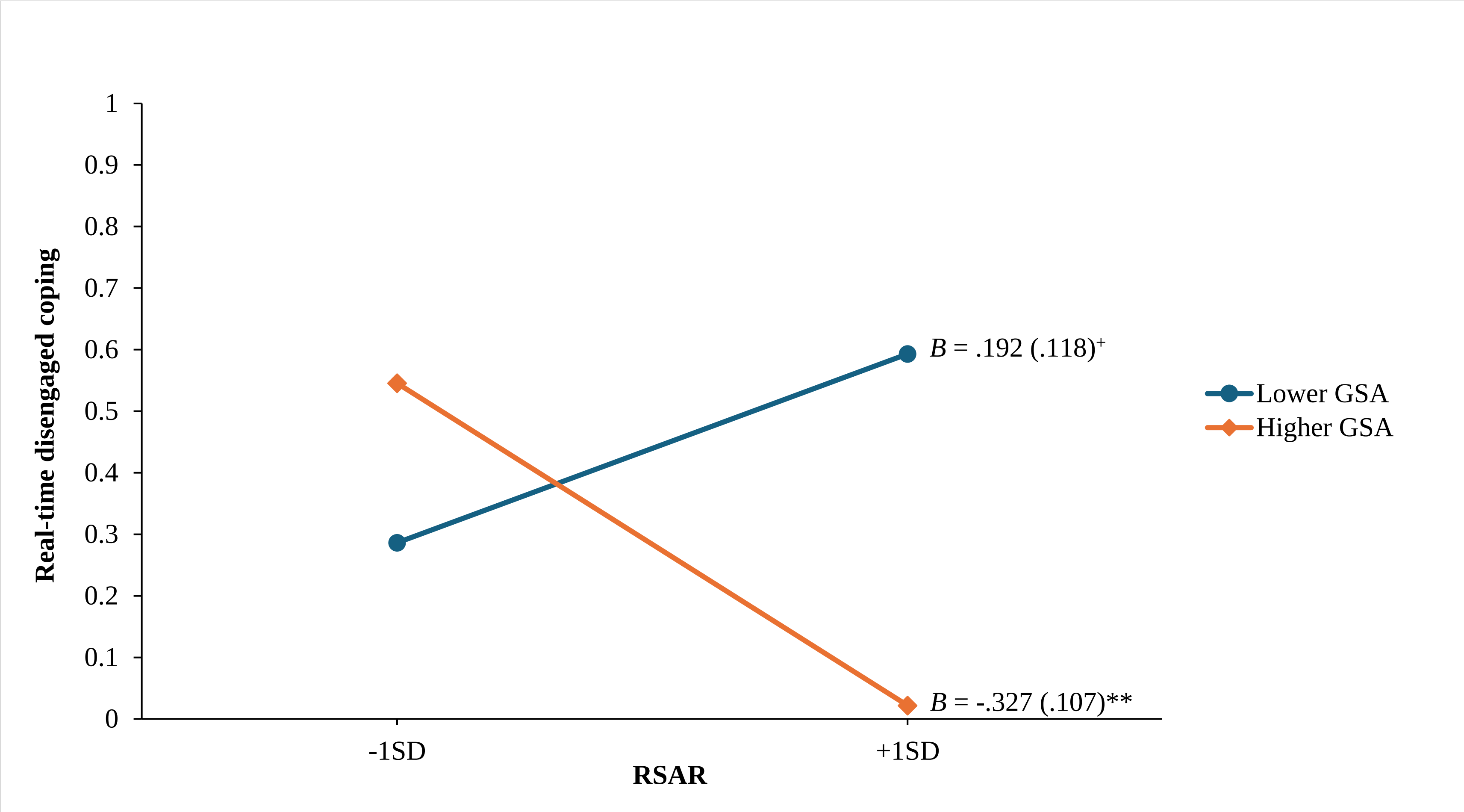

Figure 12. The association between respiratory sinus arrhythmia reactivity (RSAR) and real-time disengaged coping responses moderated by global social anxiety (GSA) – From the set of models with RSAR and PEPR. $^{+}p < .10$, $*p < .05$, $**p < .01$

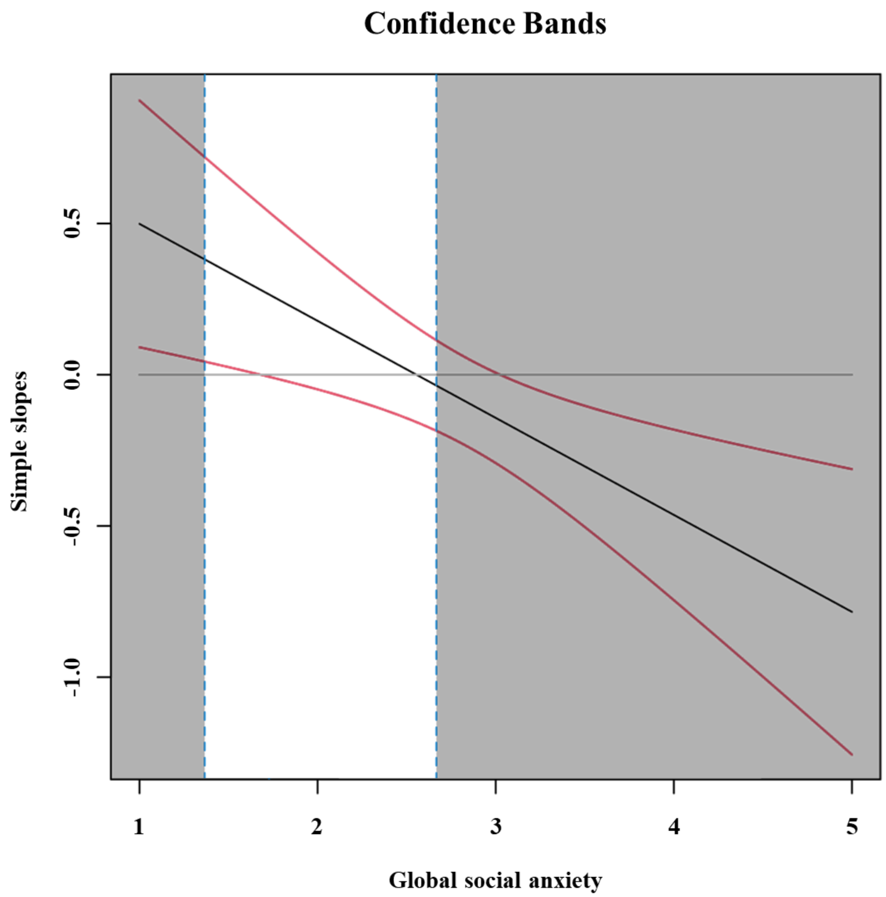

Figure 13. Regions of significance for the interaction between respiratory sinus arrhythmia reactivity (RSAR) and global social anxiety (GSA) as a predictor of real-time disengaged coping responses. The association between RSAR and real-time disengaged coping responses was significantly positive at global social anxiety scores below 1.29 (-1.4 SDs) and significantly negative at scores above 2.64 (+0.3 SDs).

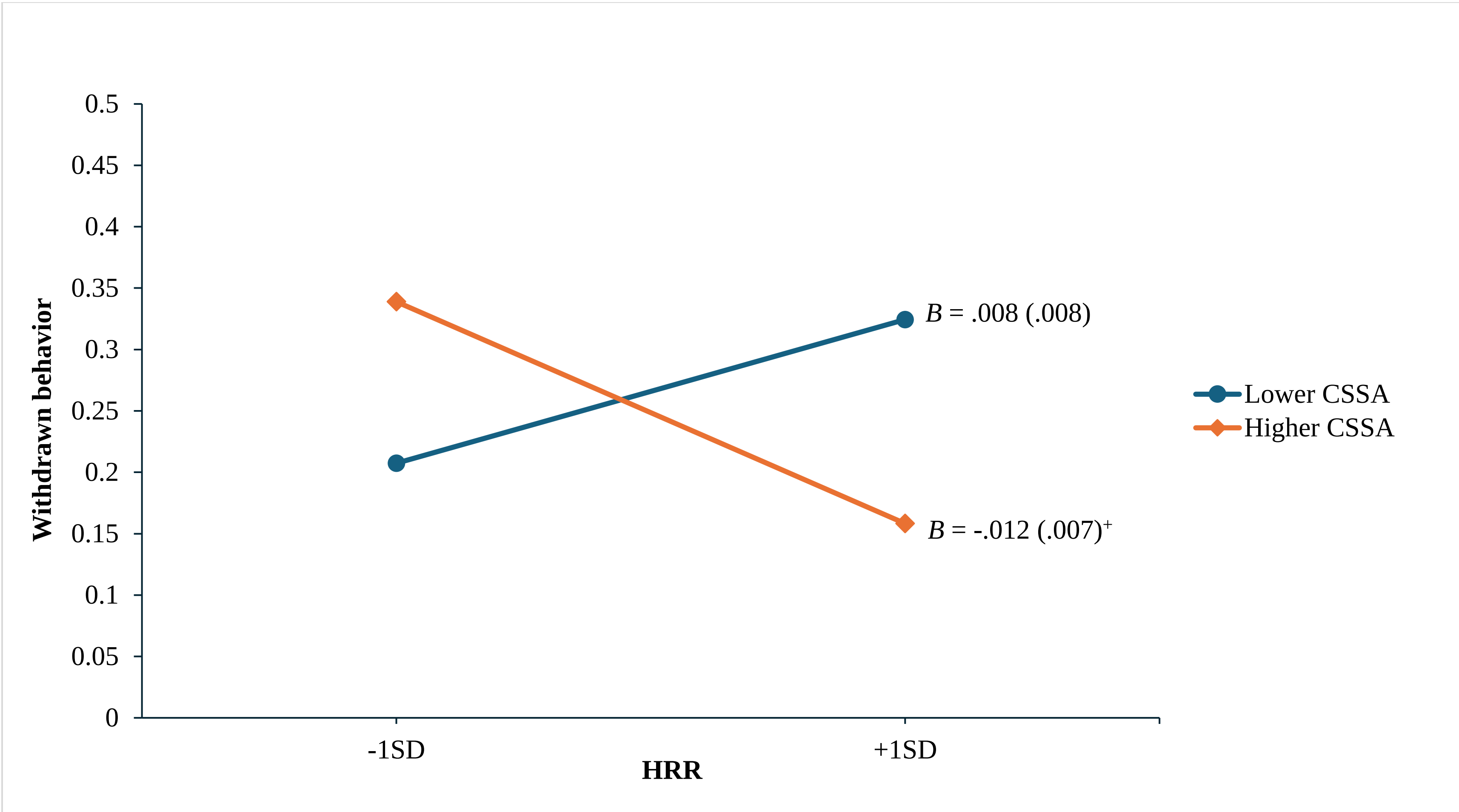

Figure 14. The association between heart rate reactivity (HRR) and teacher-reported withdrawn behavior moderated by context-specific social anxiety (CSSA). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

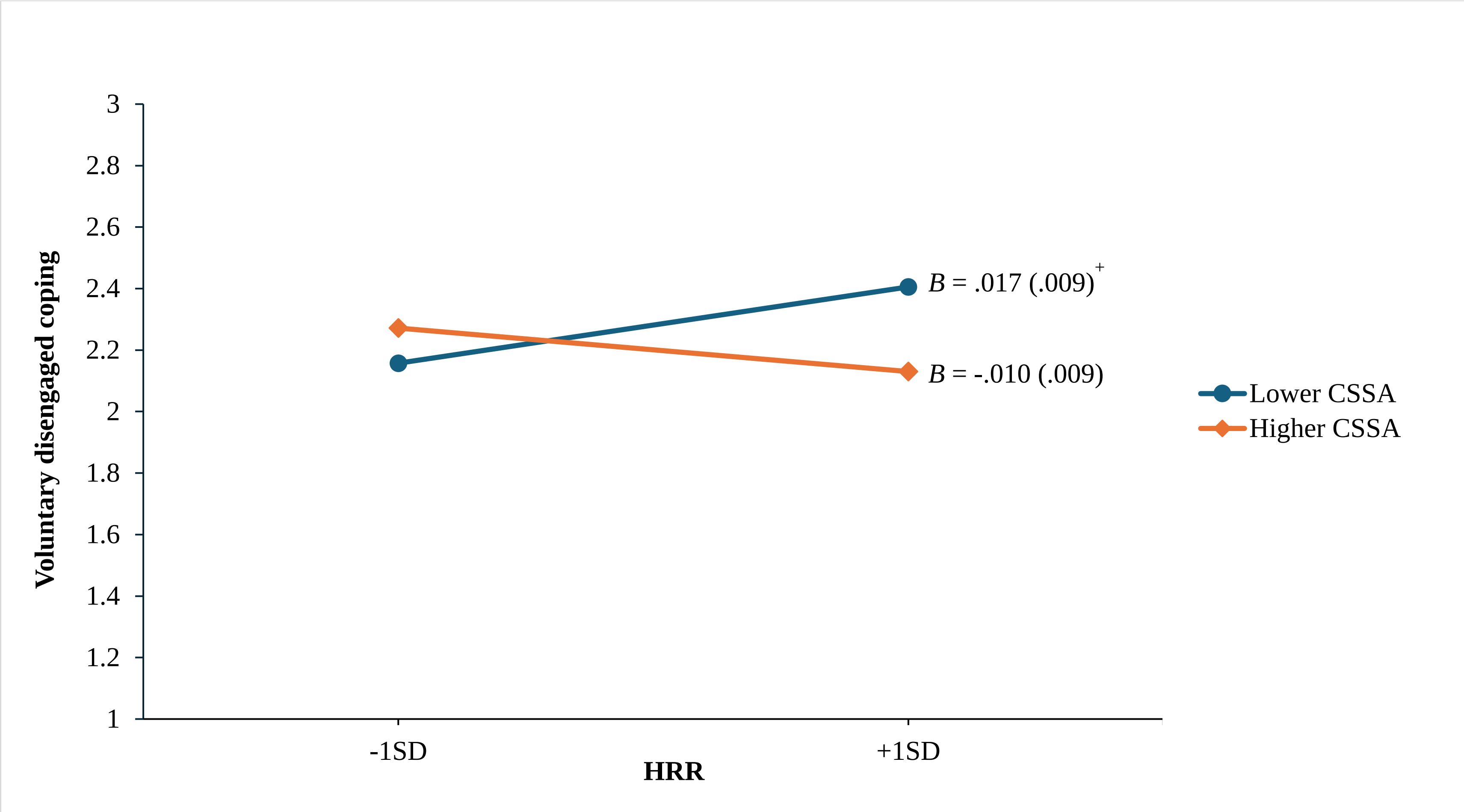

Figure 15. The association between heart rate reactivity (HRR) and voluntary disengaged coping responses moderated by context-specific social anxiety (CSSA). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

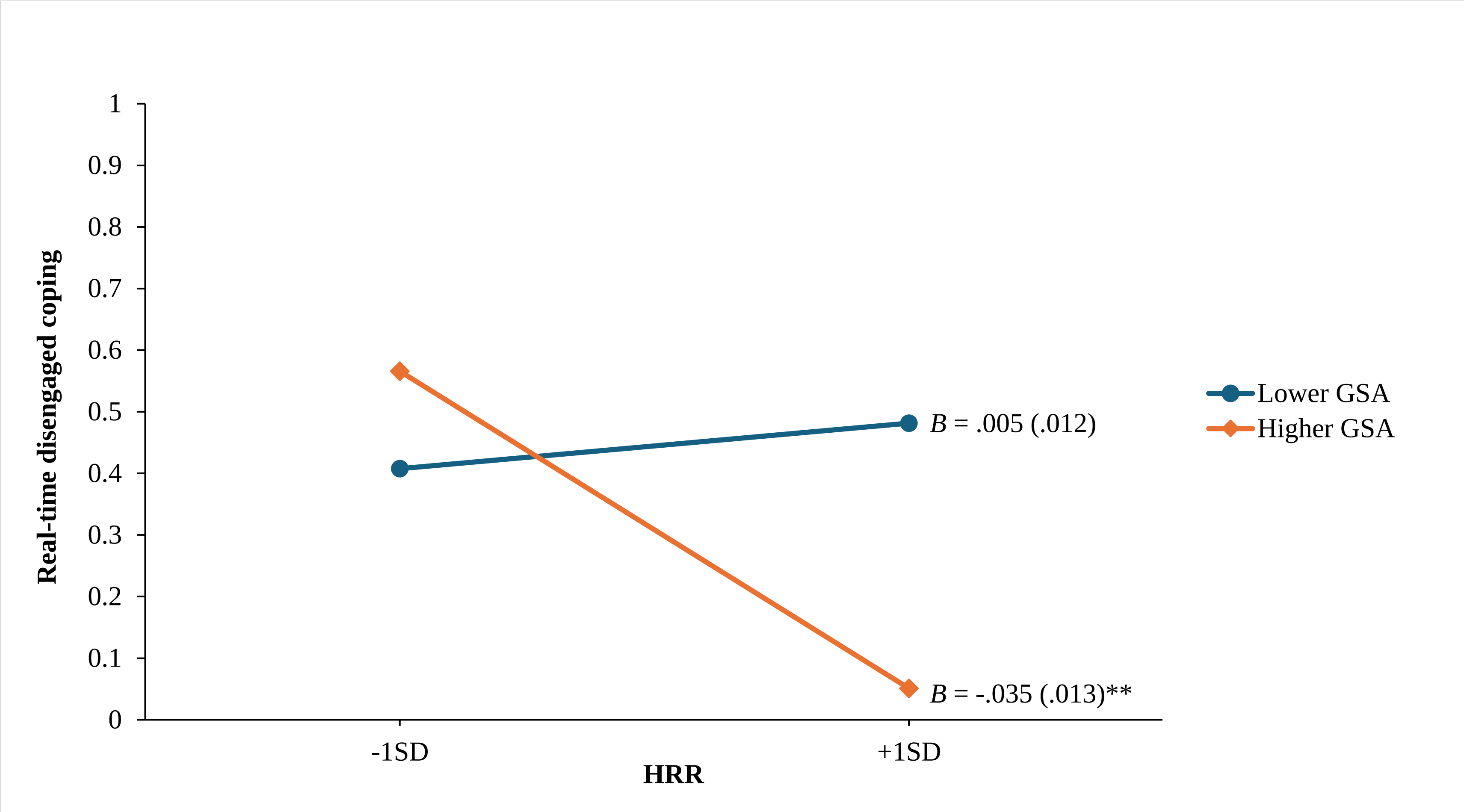

Figure 16. The association between heart rate reactivity (HRR) and real-time disengaged coping responses moderated by global social anxiety (GSA). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

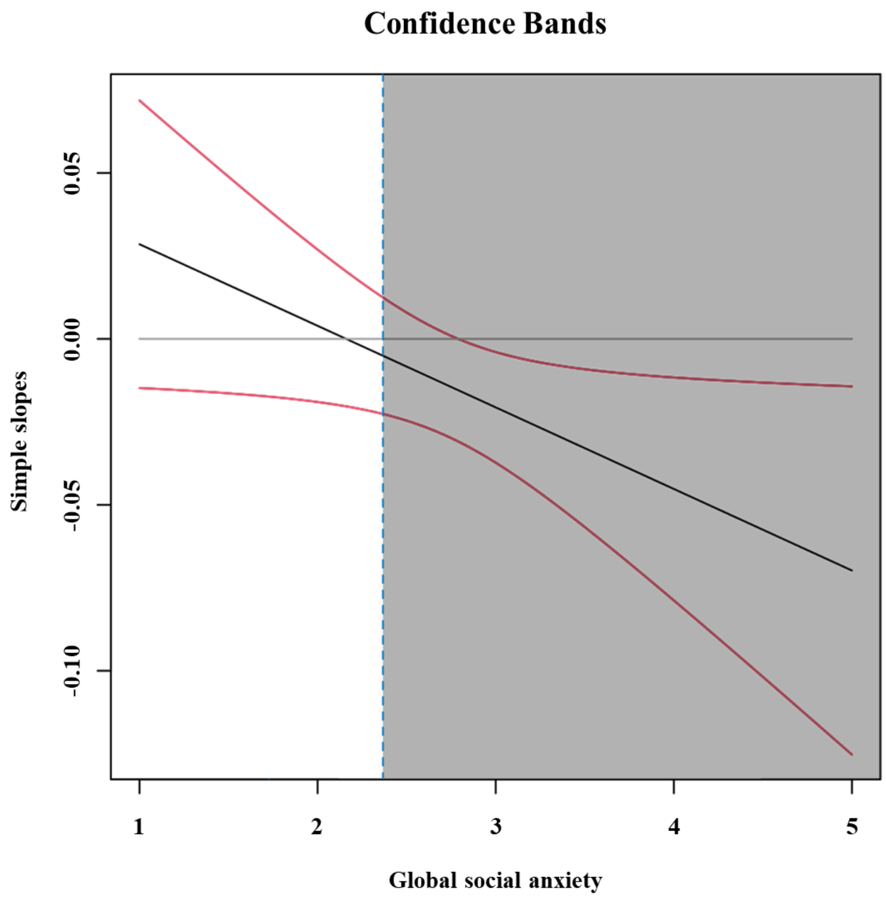

Figure 17. Regions of significance for the interaction between heart rate reactivity (HRR) and global social anxiety (GSA) as a predictor of real-time disengaged coping responses. The association between HRR and real-time disengaged coping responses was significantly negative at global social anxiety scores above 2.35 (+/-0 SDs).

APPENDIX A

Supplemental Analyses – Fear of Negative Evaluation Subscale

This appendix contains information about supplemental analyses that were conducted to examine potential differences in interactive effects when the "fear of negative evaluation" (FNE) subscale from the Social Anxiety Scale for Adolescents (SAS-A) was used in place of the full SAS-A as a measure of global social anxiety in interaction analyses. The two other subscales from the SAS-A – social distress/avoidance in novel situations and social distress/avoidance in general – both include items that assess avoidant behaviors or responses that may overlap with the types of AWD responses that were examined as outcome variables in the present study. As such, exploratory analyses were conducted to see if the observed pattern of interactive effects changed when social distress and avoidance items were omitted.

Correlations between FNE and study variables are shown in table 2 while regression coefficients can be found in tables 9-11 and plotted interactions are shown in figures 18-22 (located below). Overall, results from this set of supplemental analyses were similar to those observed in the original analyses utilizing the full SAS-A. The only observed difference was that the interaction between HRR and global social anxiety emerged as a significant predictor of voluntary disengaged responses when the FNE subscale was used. This additional finding is relatively consistent with the overall pattern of interactive effects observed in the original analyses, further enhancing confidence in the reliability of results from the present study.

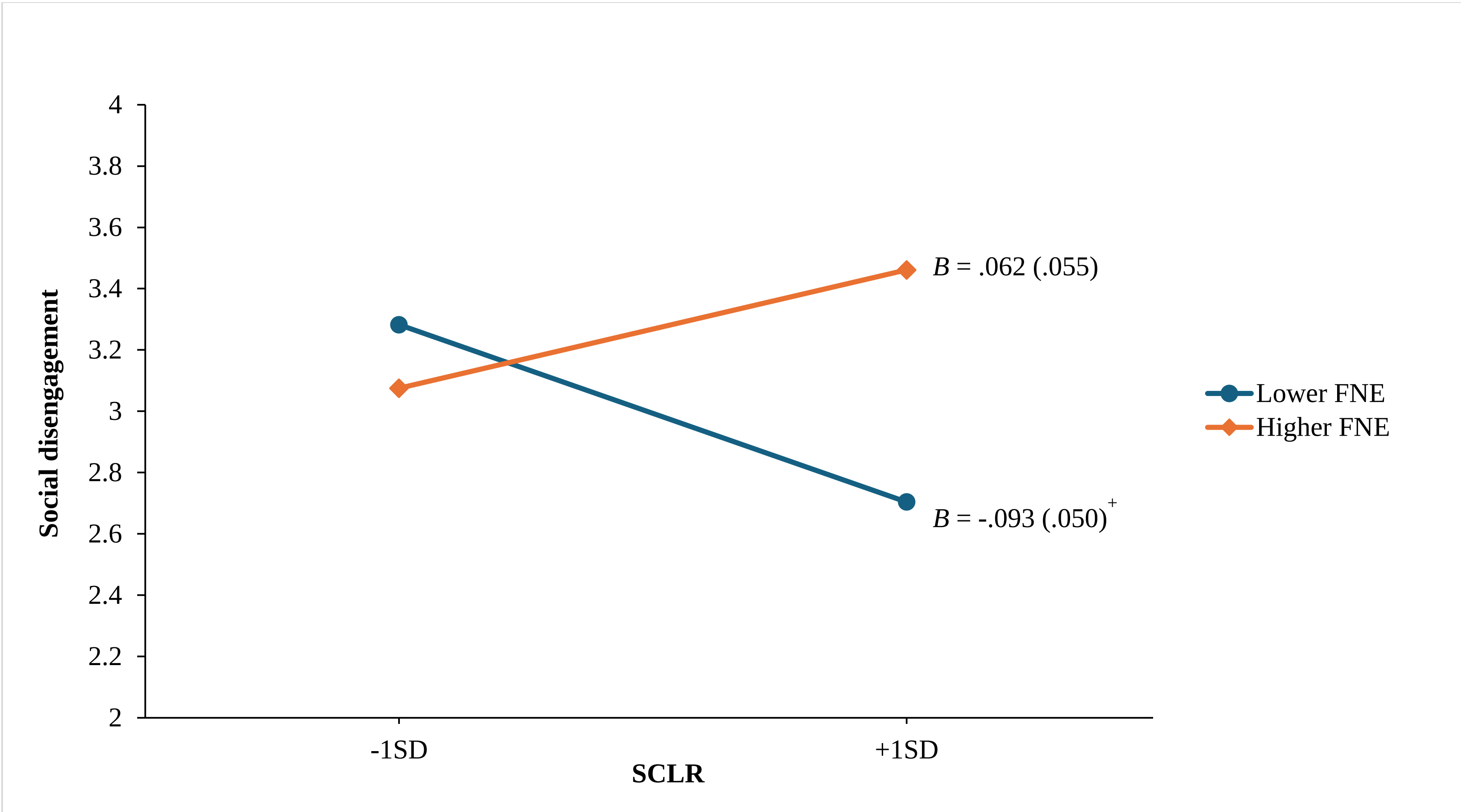

Figure 18. The association between skin conductance level reactivity (SCLR) and observed social disengagement moderated by fear of negative evaluation (FNE). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

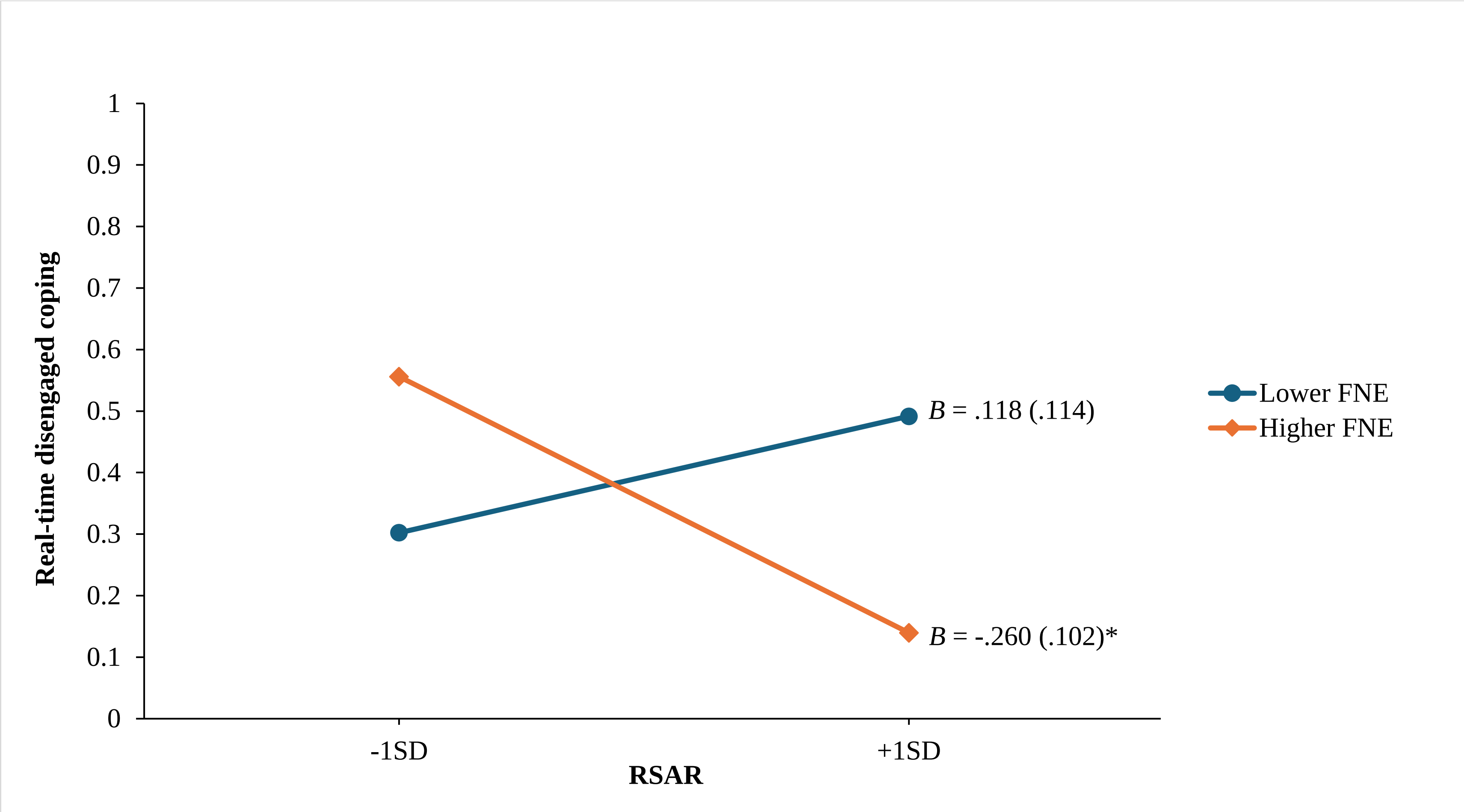

Figure 19. The association between respiratory sinus arrhythmia reactivity (RSAR) and real-time disengaged coping responses moderated by fear of negative evaluation (FNE) – From the models including RSAR and SCLR. $^{+}p < .10$, $*p < .05$, $**p < .01$

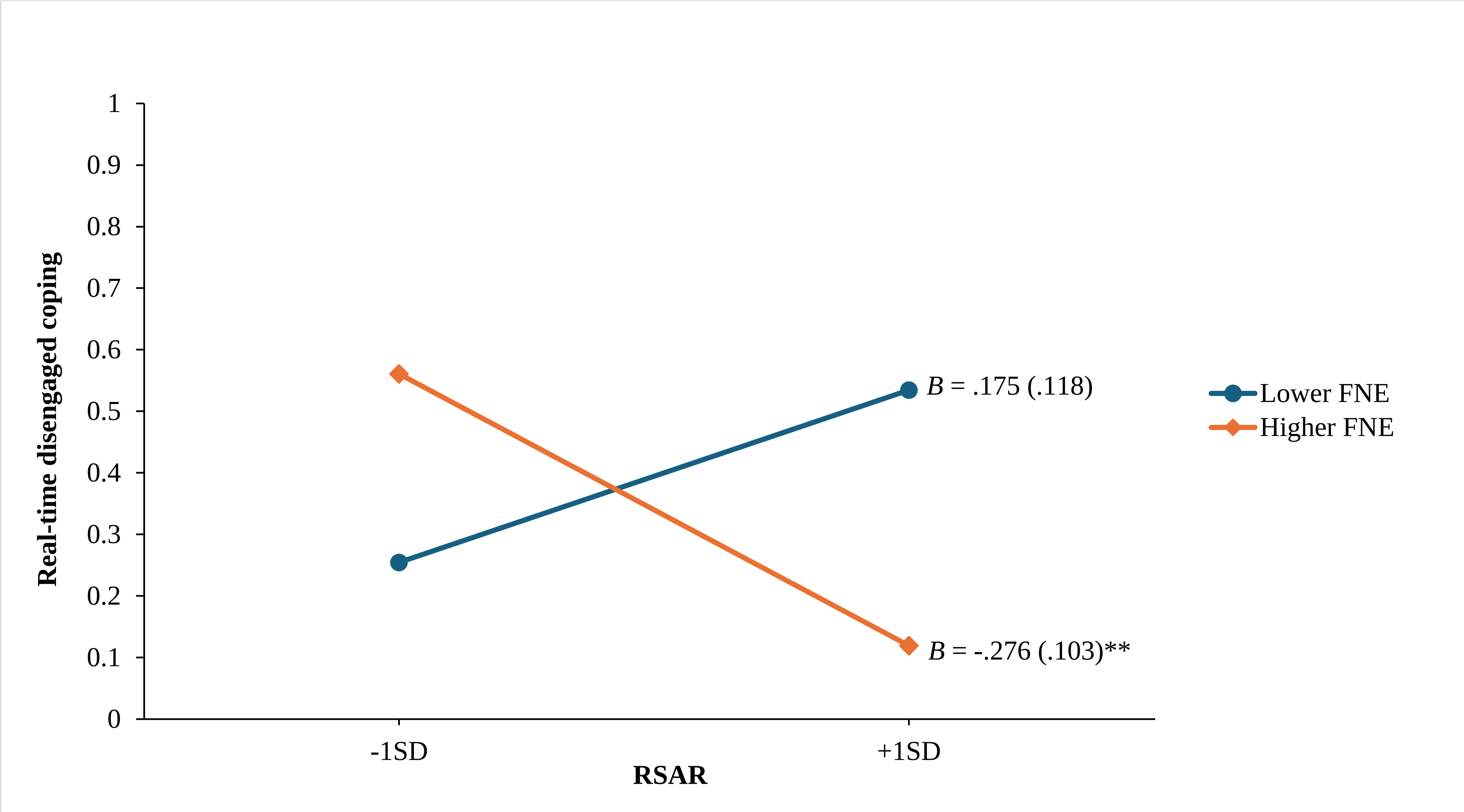

Figure 20. The association between respiratory sinus arrhythmia reactivity (RSAR) and real-time disengaged coping responses moderated by fear of negative evaluation (FNE) – From the models including RSAR and PEPR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

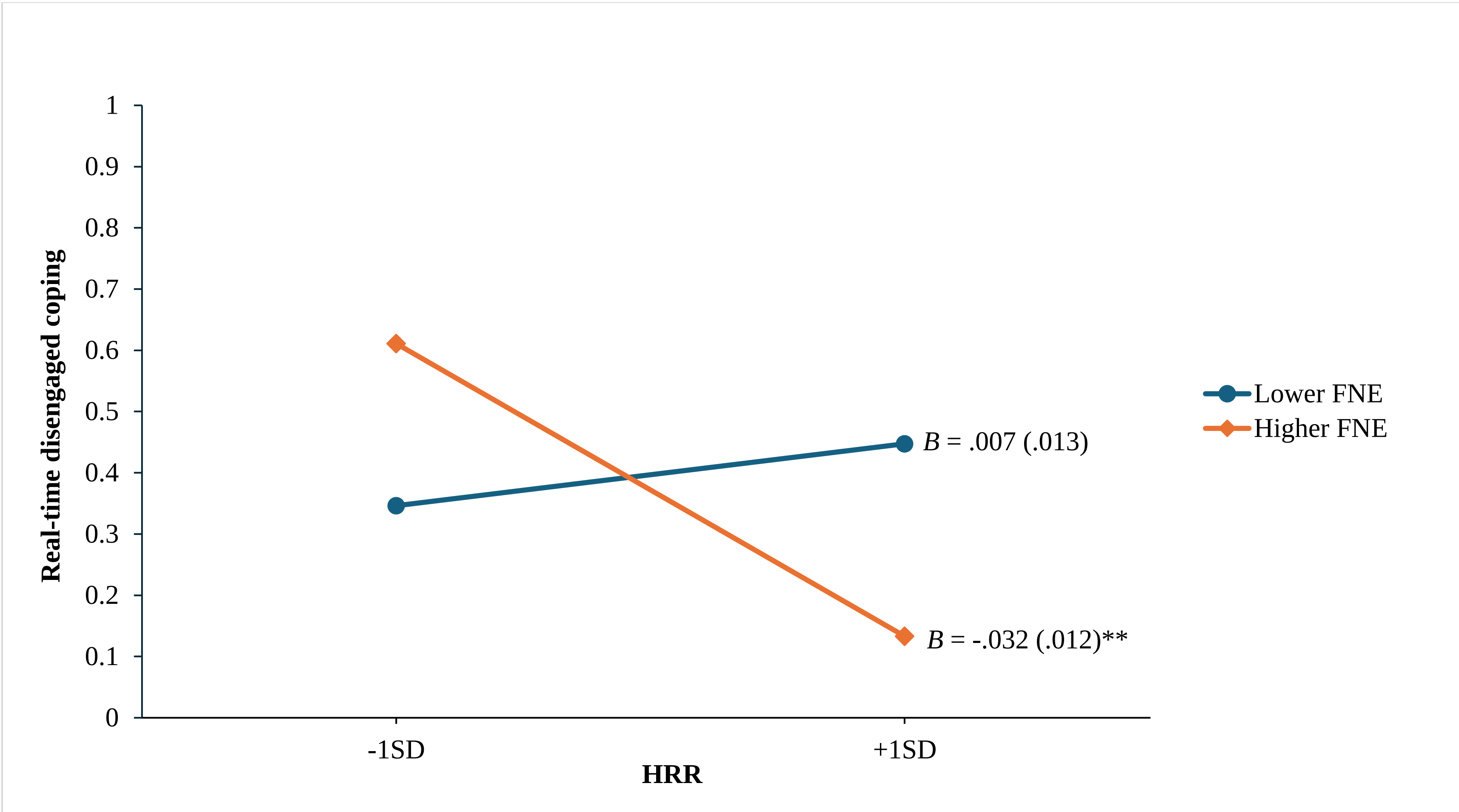

Figure 21. The association between heart rate reactivity (HRR) and real-time disengaged coping responses moderated by fear of negative evaluation (FNE). $^{+}p < .10$, $*p < .05$, $**p < .01$

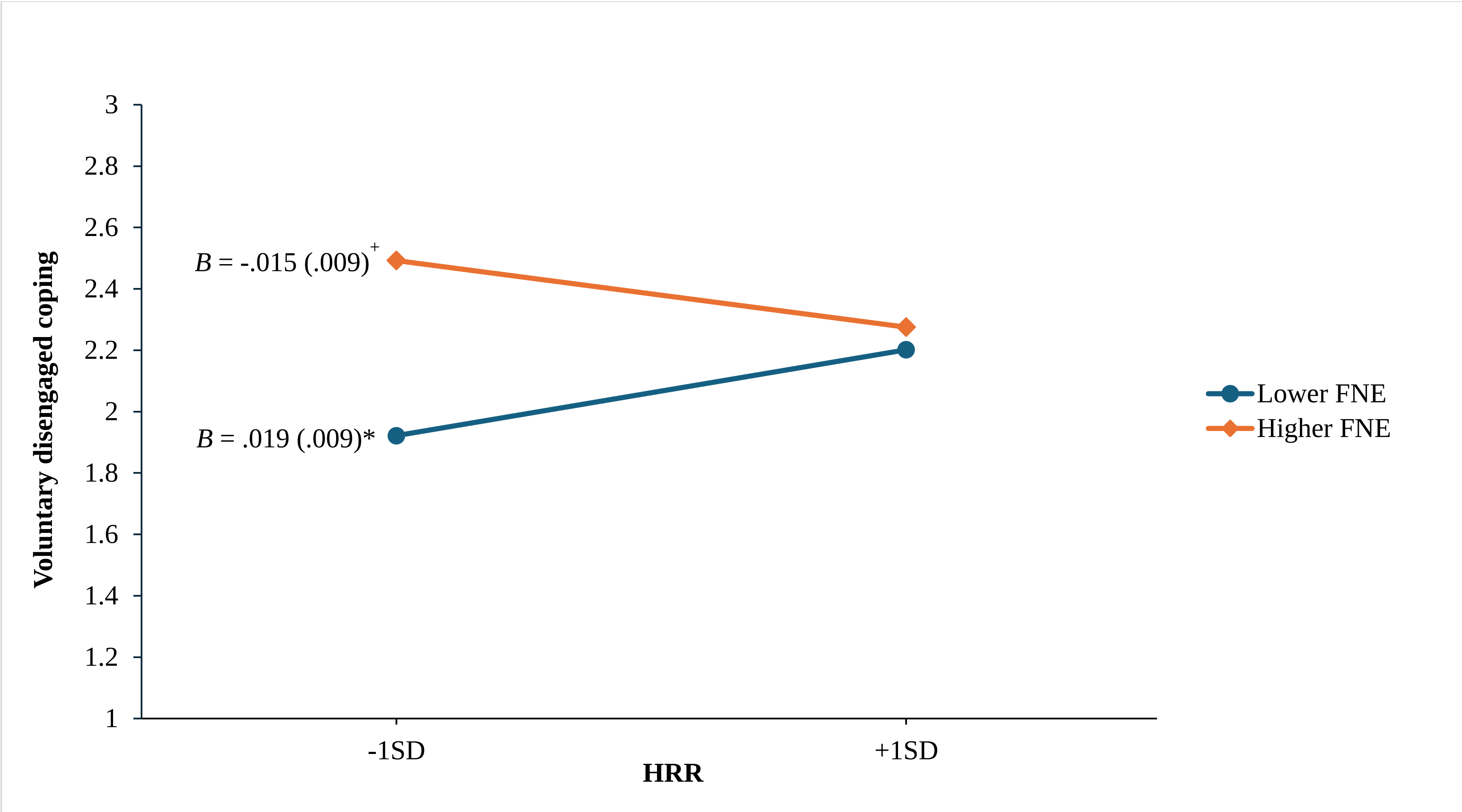

Figure 22. The association between heart rate reactivity (HRR) and voluntary disengaged coping responses moderated by fear of negative evaluation (FNE). $^{+}p < .10$, $*p < .05$, $**p < .01$

APPENDIX B

Supplemental Analyses – Social Anxiety as a Moderator

To better understand interactions between ANS and anxiety variables, we conducted additional analyses testing associations between the social anxiety variable initially designated as the moderator and AWD response variables at higher and lower levels of the ANS reactivity variable initially designated as the predictor (i.e., analyses where predictor and moderator variables were switched). For example, instead of examining RSAR as a predictor of AWD responses and testing social anxiety as a moderator, supplementary analyses examined the association between social anxiety and AWD responses with RSAR as the moderating variable. Switching predictor and moderating variables did not change regression coefficients (found in tables 3-11) and the plotted interactions are included below (see Figures 23-38). These interactions and corresponding figures are descriptively similar to the original findings and figures (i.e., Figures 1-17) insofar as they show that social anxiety tends to be either negatively associated with or unrelated to AWD responses at higher levels of ANS reactivity and positively associated with or unrelated to AWD responses at lower levels of ANS reactivity. This further supports the notion that higher levels of ANS reactivity to social stress may actually be protective or adaptive for early adolescents who report higher levels of social anxiety in some cases.

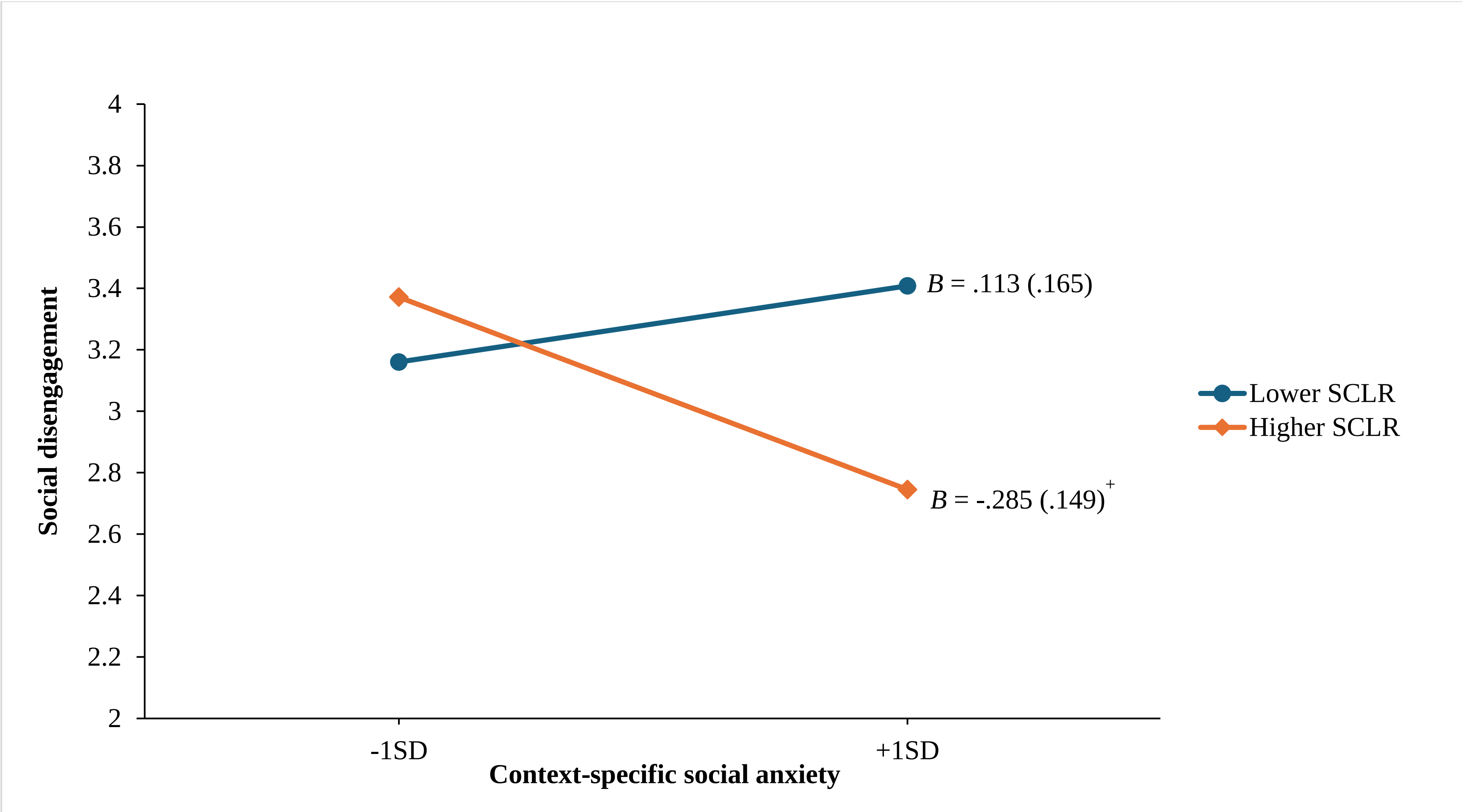

Figure 23. The association between context-specific social anxiety (CSSA) and observed social disengagement moderated by skin conductance level reactivity (SCLR). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

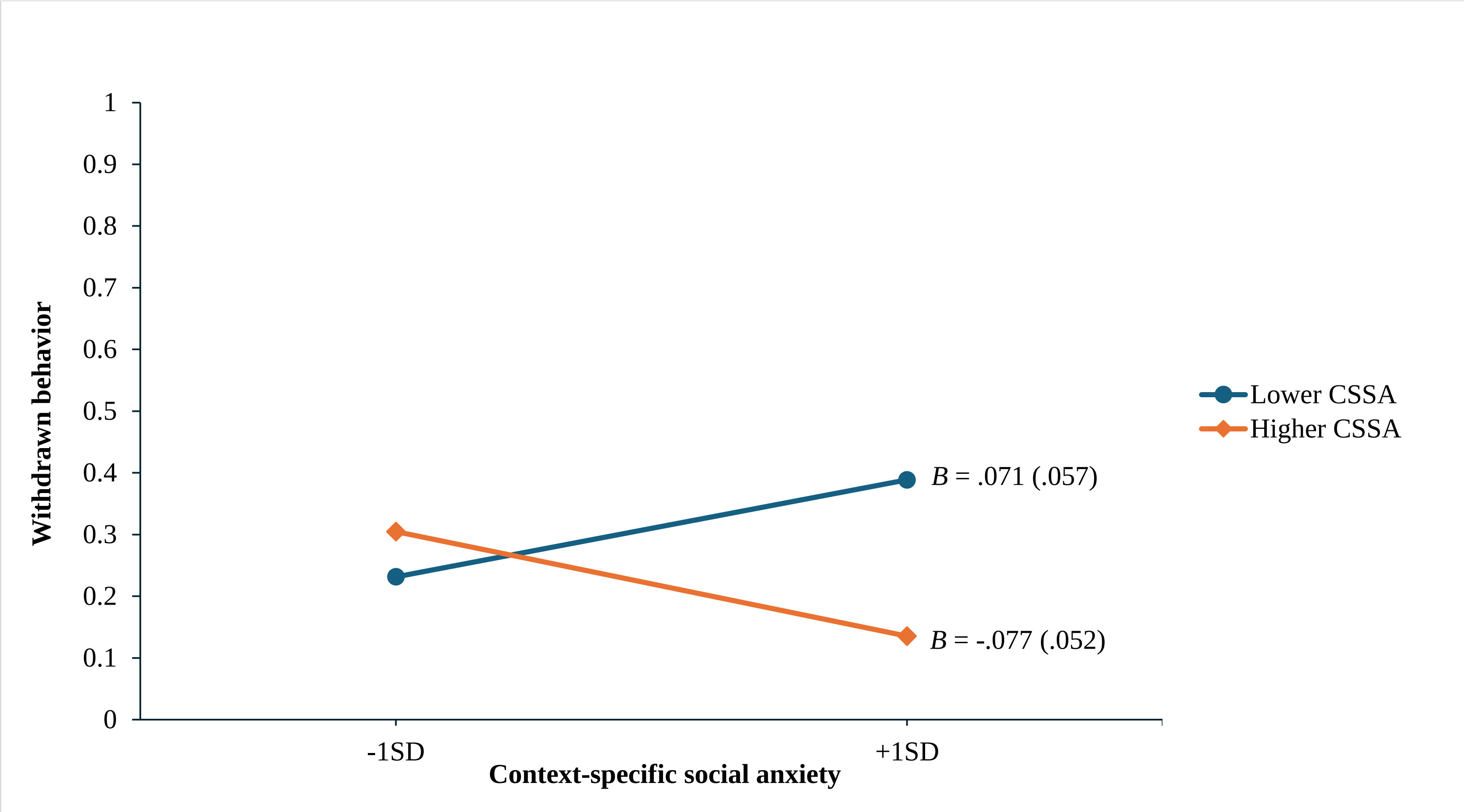

Figure 24. The association between context-specific social anxiety (CSSA) and teacher-reported withdrawn behavior moderated by skin conductance level reactivity (SCLR). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

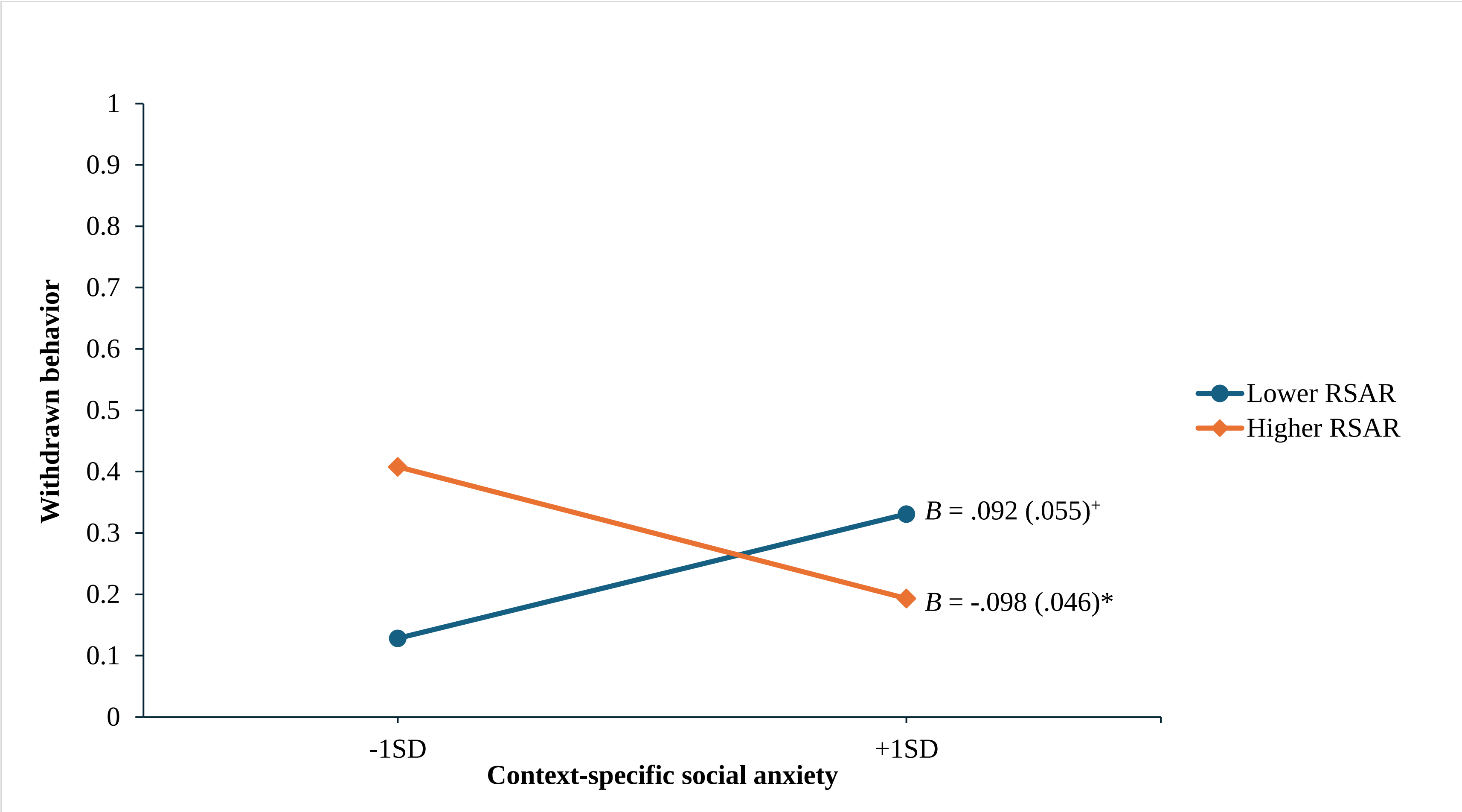

Figure 25. The association between context-specific social anxiety (CSSA) and teacher-reported withdrawn behavior moderated by respiratory sinus arrhythmia reactivity (RSAR) – From the set of models with RSAR and SCLR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

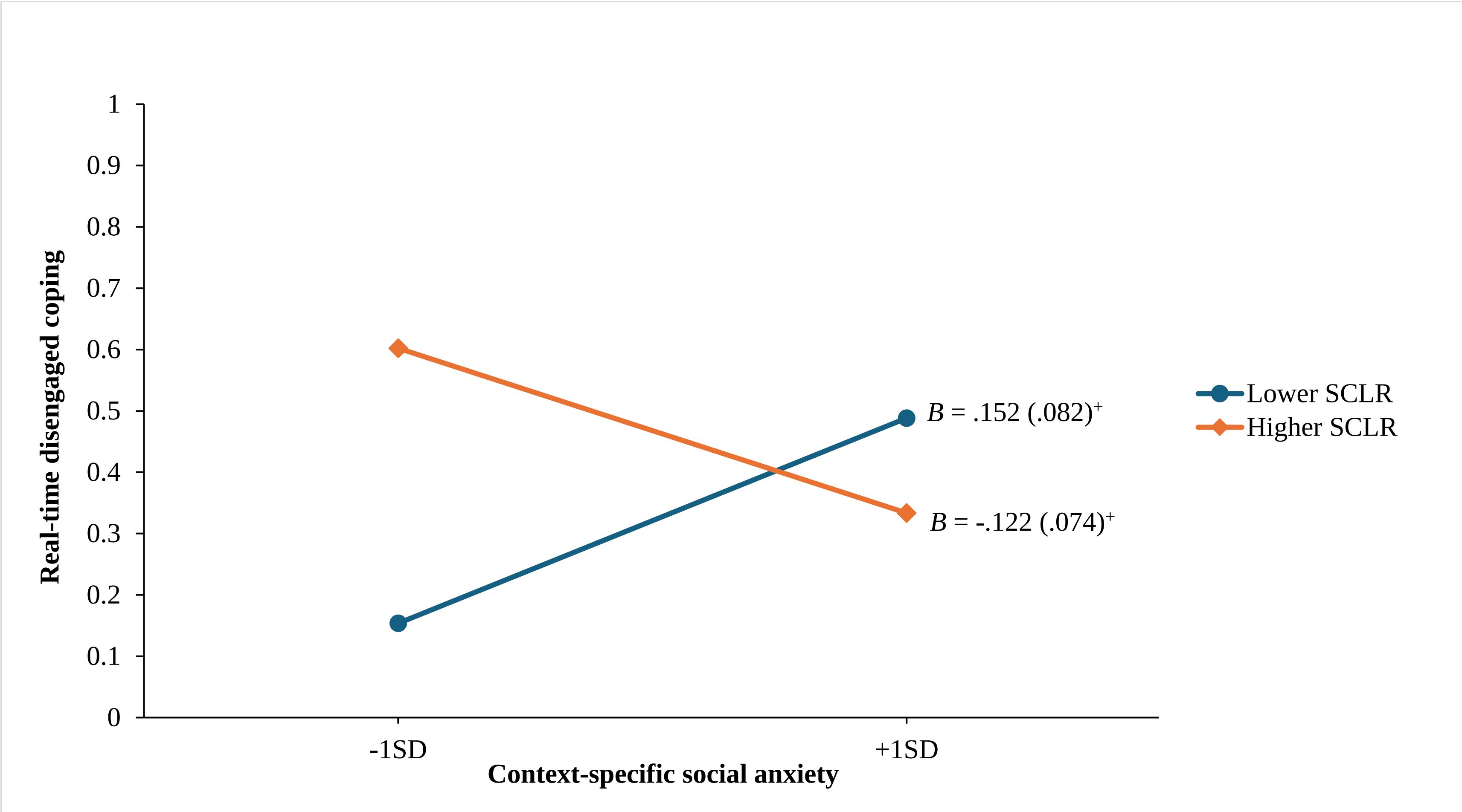

Figure 26. The association between context-specific social anxiety (CSSA) and real-time disengaged coping responses moderated by skin conductance level reactivity (SCLR). $^{+}p < .10$, $*p < .05$, $**p < .01$

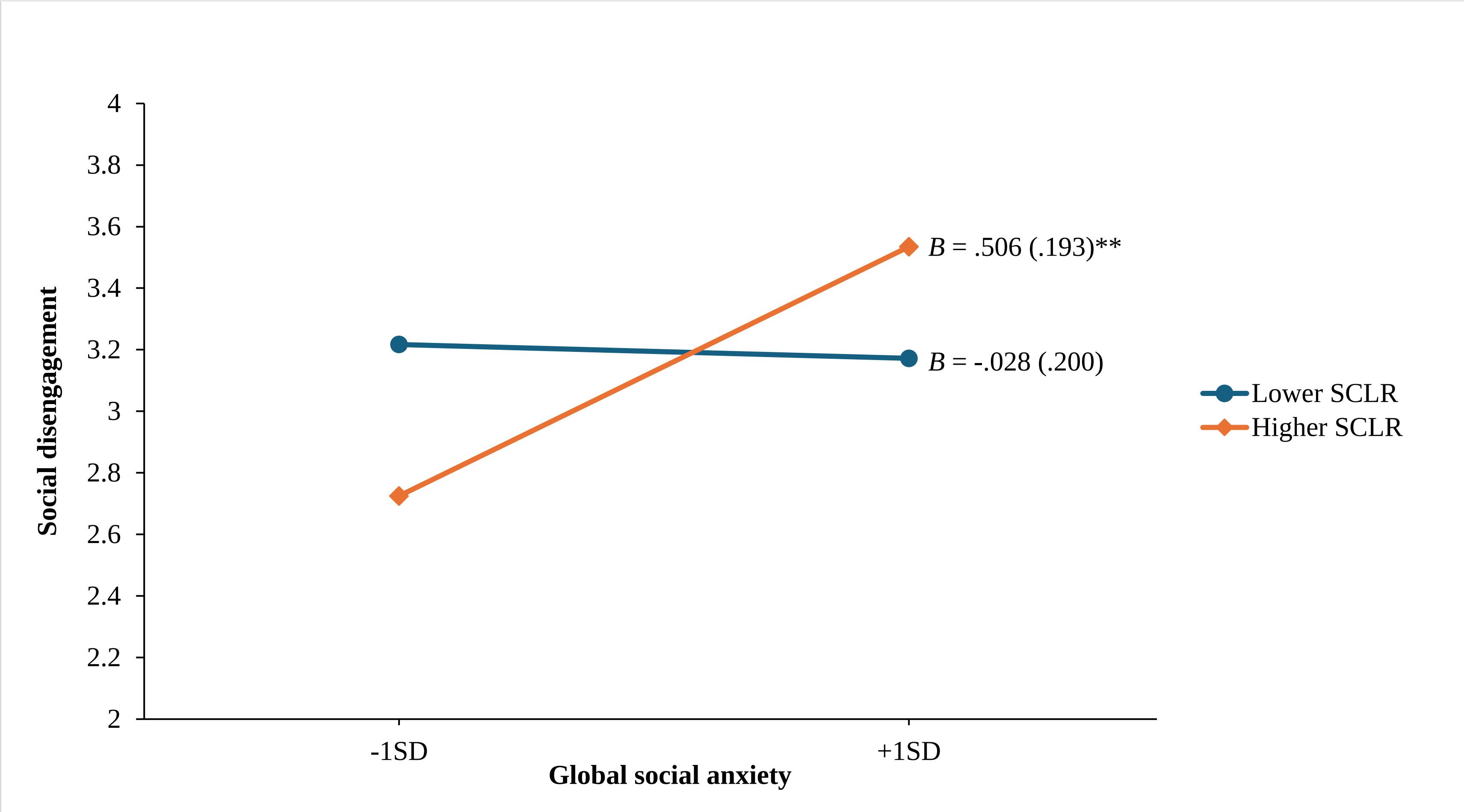

Figure 27. The association between global social anxiety (GSA) and observed social disengagement moderated by skin conductance level reactivity (SCLR). $^{+}p < .10$, $*p < .05$, $**p < .01$

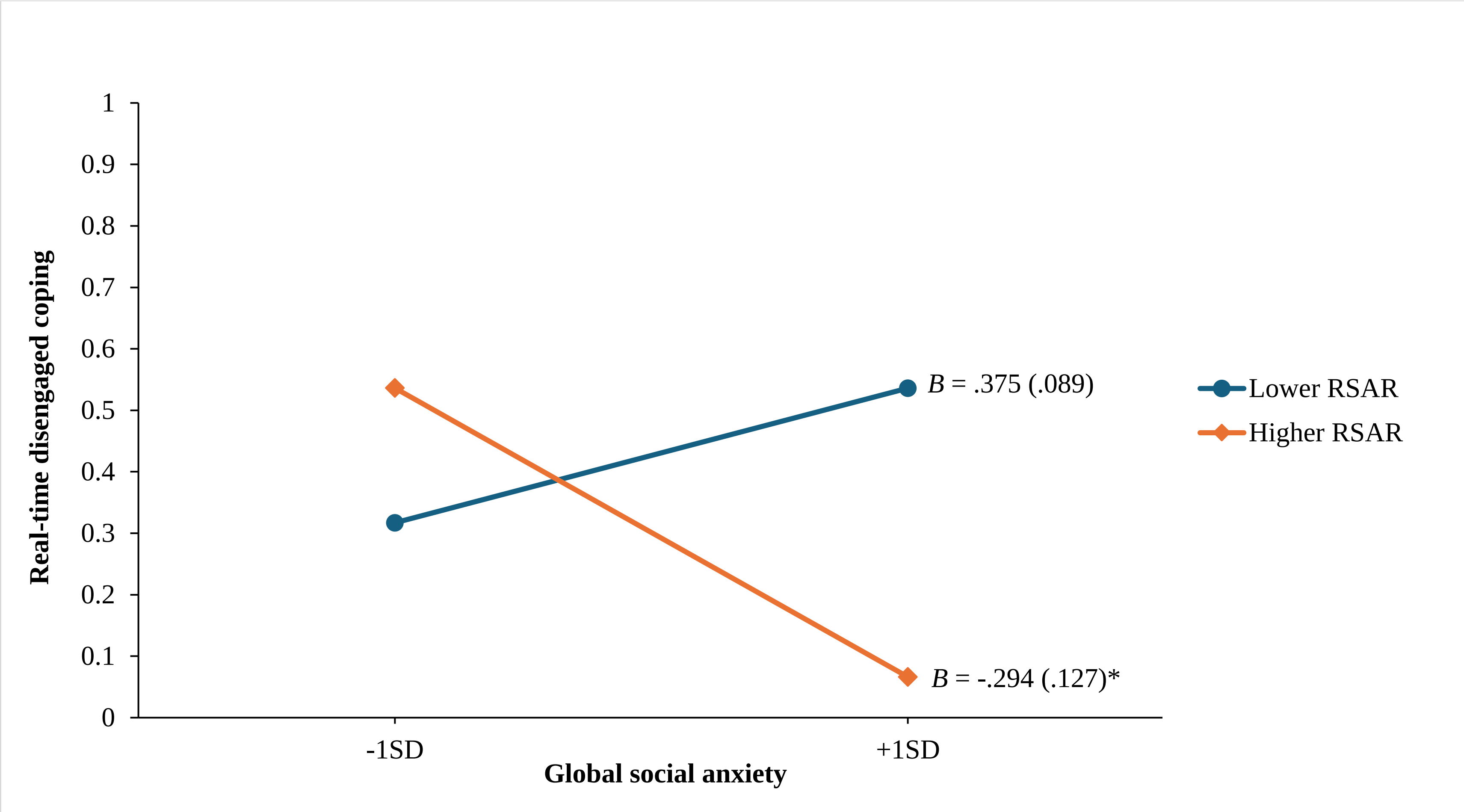

Figure 28. The association between global social anxiety (GSA) and real-time disengaged coping responses moderated by respiratory sinus arrhythmia reactivity (RSAR) – From the set of models with RSAR and SCLR. $^{+}p < .10$, $*p < .05$, $**p < .01$

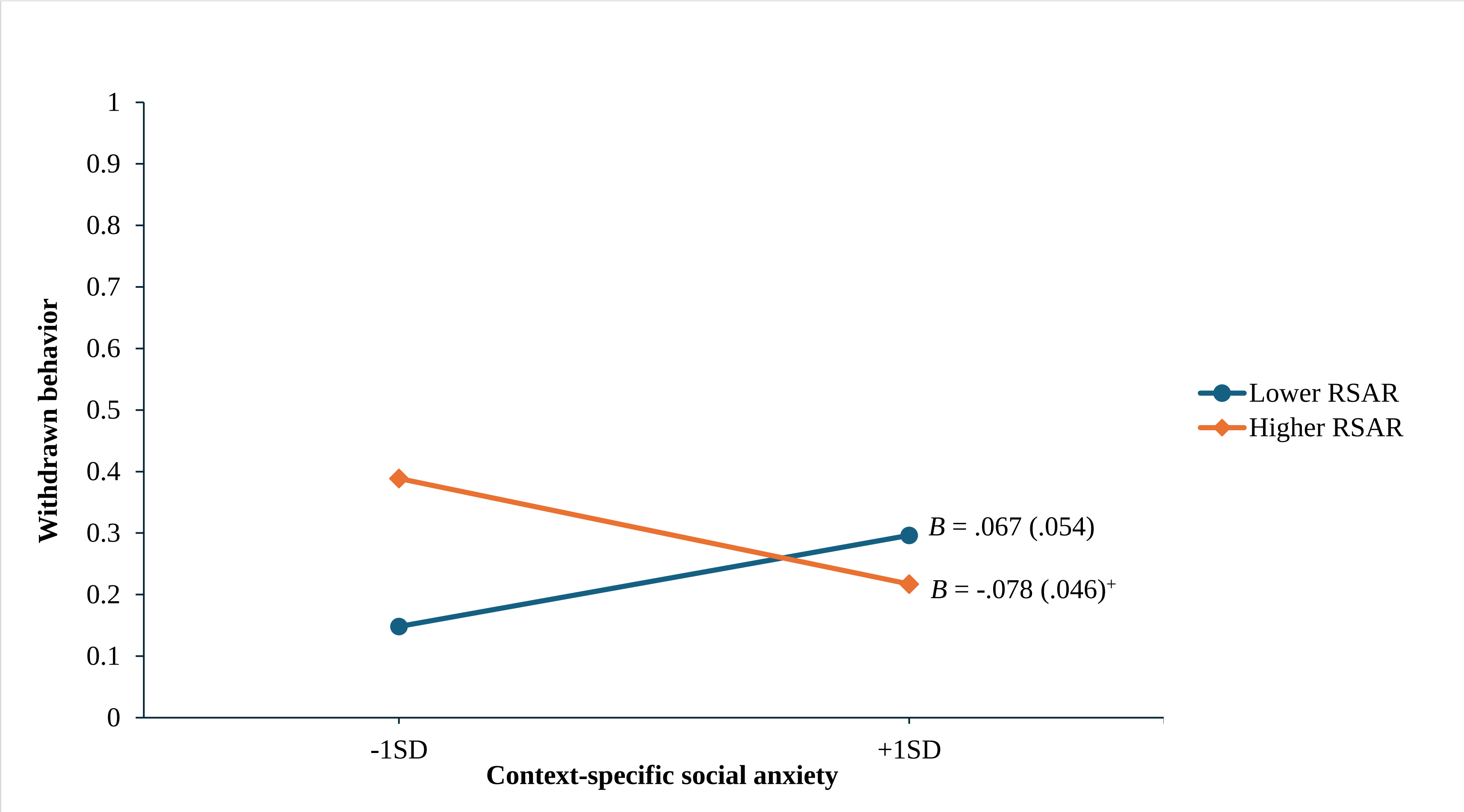

Figure 29. The association between context-specific social anxiety (CSSA) and teacher-reported withdrawn behavior moderated by respiratory sinus arrhythmia reactivity (RSAR) – From the set of models with RSAR and PEPR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

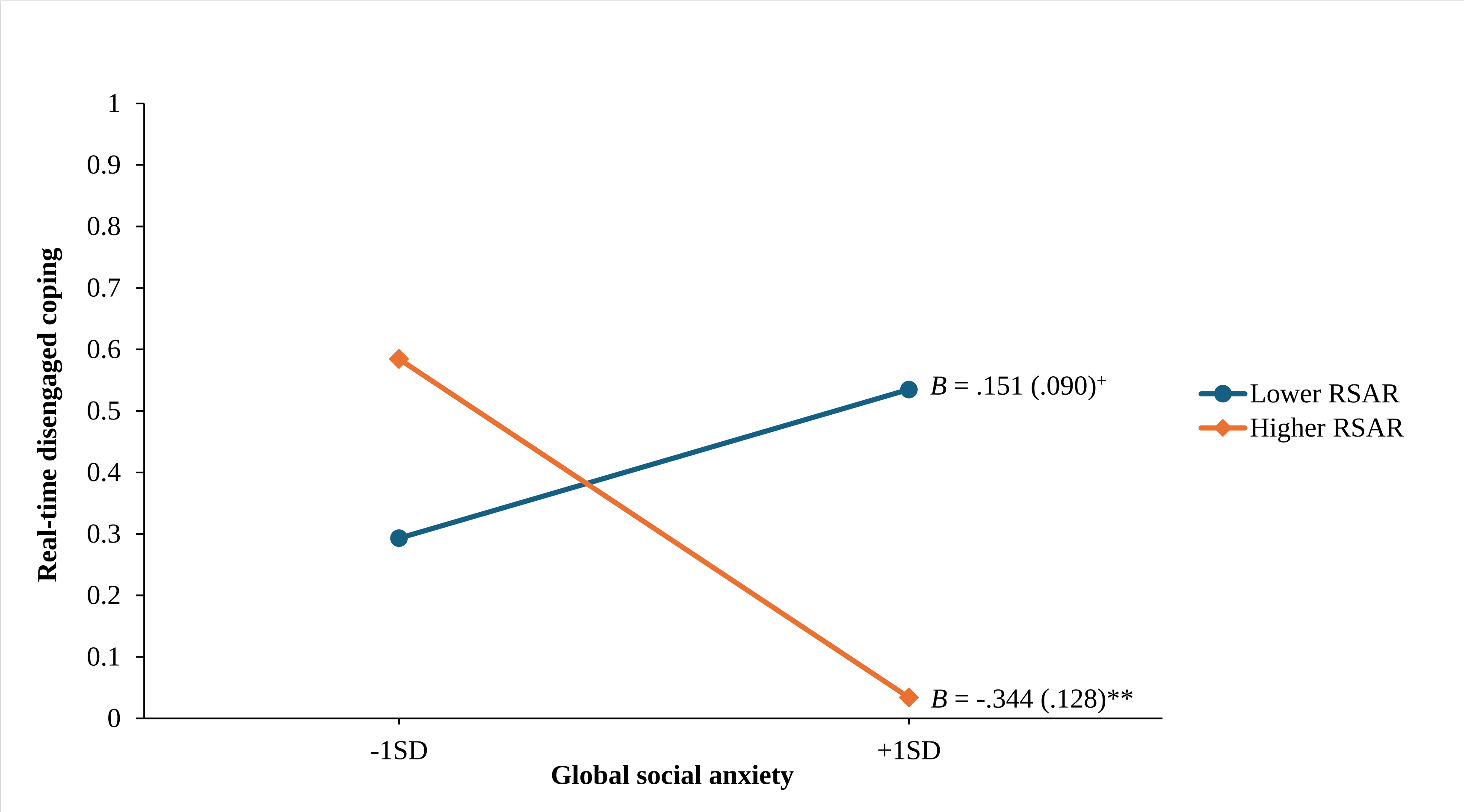

Figure 30. The association between global social anxiety (GSA) and real-time disengaged coping responses moderated by respiratory sinus arrhythmia reactivity (RSAR) – From the set of models with RSAR and PEPR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

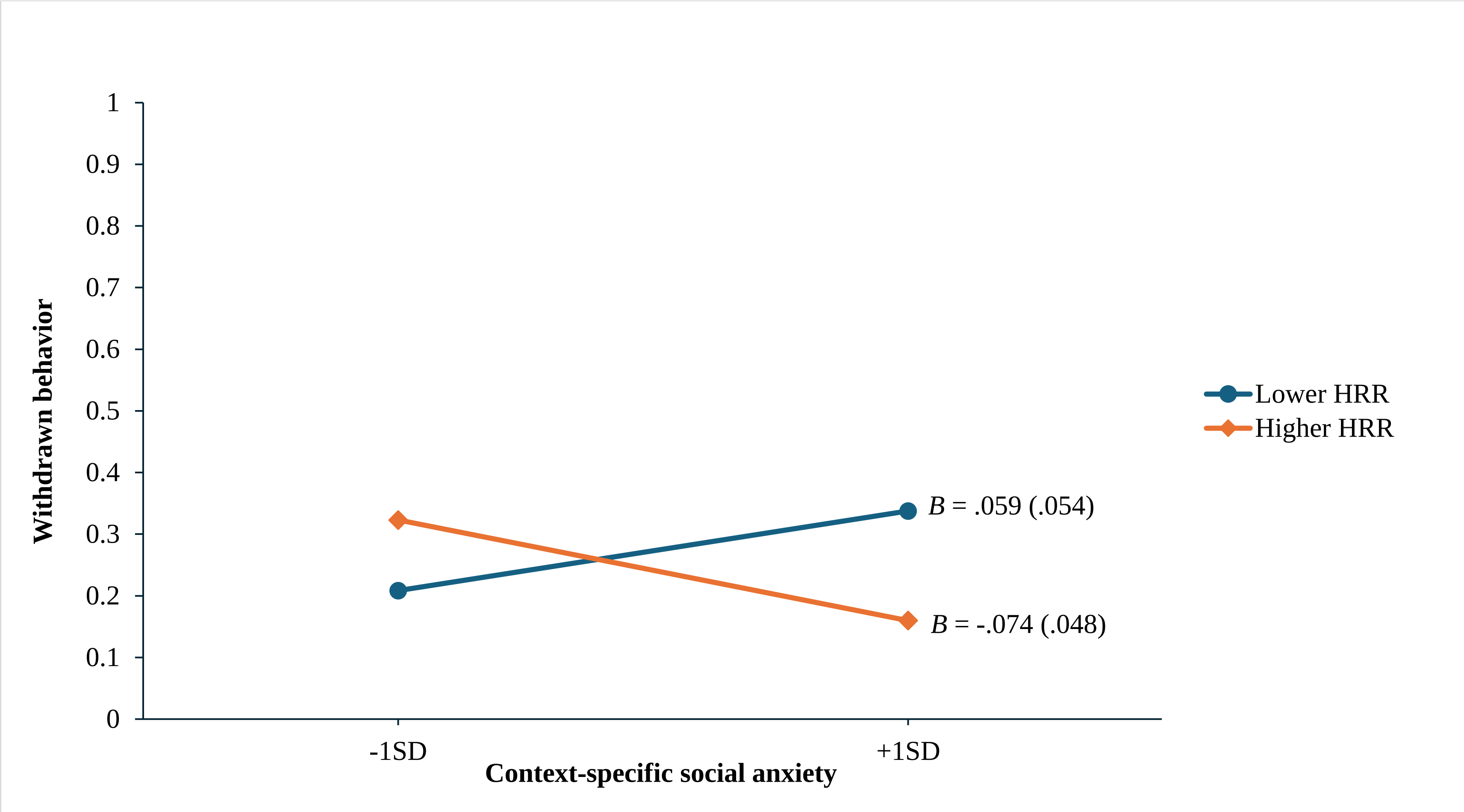

Figure 31. The association between context-specific social anxiety (CSSA) and teacher-reported withdrawn behavior moderated by heart rate reactivity (HRR). $^{+}p < .10$, $*p < .05$, $**p < .01$

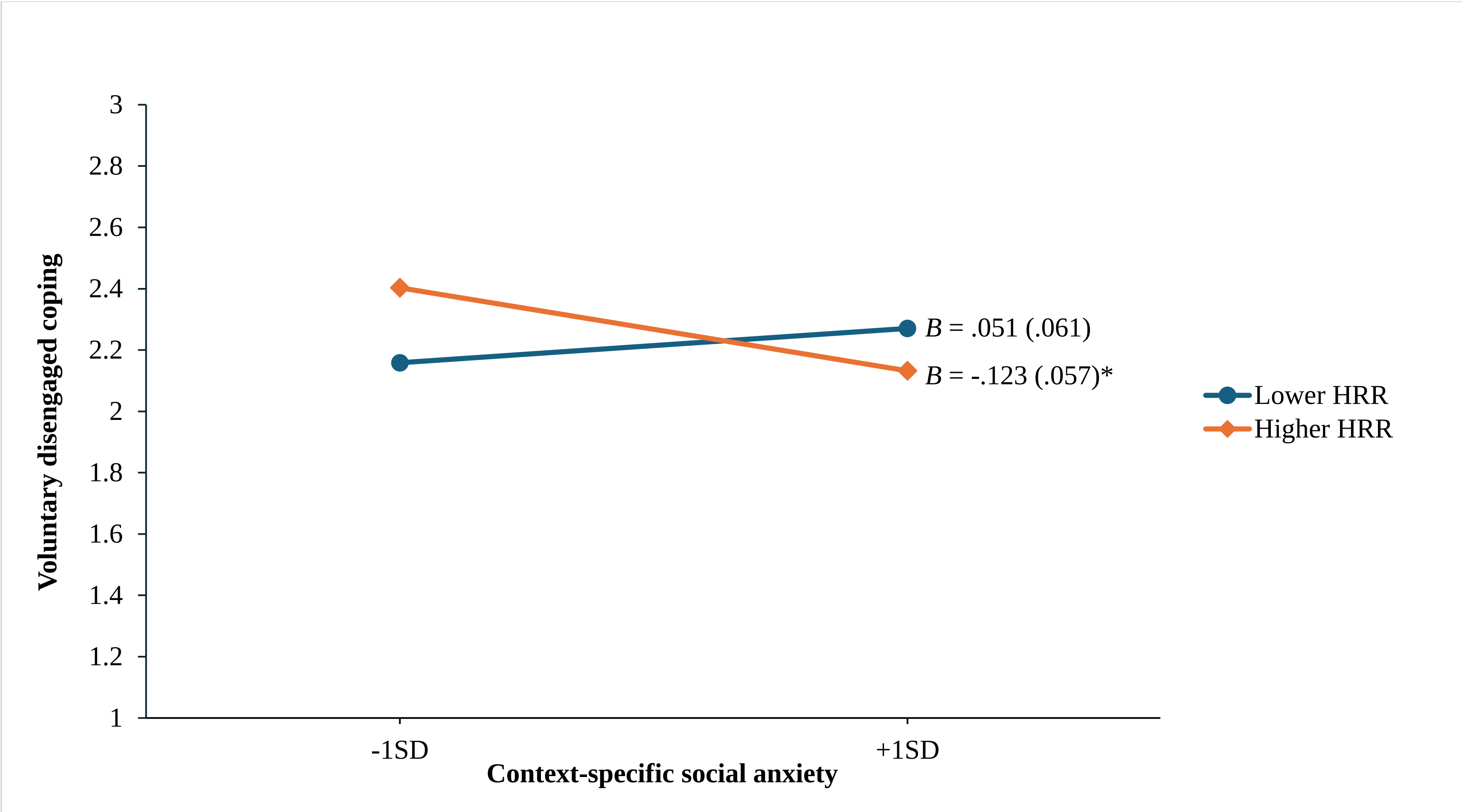

Figure 32. The association between context-specific social anxiety (CSSA) and voluntary disengaged coping responses moderated by heart rate reactivity (HRR). $^{+}p < .10$, $*p < .05$, $**p < .01$

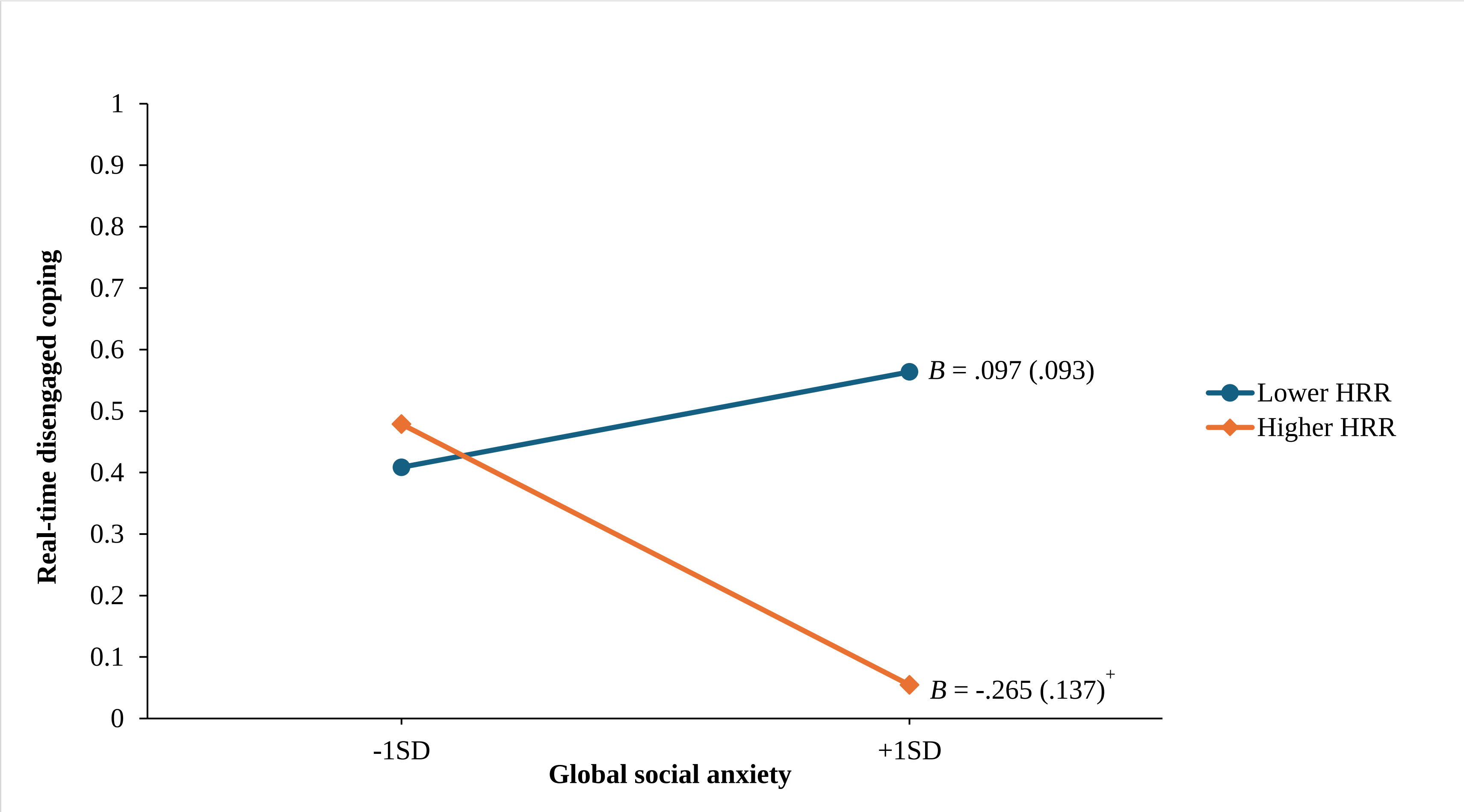

Figure 33. The association between global social anxiety (GSA) and real-time disengaged coping responses moderated by heart rate reactivity (HRR). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

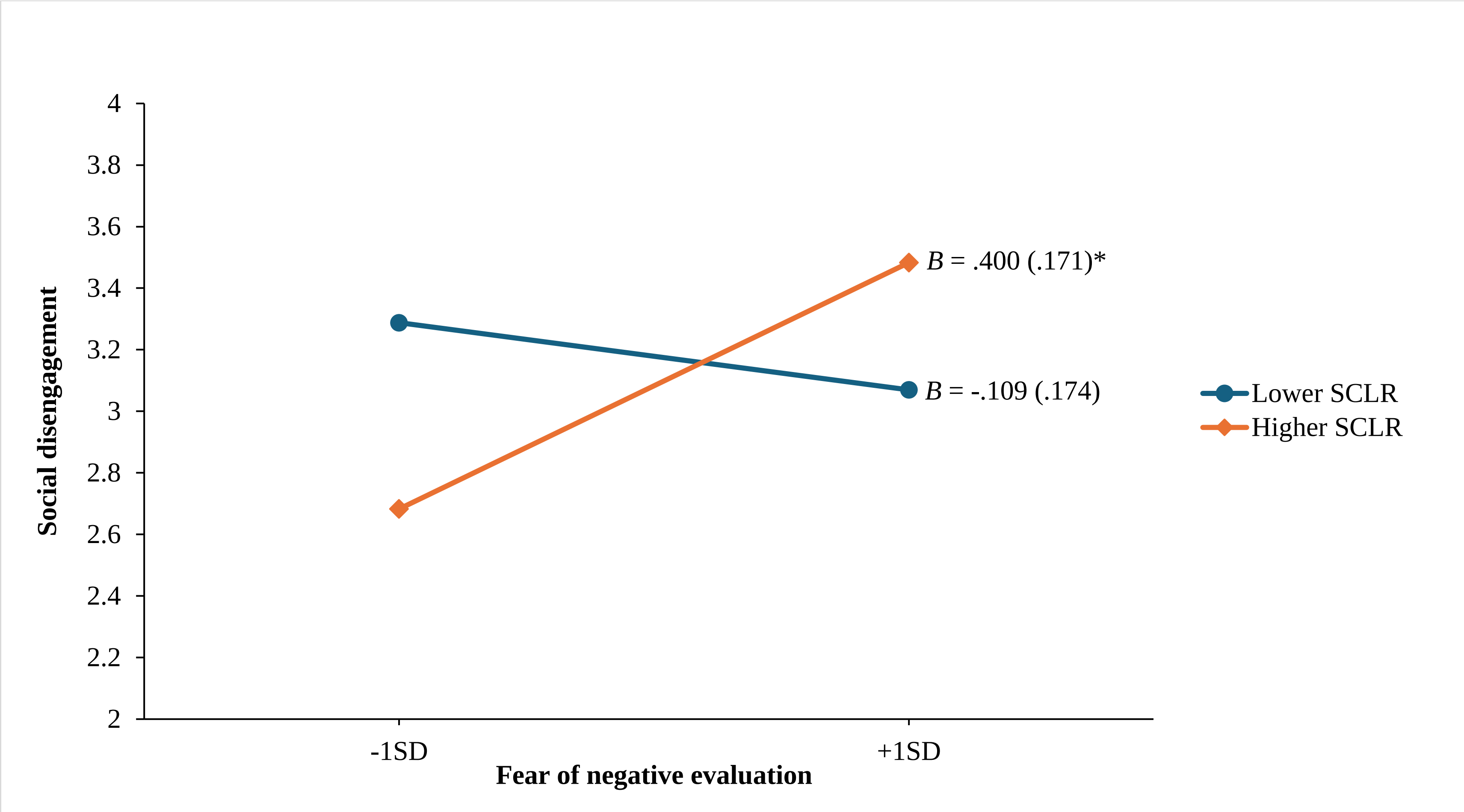

Figure 34. The association between fear of negative evaluation (FNE) and observed social disengagement moderated by skin conductance level reactivity (SCLR). $^{+}p < .10$, $*p < .05$, $**p < .01$

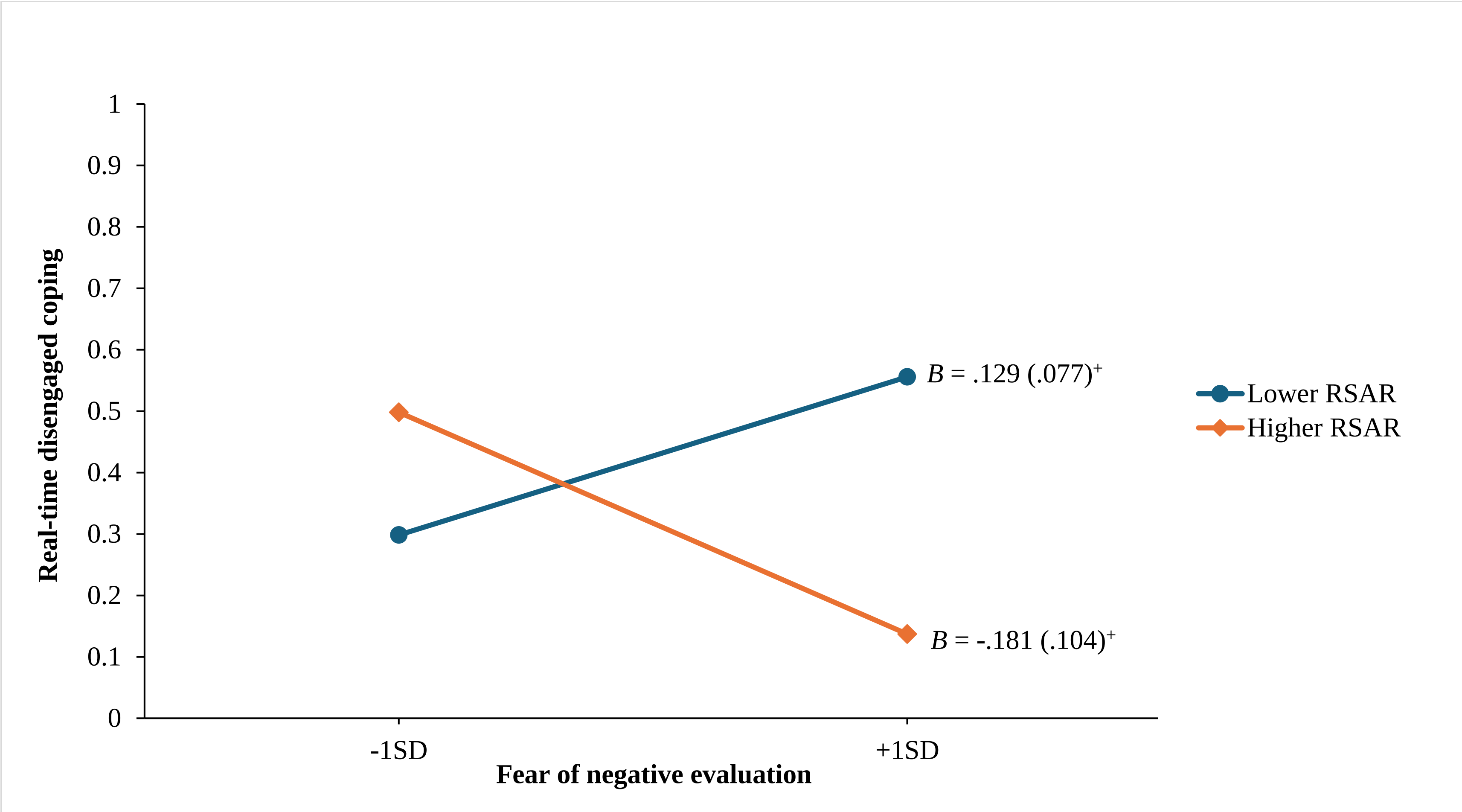

Figure 35. The association between fear of negative evaluation (FNE) and real-time disengaged coping responses moderated by respiratory sinus arrhythmia reactivity (RSAR) – From the set of models with RSAR and SCLR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

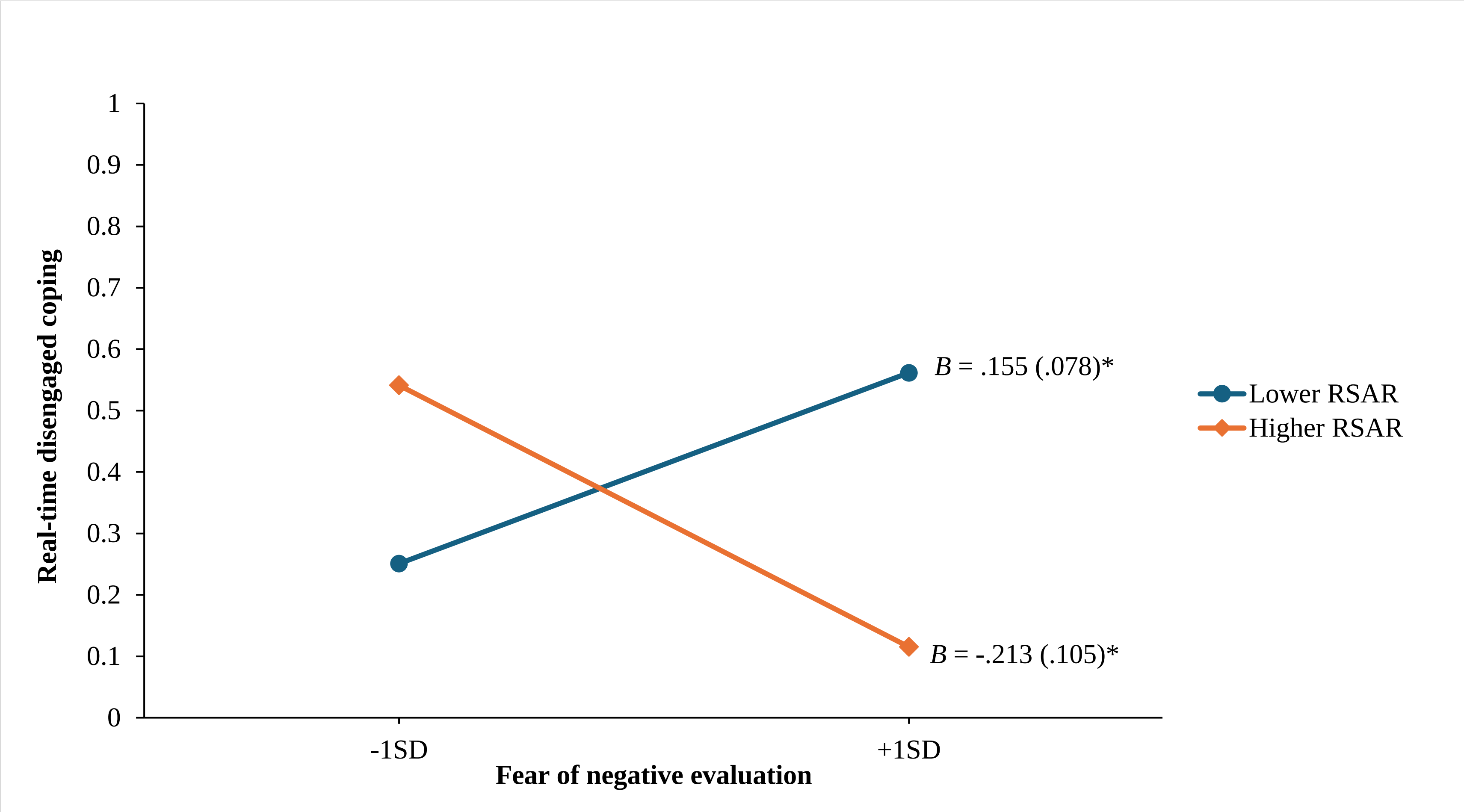

Figure 36. The association between fear of negative evaluation (FNE) and real-time disengaged coping responses moderated by respiratory sinus arrhythmia reactivity (RSAR) – From the set of models with RSAR and PEPR. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$

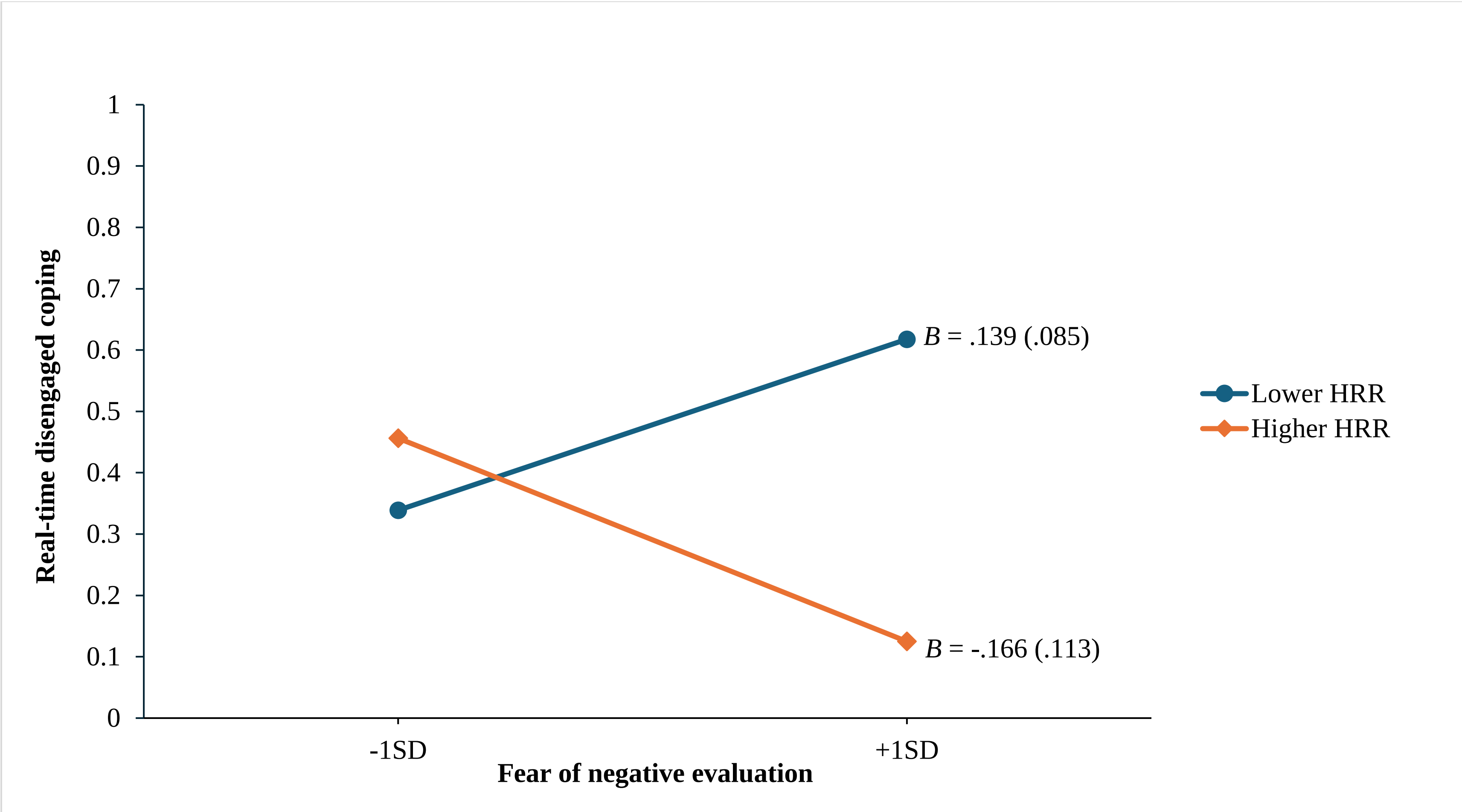

Figure 37. The association between fear of negative evaluation (FNE) and real-time disengaged coping responses moderated by heart rate reactivity (HRR). $^{+}p < .10$, $*p < .05$, $**p < .01$

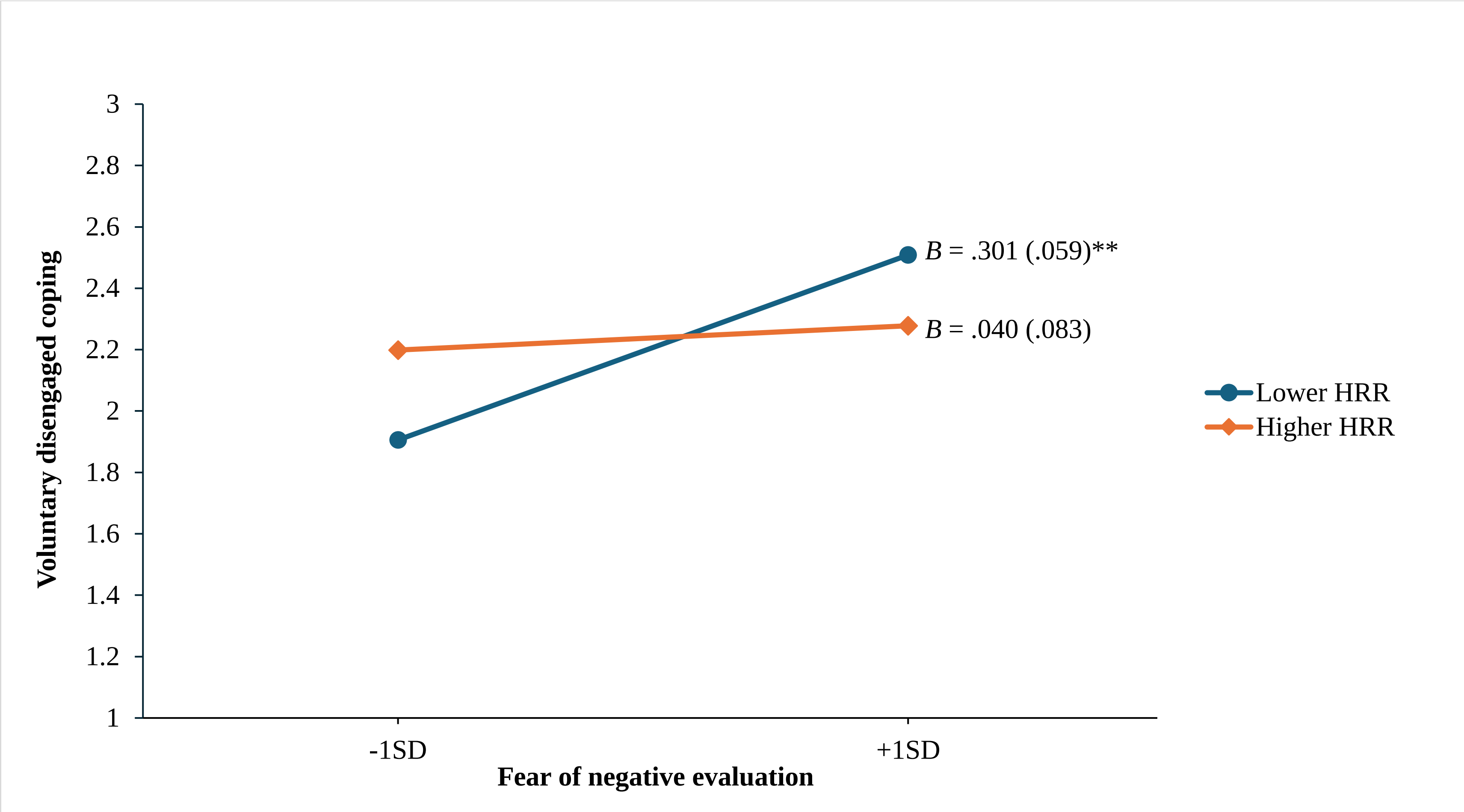

Figure 38. The association between fear of negative evaluation (FNE) and voluntary disengaged coping responses moderated by heart rate reactivity (HRR). $^{+}p < .10$, $*p < .05$, $**p < .01$