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How the Quality of Peer Experiences Moderate BI Adolescent's Physiological Reactivity to
Stress

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ABSTRACT

Temperament, such as behavioral inhibition (BI), has been found to be a predictor of social anxiety in adolescents. Additionally, poor emotional regulation underlies social anxiety. However, it is thought that positive peer friendships may serve as a protective mechanism against social anxiety in BI adolescents. Additionally, prior studies have found that both poor baseline respiratory sinus arrhythmia (RSA) and RSA withdrawal is associated with social anxiety. The goal of the present study is to analyze how peer experiences moderate the association between behavioral inhibition and adolescent social anxiety, and how adolescent social anxiety is associated with biological reactivity to stress during the adolescent developmental period. Results suggest that higher levels of perceived support from a best friend are positively associated with social anxiety specifically for BI adolescents. In addition, lower baseline RSA was associated with higher levels of social anxiety, while RSA reactivity to a stress task was not significantly associated with social anxiety. Overall, our results highlight that BI adolescents' quality of peer relationships may not necessarily be a protective factor in the development of social anxiety during adolescence. Additionally, adolescents with low baseline RSA may have difficulty regulating emotions, leading to the emergence of social anxiety.

TABLE OF CONTENTS

LIST OF FIGURES	iii
LIST OF TABLES	iv
ACKNOWLEDGEMENTS	v
Chapter 1 Introduction	1
The Development of Social Anxiety in Adolescence	2
Behavioral Inhibition (BI) and Risk for Social Anxiety	3
Peer Relationships Moderate the Association Between BI and Social Anxiety	5
The Significance of Physiology Underlying Social Anxiety	6
The Present Study	8
Chapter 2 Methods	9
Participants.....	9
Procedures.....	10
Screening Questionnaire	10
Adolescent At-Home Questionnaire	10
Trier Social Stress Task	10
Measures	11
Behavioral Inhibition Questionnaire (BIQ)	11
Social Anxiety Scale for Adolescent (SAS-A)	12
Network of Relationships Inventory-Social Provisions Version (NRI-SPV).....	12
Respiratory Sinus Arrhythmia (RSA).....	13
Data Analytic Plan	14
Chapter 3 Results	15
Descriptives and Correlations	15
Perceived Support and BI as a Predictor of Social Anxiety	16
Perceived Conflict and BI as a Predictor of Social Anxiety	17
Chapter 4 Discussion	19
Peer Experiences Moderate the Association between Behavioral Inhibition and Social Anxiety	19
Assessing Correlations Between BI, RSA, and Social Anxiety	21
Limitations and Future Directions	23
Conclusion	25
Appendix A Tables and Figures	27
BIBLIOGRAPHY	29
ACADEMIC VITA.....	34

LIST OF FIGURES

Figure 1: Regression results between BIQ and SASA moderated by supportive peer relations 27

Figure 2: Regression results between BIQ and SASA moderated by conflict peer relations.. 28

LIST OF TABLES

Table 1: Means, Standard Deviation, and Bivariate Correlations	27
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Chapter 1

Introduction

Social anxiety disorder (SAD) is characterized by persistent, intense fear or anxiety about specific social situations because you may be judged, embarrassed, or humiliated. The typical age of diagnosis of social anxiety is during the adolescent time period (Stein & Stein, 2008) . There are biological (i.e. puberty) as well as social changes that make the transition from childhood to adolescence a period of development associated with greater risk for social anxiety (Stein & Stein, 2008). There are individual differences that may help identify which adolescents are at most risk for developing social anxiety, such as temperament (Stein & Stein, 2008). Behavioral inhibition is an early temperament trait that is the tendency to withdraw from unfamiliar situations and environments (Fox et al., 2005). However, not all BI children go onto develop social anxiety, and there are several factors that have shown to moderate the association. One possible moderator is the quality of peer relationships, as this developmental period is when peer groups become increasingly more important (Jaworska & MacQueen, 2015). Adolescents will typically trust and build friendships that will carry on past this time period. Therefore, the presence or absence of supportive peer friendships may play a role in protecting against social anxiety in adolescence.

The purpose of the present study is to understand how the quality of peer experiences moderate BI children's physiological reactivity to stress. More specifically, we are interested in how perceived support from a best friend could be protective. The identification of potential risk

and protective factors of social anxiety could provide insight to developmental processes to target during intervention of SAD.

The Development of Social Anxiety in Adolescence

The adolescent developmental period is a period of risk for developing social anxiety disorder (Jaworska & MacQueen, 2015). Studies show that the onset of social anxiety disorder is commonly during ages 10-19 (Beesdo et al., 2007). Adolescence is a period of developmental change that includes social changes in the environment as well as physical and biological changes as an adolescent undergoes puberty (Jaworska & MacQueen, 2015). This may impact the ability for the adolescent to properly regulate their emotions, leading to an increased risk of developing anxiety (Jaworska & MacQueen, 2015). Social anxiety is an internalizing disorder that affects one's ability to engage in social situations. There are both specific behaviors and physical symptoms that occur with social anxiety (Stein & Stein, 2008). People will often exhibit fear of social situations and avoid them. This is due to an intense fear of saying or doing something wrong resulting in embarrassment (Stein & Stein, 2008). Physical symptoms typically include a rapid heartbeat, excessive sweating, trembling, and trouble concentrating.

One possible factor that may lead to increases in social anxiety during adolescence is the role of self-regulation. During adolescence, there are changes in autonomy in the development emotional regulation that may also be heightened by biological changes associated with puberty. During childhood, emotion regulation may occur with the help of caregivers or parents (Sameroff, 2010). When a child transitions to adolescence, the caregiver plays a less prominent role in regulating emotions and thus the adolescent must regulate independently (Sameroff,

2010). If an adolescent has difficulty regulating emotional reactivity during stressful situations, there may be an increased risk for developing social anxiety and other internalizing symptoms (Young et al., 2019). This shift to independent emotional regulation coincides with changes in both biological and social contexts from childhood to adolescence, thus increasing risk for SAD.

There are multiple individual and social factors that have been identified as associated with greater or less risk of developing social anxiety. These factors can be used as an early indication of social anxiety in adolescents. By identifying factors associated with greater risk of SAD earlier, diagnosis and subsequent treatment can occur faster. Additionally, identification of the factors that pose greater risk of developing SAD will allow for future research to examine them more and ways to treat SAD before cases could get severe.

Behavioral Inhibition (BI) and Risk for Social Anxiety

One factor that increases risk for developing social anxiety in adolescents is a variation in temperament. Temperament is the early appearing variation in emotional stability that tends to stay constant throughout one's life (Fox et al., 2005). One aspect of temperament is behavioral inhibition (BI), which is defined as the persistent tendency to show extreme reticence, fearfulness, or avoidance in novel situations and with unfamiliar people (Hirshfeld-Becker et al., 2008). BI has been suggested to confer risk of social anxiety in childhood and the adolescent time period (Hirshfeld-Becker et al., 2008).

There are multitude of studies highlighting how having BI can influence the development of anxiety. Longitudinal studies have shown that toddlers exhibiting high levels of BI at age 2 had higher risk for developing social anxiety at age 13 (Fox et al., 2005). This research

highlights that temperament may predict trajectories of social anxiety in children across childhood into adolescence. Similarly, a cross sectional study of 12-18-year-olds assessed levels of BI and internalizing symptoms such as anxiety. It was found that individuals with high levels of inhibition also had increased development of internalizing symptoms (Muris et al., 2001). Similarly, a 20 year longitudinal study of children from birth into adolescence has shown that BI symptoms appearing at ages 14 are associated with increased social anxiety (Frenkel et al., 2015).

However, not all children with BI go on to developing social anxiety. Nearly 60% of children with BI do not go to develop social anxiety in adolescence (Fox et al., 2020). From a biopsychosocial approach, we know that development trajectories can be altered by both the individual's temperament and the surrounding context of the individual such as their friends and caregivers (Sameroff, 2010). One possibility may be how BI children process their environment. Children that typically exhibit BI psychopathology when interacting with peers are said to utilize a stimulus driven automatic control process (Fox et al., 2020). The child remains fixated on the peer's thoughts and judgements about themselves and shifts their focus away from the goal of socializing. The automatic control process is defined as reactive changes in attention inhibition in response to a stimulus (Fox et al., 2020). A child that deploys this process is considered at risk for social anxiety. A BI child that engages in more goal-driven (planful) processes are able to focus on social engagement, decreasing risk of developing social anxiety. Planful control is defined as proactive changes in attention inhibition in support of a specific goal (Fox et al., 2020). Therefore, the way that adolescents process their environment may influence the risk of developing social anxiety. Additionally, this research shows that not all individuals affected by BI go on to develop social anxiety.

Peer Relations in Adolescence

The presence of positive or negative peer relations may influence the risk of developing social anxiety in adolescents. The period of adolescence is often a time where adolescents invest time in fostering important relationships. Oftentimes, adolescents will designate one specific friend as their best friend. Specifically, there is research that the best friend relationship may help to promote and maintain prosocial behavior (Pickering et al., 2020). Having a best friend increases peer acceptance and positive peer relations. Additionally, supportive best friendships can be protective for socioemotional outcomes. A supportive best friend increased peer support and decreased any peer victimization that may occur as a result of the child being seen as awkward or shy (Pickering et al., 2020). Additionally, the positive friend protects against social anxiety (Pickering et al., 2020). Therefore, the relationship with a best friend may be associated with a reduced risk of developing social anxiety for children higher in BI.

Peer Relationships Moderate the Association Between BI and Social Anxiety

There is an interplay between the degree of behavioral inhibition and the quality of peer relations in emotion development. A study of 224 toddlers examined the relation between BI and peer relations. It was found that toddlers that exhibited high levels of behavioral inhibition and negative peer relations, were not able to accurately process conflicting emotions (Suway et al., 2012). This is identified as the Theory of Mind (ToM). These children have a harder time regulating emotions and therefore are at risk of developing associated internalizing symptoms. Although this study examines a much younger demographic than the current one, it is likely that the interplay of BI and peer interactions may continue as the child enters into adolescence.

Peer relations may moderate the relationship between BI and the emergence of internalizing symptoms, including social anxiety, in adolescence. A 20-year longitudinal study of 165 participants examined the moderating effects of positive and negative peer relations on BI children and their resulting internalizing symptoms (Frenkel et al., 2015). The children that exhibited BI were found to have an increased risk of developing social anxiety. Additionally, the added factor of negative social interaction in the adolescent time period heightened the risk for the development of internalizing symptoms. The positive effects of adolescent socialization lowered the risk of developing internalizing symptoms (Frenkel et al., 2015). The moderating effect of positive peer relations may act as a protective factor against the development of internalizing symptoms while also exhibiting BI. This again highlights the importance of the adolescent development period in examining some of these processes. Therefore, the quality of these friendships can be protective or detrimental to the risk of developing psychopathology later in life.

The Significance of Physiology Underlying Social Anxiety

Physiological response to stressful stimuli can be used to predict the risk of developing internalizing symptoms in adolescents (Porges, 1995). Respiratory Sinus Arrhythmia (RSA) is a measure of parasympathetic nervous system activity to assess the stress response and vulnerability to stress. The vagus nerve is responsible for the parasympathetic regulation of the heart and thought to regulate emotions in challenging situations (Porges, 1995). There are two common measurements of RSA, resting baseline and reactivity. Resting RSA is thought to highlight the physiological flexibility in response to emotional challenges, while the change in

RSA is thought to be a biomarker for one to adaptively regulate emotions during a task (Fortunato et al., 2013; Khurshid et al., 2019). Reactive RSA can also be thought of how quickly the body is able to react to stressors. Many studies find that low baseline RSA and high RSA suppression (reduction in reactivity) are associated with emotional dysregulation and internalizing symptoms in children (Fortunato et al., 2013; Khurshid et al., 2019). Therefore, both RSA baseline and reactivity are useful tools to measure the risk for developing internalizing symptoms.

RSA has been utilized as a biomarker in many BI adolescent studies as a physiological indicator of anxiety. Prior research has also demonstrated that both baseline and reactivity RSA can predict internalizing symptoms in preschool aged children (Viana et al., 2017). A study of 44 behaviorally inhibited 9-year-olds interacting with a mystery guest found that low baseline and high RSA suppression were associated with high degree of internalizing symptoms, while low levels of BI did not show this interaction (Viana et al., 2017) . This study highlights when children were presented to a strange individual low baseline RSA and RSA withdrawal served as physiological biomarkers for internalizing symptoms. Additionally, a study of 160 12-year-old boys examined how high degrees of social withdrawal and low RSA reactivity predicted increased risk for social anxiety (Morgan et al., 2013). These studies highlight the use of RSA to analyze the risk of developing internalizing symptoms during late childhood, but we are interested in this association during the adolescent developmental period. Knowing the adolescent development period is a time of increased risk for developing anxiety, the amount of social behavior may influence the physiological response to novel stimuli. However, BI may inhibit many adolescents from acquiring positive peer interactions and lead to the inability to physiologically regulate their emotions, putting them at risk for anxiety.

The Present Study

Previous research demonstrates that the adolescent developmental period is the typical age of diagnosis for SAD, therefore research on this developmental period is important. Prior studies have shown that behavioral inhibition increases the risk for developing social anxiety during the adolescent development period (Frenkel et al., 2015; Suway et al., 2012; Viana et al., 2017). However, positive peer relations have been found to protect against the emergence of social anxiety in adolescents (Daniel et al., 2020; Pickering et al., 2020). Furthermore, adolescents with BI typically have trouble regulating emotions. Prior research has found that low baseline RSA, along with RSA withdrawal during stressful tasks, were successfully able to regulate emotions and decreased emergence of social anxiety.

. Our current study is interested in the emergence of social anxiety in adolescents due to peer relations. Furthermore, the design of the TSST is to simulate a stressful social situation. Due to our interest in social stress, the TSST allows for testing both behavioral and physiological reacts to these social stressors, which can be indicators for risk of social anxiety in the future.

The goal of the present study is to analyze (1) how peer experiences moderate the association between behavioral inhibition and social anxiety symptoms, and (2) associations between resting RSA, RSA reactivity to stress and social anxiety symptoms. We hypothesized that peer relationships will moderate the associations between behavioral inhibition and social anxiety. Specifically, high support friendships will be associated with lower reports of social anxiety in BI adolescents. We also hypothesized that both baseline and reactivity RSA will be negatively correlated with behavioral inhibition and social anxiety.

Chapter 2

Methods

Participants

115 adolescents (54.1% female, 43.5% male, and 2.4% other) and their parents were recruited as a part of an ongoing, longitudinal study conducted in two locations (one small city/semi-rural, one urban). Data for the current study are from the first wave of data collection when adolescents were aged 13-14. The ethnicities of the adolescents were White (71.3%), Asian (1.7%), Black/African American (7.8%), Hispanic or Latinx (4.3%), Native Hawaiian (0.9%), and American Indian (1.7%). The adolescents' annual family incomes were as follows: less than \$15,000 (2.5%), \$16,000-\$20,000 (3.7%), \$21,000-\$30,000 (2.5%), \$31,000-\$40,000 (9.9%), \$41,000-\$50,000 (9.9%), \$51,000-\$60,000 (6.2%), above \$60,000 (65.4%).

Data collection was impacted by the COVID-19 pandemic, with 43.8% of data collected pre-pandemic, and 56.3% collected during the pandemic. As a result, we created a variable indicating if data collection was prior or during the pandemic, and controlled for this variable in all analyses. However, we only have physiology data on 34 adolescents that were collected pre-pandemic.

Procedures

Screening Questionnaire

Screening questionnaires were given administered to parents prior to any lab visit, and parents completed questionnaires on their adolescents' temperament and anxiety symptoms.

Adolescent At-Home Questionnaire

The adolescent at-home questionnaires were questionnaires that adolescents completed at home online, including questionnaires assessing self-reported anxiety symptoms and perceived relationships.

Trier Social Stress Task

The Trier Social Stress Task (TSST; (Kirschbaum et al., 1993)) is a socio-evaluative task driven experiment to gather RSA data during both baseline and stressful situations. All participants were scheduled for lab visits between 4 PM and 6 PM. The participants were given a baseline task where they sat quietly for 3 minutes, stood quietly for 2 minutes and read out a neutral passage for 1 minute. Participants were then given questionnaires to complete for 30 minutes.

After the baseline measurements, the participant is instructed that they will be giving a speech about themselves for 5 minutes to two judges. The participant has 5 minutes to prepare

their speech and is given a whiteboard to jot down notes. After 5 minutes, the judges enter the room and instruct the participant that they have 5 minutes to present their speech to them. While the participant gives their speech, the judges are instructed to show no emotion and stay neutral. Once the 5 minutes has expired, the math portion of the study commences. This involves a 5-minute subtraction problem. The participant subtract 13 consecutively from the number 6233 until the 5 minutes is expired. If the participant subtracts incorrectly, a judge tells them they must begin again at the number 6233.

After this period, the participant gives another saliva cortisol sample and the recovery phase begins. This consists of both sitting alone in a room for 15 minutes and also a 15-minute non-affective video recovery phase. The parent and child both receive compensation for their time. As a student research assistant in this lab I was responsible for being the judge on multiple adolescent TSST studies.

Measures

Behavioral Inhibition Questionnaire (BIQ)

The BIQ (Kim et al., 2011) is a 30-item questionnaire administered to parents to assess levels of behavioral inhibition in their adolescents. Each item describes an observation of the child from the parent's view (*Approaches new situations or activities very hesitantly*). Parents use a 7-point scale to rank observed behaviors on their child's behavioral inhibition (1-hardly ever, 2-Infrequently, 3-Once in a while, 4-sometimes, 5-often, 6-very often, 7-almost always). There are two broad subscales: Social Novelty Inhibition and Situational Novelty Inhibition. Social novelty inhibition is made up of subscales on social novelty inhibition around adults, peer

and performance. Separation, New situations, and Physical Challenges make up the situational novelty subscale score. All items on the questionnaire also are summed to create a total Behavioral Inhibition score, with higher levels indicating that the adolescents have behavioral inhibition.

Social Anxiety Scale for Adolescent (SAS-A)

The SAS-A (García-López et al., 2001) is a 22-item adolescent self-report questionnaire to assess their fears, concerns or worries regarding peer's negative evaluations and distress with new social situations. Each item assesses how much the adolescent feels that attribute is true for them (*I worry about doing something new in front of others or I like to do things with my friends*). This is scored on a 5-point scale to rank how much they feel each item is true for them (1-not at all, 2-Hardly ever, 3-sometimes, 4-Most of the Time, 5-all of the time). There are 3 subscales which include Fear of Negative Evaluation (FNE), consisting of 8 items examining concerns of negative peer evaluations. Another subscale is the Social Avoidance and Distress in New Situations (SAD-New) which consist of 6 items examining avoidance with new social situations. The final subscale is Social avoidance and distress -general (SAD-General) which consist of 4 items examining social inhibition and distress. There is also a total score that is the average of the two subscales (SAD-Total).

Network of Relationships Inventory-Social Provisions Version (NRI-SPV)

The NRI-SPV (García-López et al., 2001) is 39-item adolescent self-report questionnaire to examine relationship characteristics across different types of personal relationships. Each item

examines a characteristic of the subject's relationship (*How much do you and this person get upset with or mad at each other?*). These include evaluating relationships with a mother figure, father figure, sibling, relative, romantic friend, same-sex friend, other-sex friend, and an extra person. There is a 5-point scale to explain how often the particular item pertains to each relationship (1-little or none, 2-somewhat, 3-very much, 4- Extremely much, 5-the most). The NRI-SPV has 10 subscales (i.e., Companionship, Conflict) with three items per subscale. There are two second order factors (Support and Negative Interactions) that are computed by averaging items such as Companionship under the factor Support and Conflict under the factor Negative Interactions. Support interactions include Companionship, Instrumental Aid, Intimate Disclosure, Nurturance, Affection, Admiration, and Reliable Alliance. Negative interactions include Conflict and Antagonism. Adolescents were asked to identify which friend (or relative) they considered their best friend, and Support and Negative Interactions for that relationship were used in the present study.

Respiratory Sinus Arrhythmia (RSA)

Electrocardiogram (ECG) data was collected with the use of Mindware WiFi ACQ software, Version 1.0 (Mindware Technologies, Ltd., Westerville, OH) at a sampling rate of 500 ms. Three electrodes were placed over participants' distal right collarbone, lower left rib, and lower right rib to acquire the ECG signal (four additional electrodes were placed on participants' torsos to derive impedance data, which are not considered in this report).

Data was analyzed offline using the Mindware editing program Mindware HRV, Version 3.1.4, which identified interbeat-intervals (IBIs) and detected physiologically improbable

intervals based on overall distribution using a validated algorithm (Berntson et al., 1990). All data were visually inspected for artifact identification and editing by trained personnel. RSA was calculated in 30-second epochs for the frequency band 0.12-0.40 Hz power band. Interrater reliability was calculated on approximately 20% of the data. For data to be considered as reliable, final RSA values for any 30 second epoch from two scorers needed to fall within 0.1 of one another (Buss et al., 2011).

Reactivity scores were computed by subtracting the mean baseline scores and the mean RSA speech scores. A positive number indicates that the RSA increased from baseline (RSA Augmentation). A negative number indicates that RSA decreased compared to the baseline (RSA Suppression). As a student research assistant, I was responsible for cleaning and working with the RSA data received from the TSST studies. I was responsible for ensuring the accuracy of both the baseline RSA and the RSA reactivity in accordance with correct IBIs.

Data Analytic Plan

To test if supportive or conflictive peer relations moderate the association between BI and social anxiety in adolescents, we conducted multiple regressions with SAS-A data, BIQ data, and self-reported support and conflict peer relationships as predictors. The outcome was if support or conflict peer relations moderate the risk for social anxiety.

To test the association between resting RSA, RSA reactivity to stress and social anxiety symptoms in adolescents, I conducted correlations between BIQ data and both baseline and reactive RSA. Additionally, I ran correlations between SAS-A data and both baseline and reactive RSA. Finally, I ran correlations between baseline RSA and RSA reactivity.

Chapter 3

Results

Descriptives and Correlations

Variables	1	2	3	4	5	6	7	8
1. NRI Support	-							
2. NRI Conflict	-0.60	-						
3. BIQ Total	-0.12	-0.13	-					
4. SASA Total	0.27	-0.07	0.36	-				
5. RSA Sitting	0.25	-0.10	-0.29	-0.38	-			
6. RSA Talking	-0.01	0.13	-0.37	-0.41	0.42	-		
7. RSA Speech	-0.04	0.25	-0.18	-0.56	0.57	0.63	-	
8. RSA Speech Reactivity	0.01	0.09	0.27	-0.03	-0.02	-0.59	0.21	-
Mean	3.58	1.81	118.81	57.20	6.89	6.51	6.69	0.16
SD	0.71	0.84	33.28	12.91	1.09	0.96	0.81	0.78
N	71	72	114	80	32	30	27	27

Table 1: Means, Standard Deviation, and Bivariate Correlations

Table 1 highlights the means, SD, and N for the participants. Bolded R^2 values indicate significant findings with $p < 0.05$.

Table 1 contains the results of the bivariate correlations between RSA, BIQ and SASA data and descriptive statistics. Highlighted entries correspond to a $p < 0.05$. Correlations between RSA measures.

Resting RSA were all positively correlated. RSA during the speech task was significantly correlated with both the sitting resting and talking conditions of baseline. RSA during the talking and RSA Speech Reactivity were significantly correlated.

BIQ and RSA Talking were significantly correlated such that greater BIQ was associated with lower baseline RSA while talking. Refer to table 1.

SASA and RSA Sitting were significantly correlated such that lower baseline RSA is associated with greater scores of social anxiety (refer to table 1). SASA and RSA Talking were

significantly correlated such that lower baseline RSA was associated with higher scores of social anxiety on the SASA. SASA and RSA Speech were significantly correlated, such that lower RSA during the speech is associated with higher scores of social anxiety on the SASA (refer to table 1).

Perceived Support and BI as a Predictor of Social Anxiety

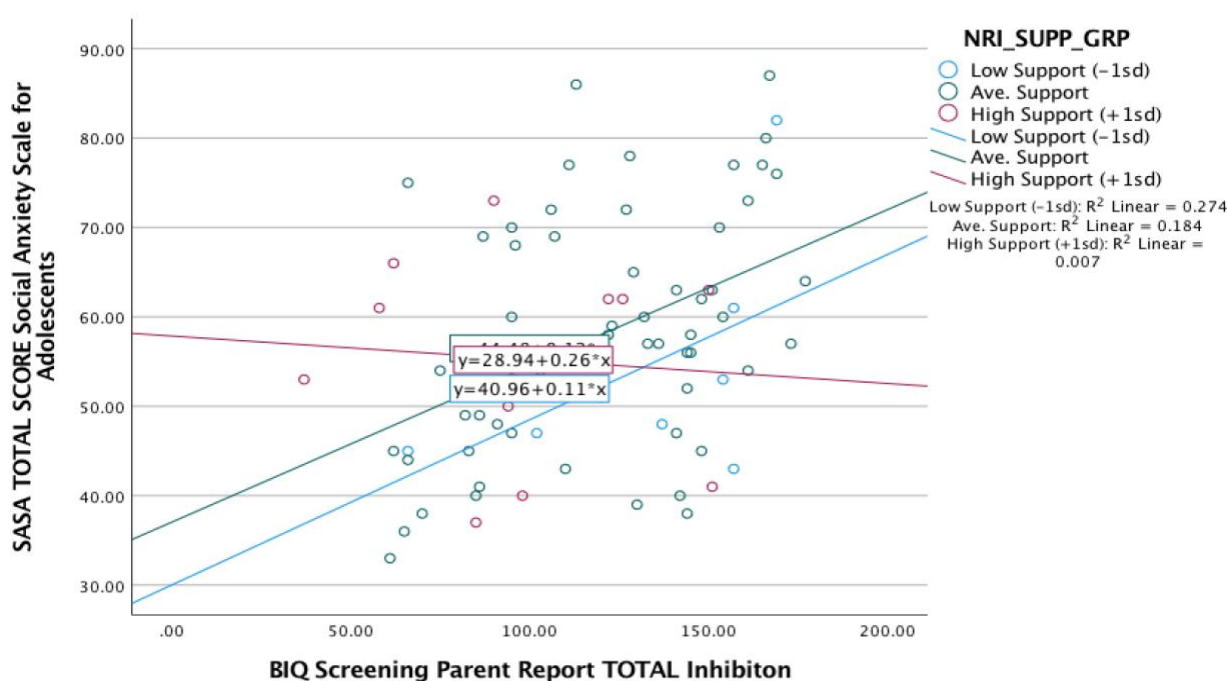


Figure 1: Regression results between BIQ and SASA moderated by supportive peer relations

Figure 1 is a regression utilizing NRI_SUPP_GRP as a predictor, which categorized level of adolescent self-reported supportive friendships as (+/-) 1 standard deviation from the mean. +1 sd corresponds to high support while -1sd corresponds to low support. Refer to table 1 for NRI_Support mean values. High support friendships were associated with higher levels of social anxiety.

Multiple regression analysis was used to examine if behavioral inhibition scores, perceived support from a best friend, and their interaction significantly predicted participants' ratings of social anxiety. The results of the regression indicated that the three predictors and two

covariates (child sex and COVID-19 status) explained 21.9% of the variance ($R^2 = .219$, $F(5, 62)=3.47$, $p < .01$). There was a main effect of behavioral inhibition scores on participants' social anxiety, $B = .34$, $t = 2.99$, $p < .01$. For participants with higher levels of behavioral inhibition, they also endorsed higher levels of social anxiety. There was no significant main effect of perceived support from a best friend, $B = .05$, $t = 0.46$, $p > .05$. However, there was an approaching interaction effect of behavioral inhibition scores and perceived support from a best friend on participants' social anxiety, $B = 0.22$, $t = 1.91$, $p = .06$. For participants with higher perceived support from a best friend, behavioral inhibition scores were more positively associated with social anxiety (see Figure 1).

Perceived Conflict and BI as a Predictor of Social Anxiety

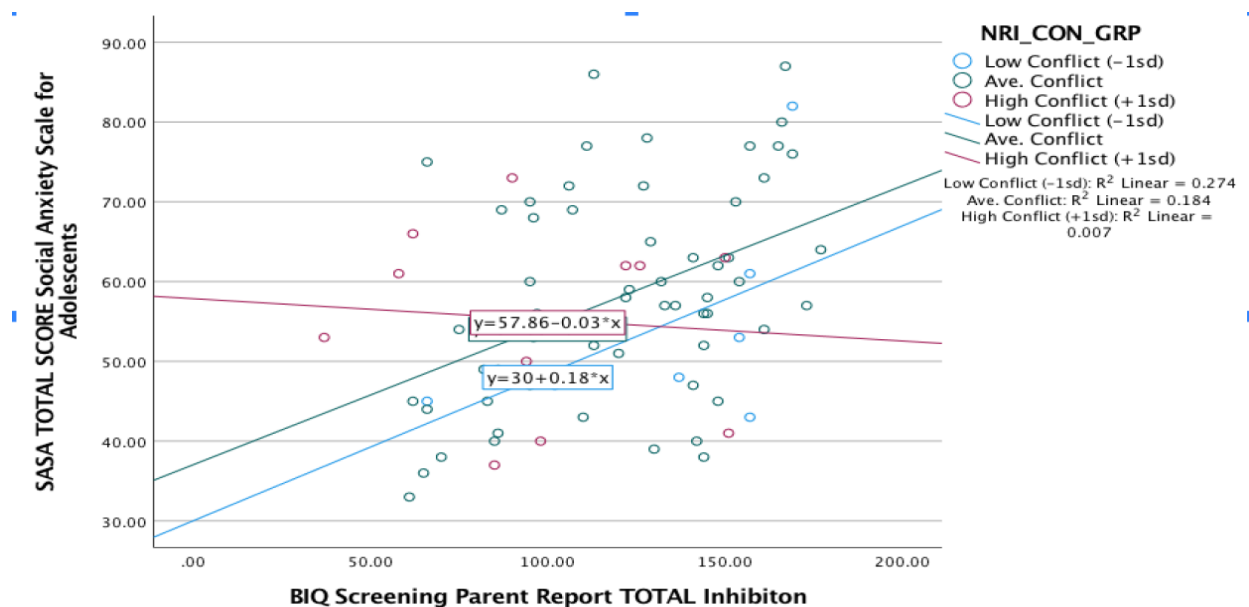


Figure 2: Regression results between BIQ and SASA moderated by conflict peer relations

Figure 2 is a regression utilizing NRI_CON_GRP as a predictor, which categorized level of adolescent self-reported conflict friendships as (+/-) 1 standard deviation from the mean. +1 sd corresponds to high conflict while -1sd corresponds to low conflict. Refer to table 1 for NRI_Support mean values No significant findings were found.

Multiple regression analysis was used to examine if behavioral inhibition scores, perceived negative interactions from a best friend, and their interaction significantly predicted participants' ratings of social anxiety. The results of the regression indicated that the three predictors and two covariates (child sex and COVID-19 status) explained 19.4% of the variance ($R^2 = .194$, $F(5, 63)=3.03$, $p < .05$). There was a significant main effect of behavioral inhibition scores on participants' social anxiety, $B = .36$, $t = 3.13$, $p < 0.01$. There was no significant main effect of perceived conflict from a best friend, $B = -0.09$, $t = -0.65$, $p > .05$. There was no interaction effect of behavioral inhibition scores and perceived conflict from a best friend on participants' social anxiety, $B = -0.18$, $t = -1.34$, $p > 0.05$. (see Figure 2).

Chapter 4

Discussion

The goal of the present study was to examine how perceived friendships may moderate associations between behaviorally inhibition and adolescent social anxiety, and how physiology may underlie adolescent social anxiety symptoms. We examined this relationship through both parents and child reported questionnaires and RSA reactivity to social stress. Results are interpreted in light of the proposed hypothesizes and current research topics. Additionally, limitations and future directions are also discussed.

Peer Experiences Moderate the Association between Behavioral Inhibition and Social Anxiety

Results indicated an approaching significant interaction between behavioral inhibition and support from a best friend on social anxiety scores. However, contrary to our hypotheses, the results indicated that higher levels of both support and behavioral inhibition were associated with higher levels of self-reported social anxiety scores. These findings indicate that friendships may not always serve as protective factors against social anxiety, especially for adolescents who may have already been at risk for social anxiety.

One possibility for why higher levels of support from a best friend was associated with greater social anxiety for adolescents with higher levels of BI may be due to our focus on capturing peer support from one friend only. Adolescents with BI may struggle with creating new friendships, such that they may not be encouraged to do so if they have one supportive friendship (Freitas et al., 2019). Additionally, they may not see a need to gain more friends

therefore may exhibit a higher degree of social anxiety when around peers that they do not know. One study examined the effects of supportive friendships on 9th graders and found that there was a positive correlation between high best friend support and self-reported social anxiety (Wit et al., 2011). This study asked their participants specifically about declining friendships. Extending this to the current study, it may be that the BI adolescents that showed high levels of social anxiety and supportive friendships feel as if their supportive friendship is declining as time goes on. The adolescent would become anxious as they would be forced to try and create new friendships. Future research should examine how these processes may change across adolescence and into adulthood, as these adolescents may find some difficulty in losing supportive friendships as they age into adulthood and encounter new social situations.

Furthermore, the adolescents that participated in this study may have befriended other behaviorally inhibited adolescents. Although BI adolescents will accept other BI adolescents as their friend, it may not be the best quality of friendship (Freitas et al., 2019). First, BI adolescents typically befriend a smaller number of friends and research has shown that higher degrees of social networks increase peer acceptance and decrease peer victimization (Freitas et al., 2019). Secondly, BI adolescents are more likely to befriend other shy children which may share the same behavioral style and psychosocial problems (Freitas et al., 2019; Haselager et al., 1998; Schneider, 1999). Therefore, the current results need further testing to identify if the friend that the participant listed as their best friend is also considered behaviorally inhibited. This highlights that not only quantity and quality of friendships are important, but also the psychopathology of the friend.

Additionally, present results found no significant difference between quality of friendship and sex. This may be attributed to the smaller sample size that our study utilized. However,

research on BI adolescents has found that peer friendships may moderate the association between BI and stress reactivity, and this differs depending on child sex. A study of 684 8th graders found that supportive friendships were positively correlated with higher reports of social anxiety (Freitas et al., 2019). There was a negative correlation with girls found. Researchers found that boys with supportive friendships were more likely to experience peer victimization and social anxiety (Freitas et al., 2019). This finding may explain our results in that due to our smaller sample size and almost 50% split between male and female why supportive friendships are not serving as the protective mechanism as stated before. Although we controlled for gender and found no significance, the limited sample size may have skewed that estimate.

Assessing Correlations Between BI, RSA, and Social Anxiety

The hypothesis that behavioral inhibition is associated with lower RSA baseline is supported by the data. Results show that that adolescent BI questionnaire data were negatively correlated with baseline RSA. Given that resting RSA reflects the physiological capacity to regulate emotions, this suggest that individuals higher in BI may not be able to regulate emotions. It is thought that lower baseline RSA is associated with a greater risk of developing social anxiety (Fortunato et al., 2013; Khurshid et al., 2019). This suggests that adolescents higher in BI may have an increased risk of developing social anxiety given poorer regulatory capacity. Our results are consistent with current research. A study of 152 7-year olds assessed the relationship between shyness and baseline RSA. Results confirmed a negative correlation between high levels of shyness and decreasing levels of RSA baseline (Poole & Schmidt, 2021).

Additionally, the hypothesis that lower baseline RSA is associated with greater social anxiety symptoms is supported. The results indicated a negative correlation between high levels of adolescent self-reported social anxiety symptoms and lower levels of baseline RSA. This suggests that adolescents with lower RSA at baseline may have higher rates of social anxiety. The pathophysiology of social anxiety includes rapid heart rate, sweating, and loss of concentration. The Polyvagal theory suggests that the parasympathetic nervous system, specifically the vagal nerve and respiratory sinus arrhythmia, underlie emotional regulation. Poor emotional regulation in social contexts underlie social anxiety. Given that our findings suggest concurrent associations between baseline RSA, this may suggest that individuals with lower capacities to regulate stress have higher levels of social anxiety. The Vagus nerve is parasympathetically responsible for regulatory and adaptive control of cardiac arousal. Research done on adolescents have shown that a lower baseline RSA is correlated to an increase in anxiety disorders due to a withdrawal of vagal activity (Fortunato et al., 2013; Friedman & Thayer, 1998). A lower vagal activity will result in more excitability for the heart and a decrease in RSA. Therefore, the results of the current study suggest that adolescents with lower baseline RSA exhibit a relaxation of the vagal nerve which may underlie the emergence of social anxiety.

Additionally, RSA reactivity is the adaptability of the body to respond to a given stressor. In our study, we hypothesized that RSA withdrawal would occur to serve as a protective mechanism against social anxiety. However, our results do not support that. Our results do not indicate any significant relationship. This may be due to a variety of reasons. One reason is that our sample size is too small. Although we had 114 participants, only 34 had reliable RSA data that could be used. Therefore, if the sample size was to be increased, it is likely that a significant correlation would be found. It is likely that an adolescent with poor emotional regulatory control

will develop social anxiety. Previous research has found that RSA withdrawal allows the body to better regulate emotions. Although our results do not find any significant RSA reactivity correlations, it is likely that there may still be a relationship between RSA withdrawal and a decreased risk of social anxiety.

Limitations and Future Directions

One limitation that the current study was the impact of the COVID-19 pandemic on our sample size. Due to the pandemic, the sample size for the TEENS study, and more specifically the physiology data, was limited. Although we controlled for COVID via the pre and post COVID measurements, the lack of in-person visits impacted the number of participants. This particularly impacted the number of participants providing RSA data as that would have to be conducted in a lab setting. We were underpowered to run our multiple regressions with RSA as the dependent variable. Future studies should examine if peer support/conflict may moderate associations between BI and RSA. While we did not directly look at this, our findings that RSA and social anxiety are correlated may suggest that we would find similar patterns of interaction if we had a higher sample size. Additionally, it had also been found that behaviorally inhibited children were impacted more due to the COVID-19 pandemic (Zeytinoglu et al., 2021). The current study was conducted before and during the pandemic, therefore it is likely that the adolescents' social world shifted. With the shift to distant learning and less peer engagement, they may have a harder time socializing with peers. This shift in learning and general social engagement may have impacted the results. However, further research into how the COVID-19 pandemic has affected adolescents ability to interact with peers would be important.

Furthermore, the study does not include any measurement of sympathetic arousal. Studies have shown that both measures of parasympathetic and sympathetic help to examine the risk for developing social anxiety during adolescence (Schmitz et al., 2011; Yeragani et al., 2001). A future direction is to utilize cortisol saliva samples. As part of the sympathetic nervous system, the kidneys produce a hormone cortisol when encountering a stressful situation. Taking samples of saliva before and after social situations examine how the sympathetic nervous system reacts to social situation. Combining both cortisol saliva samples and RSA measurements could be used to understand how the body's physiology reacts to stress.

Furthermore, the current study only depicts cross-sectional data. This was due to limited data from the ongoing pandemic. Therefore, it would be important to examine longitudinal outcomes to these participants. First, it would be interesting to examine if the COVID-19 pandemic has played a role longitudinally on their ability to maintain and make new friends. Current COVID-19 research has shown that BI adolescents are impacted more than un-inhibited adolescents with making and maintaining friends (Yeragani et al., 2001). Secondly, prior research before the COVID-19 pandemic has highlighted longitudinal effects of peer friendships. Many studies have found that multiple positive friendships that are maintained throughout early and late adolescence leads to lower social anxiety disorder diagnoses in the future (Hartup, 1996; Parker & Asher, 1993; Rubin et al., 2015).

Additionally, puberty may play an important factor. As an adolescent that develops into puberty earlier may feel that they are viewed differently. For example, earlier timing of pubertal development has been associated with seeking friendships that promote risky behavior. Additionally, the quality of these friendships would be low and could exacerbate the risk of developing internalizing symptoms. A six-year longitudinal study examined the effects of

pubertal timing and risk of internalizing symptoms. It was found that girls that entered puberty early had a higher risk of developing internalizing symptoms (Platt et al., 2017). Similarly, a study analyzed the anxious behavior of early and late maturing boys and their risk for anxiety. A similar result was found in which an earlier onset of puberty may increase the risk of developing anxiety (Deardorff et al., 2007; Reardon et al., 2009).

Further research should focus on fixing the current limitations of the study by increasing sample size, exploring new ways to assess BI and social anxiety, and measure both parasympathetic and sympathetic contributions to internalizing symptoms. Additionally, future research should examine both the number of friendships as well as quality of friendships. The number of friendships increases participation in social activities and is associated with higher self-worth and less internalizing symptomology (Gest et al., 2001). The quality of the friendships still may have an impact, therefore it would be important to measure how both quality and number of friendships moderate an adolescent's physiological reactivity to stress. Additionally, further studies can examine stress of interacting with a peer in real time. A social dyad experiment where a BI adolescent interacts with strangers and perceived friends may note that a less structured social stress experience (such as general conversations) may impact RSA. It would be interesting to see how RSA baseline and reactivity means could be altered due to this change.

Conclusion

Overall, our findings suggest that there is a negative correlation between high self-reported behavioral inhibition and low RSA baseline. Additionally, there was a negative

correlation between self-reported social anxiety and low RSA baseline. Our moderation analysis yielded a positive relationship between high levels of social anxiety and high levels of support for BI adolescents. These findings suggest that quality of friendship may not be the only influential factor in protecting adolescents against social anxiety. Rather, a combination of quantity and quality of friendships may be important. Taken together, the results of this study allow us to find biomarkers that help to predict if an adolescent will develop social anxiety and pursue early interventional means to stop the development of SAD.

Appendix A

Tables and Figures

Variables	1	2	3	4	5	6	7	8
1. NRI Support	-							
2. NRI Conflict	-0.60	-						
3. BIQ Total	-0.12	-0.13	-					
4. SASA Total	0.27	-0.07	0.36	-				
5. RSA Sitting	0.25	-0.10	-0.29	-0.38	-			
6. RSA Talking	-0.01	0.13	-0.37	-0.41	0.42	-		
7. RSA Speech	-0.04	0.25	-0.18	-0.56	0.57	0.63	-	
8. RSA Speech Reactivity	0.01	0.09	0.27	-0.03	-0.02	-0.59	0.21	-
Mean	3.58	1.81	118.81	57.20	6.89	6.51	6.69	0.16
SD	0.71	0.84	33.28	12.91	1.09	0.96	0.81	0.78
N	71	72	114	80	32	30	27	27

Table 2: Means, Standard Deviation, and Bivariate Correlations

Table 1 highlights the means, SD, and N for the participants. Bolded R² values indicate significant findings with $p < 0.05$.

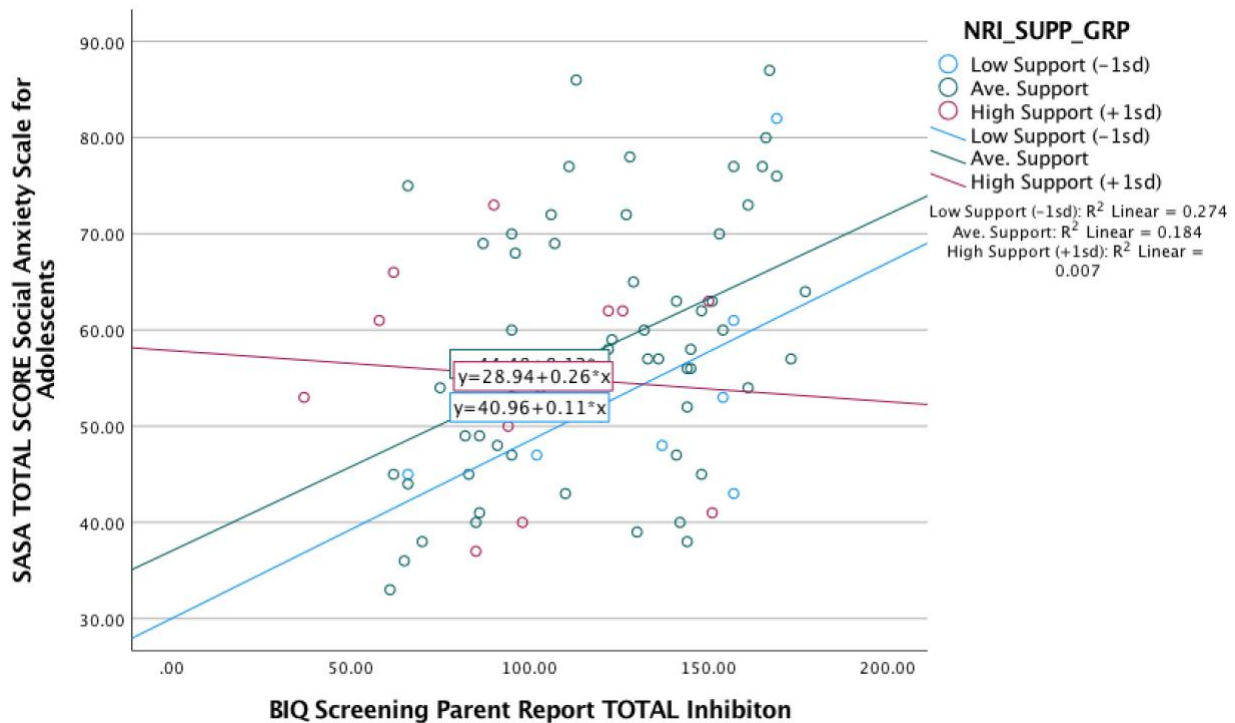


Figure 1: Regression results between BIQ and SASA moderated by supportive peer relations

Figure 1 is a regression utilizing NRI_SUPP_GRP as a predictor, which categorized level of adolescent self-reported supportive friendships as (+/-) 1 standard deviation from the mean. High support friendships were associated with higher levels of social anxiety.

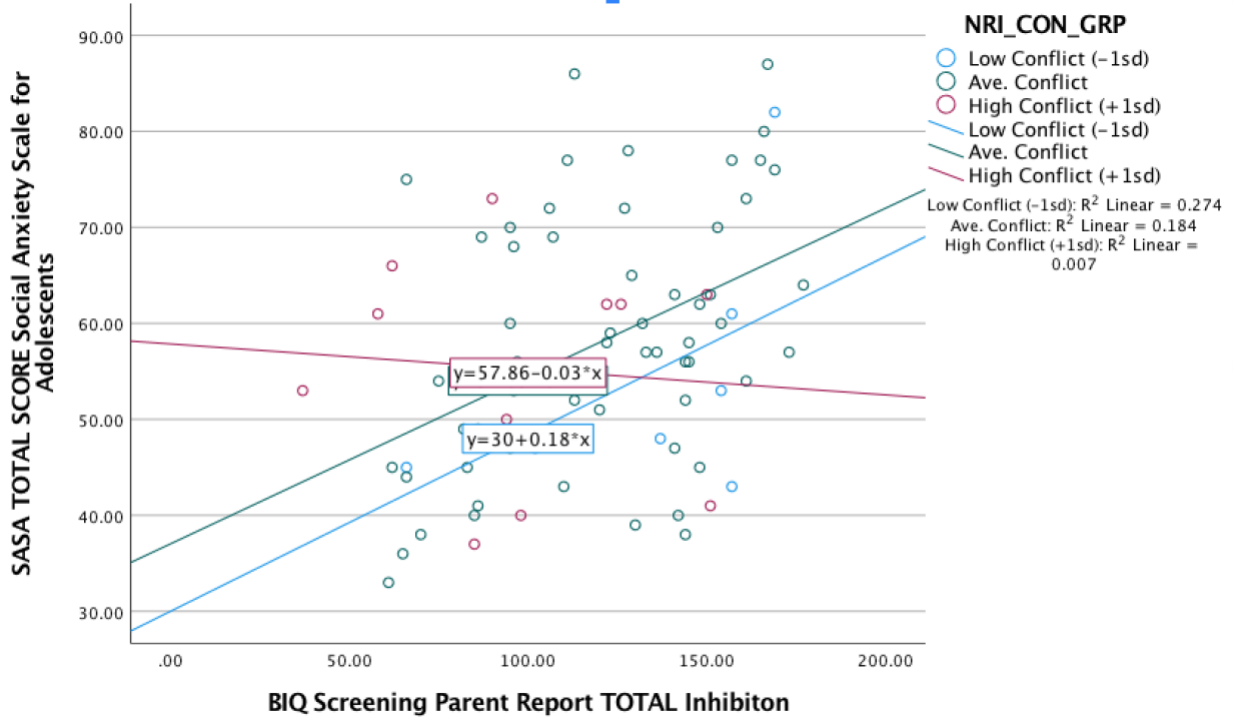


Figure 2: Regression results between BIQ and SASA moderated by conflict peer relations

Figure 2 is a regression utilizing NRI_CON_GRP as a predictor, which categorized level of adolescent self-reported conflict friendships as (+/-) 1 standard deviation from the mean. No significant findings were found.

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ACADEMIC VITA

EDUCATION

Cathedral Preparatory School

Class of 2017

The Pennsylvania State University
Schreyer Honors College, Eberly College of Science
Bachelor of Science (B.S.) in Biology

Class of 2021
University Park, PA

WORK EXPERIENCE

Emergency Room and Pharmacy Volunteer

May 2018 – August 2018

Volunteer at Saint Vincent Hospital

Erie, PA

- Worked with the hospital staff to check various vital signs, record patient symptoms, and dress patients in gowns
- Volunteered for 50+ hours

Undergraduate Research Assistant

August 2018 – March 2019

Volunteer

University Park, PA

- Work with tissue samples to analyze for various carcinogens within mouse genome
- Learn new sterile lab techniques and scientific instruments

Chemistry Tutor

Work

August 2019

University Park, PA

- Work with students to explain concepts from class more in depth.
- Assist professors with course grading and policies.

CVS Pharmacy Cashier

Work

June 2016 – August 2017

Erie, PA

- Stocked the shelves with merchandise and kept up to date records of the sales records.

LEADERSHIP EXPERIENCE

Schreyer Student Council

Secretary

August 2018 – May 2020

University Park, PA

- Keep a detailed list of attendance for the club and send out the weekly emails.
- Work with the other executive board members to create a positive environment for the club.

LECOM Summer Exposure Program

May 2016 – August 2016

Student

Erie, PA

- Learned the inner workings of the human body by examining cadavers
- Met many of the medical school administrators and doctors
- Observed dental cleanings and learned about the Medical School Admission Process

Guided Study Group Leader

Learning Assistant

August 2020 – Present

University Park, PA

- Help students in class to answer group problems and clicker problems
- Lead a workshop for students to work through problem sets and worksheets.

Homecoming Captain

Police and Security Captain

January 2020 – November 2020

University Park, PA

- Held meetings with Penn State and State College police
- Held security briefings for Parade

THON Captain

Thon Organization Member

April 2020 – March 2021

University Park, PA

- Lead a committee of 23 individuals for THON Weekend
- Served as a liaison for THON Fundraising