Interpretations of Ambiguous Social Situations and Cardiovascular Responses in Adolescents

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ABSTRACT

Background: *Previous research has documented effects of ambiguous outcome social situations on individual differences in cardiovascular reactivity in laboratory contexts.* ***Purpose:*** *This study tested whether interpretations of ambiguous social situations are associated with daily life cardiovascular responses using ambulatory approaches.* ***Methods:*** *There were 206 high school adolescents assessed on interpretations of ambiguous social situations in the laboratory who then completed ambulatory monitoring of blood pressure (BP) and heart rate (HR) for 2 days.* ***Results:*** *Adolescents who perceived threat during ambiguous situations exhibited higher systolic BP when talking to others compared to occasions of not talking with anyone, whereas the opposite was true for those with low threat perception. For high-threat adolescents, higher systolic BP was found when interacting with friends, whereas for low threat adolescents, lower systolic BP was found when interacting with parents. Greater threat interpretations were also associated with elevated HR at night.* ***Conclusions:*** *Understanding how adolescents perceive social interactions may help in gauging their daily cardiovascular responses.*

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INTRODUCTION

Social interactions have a robust association with health. The absences of social support and social conflicts have been linked to biological markers of health as well as morbidity and mortality outcomes (1–4). However, the specific responses to social interactions that are important for daily life biological outcomes are less well understood.

In particular, the way in which individuals perceive social situations may be important for their biological responses to those situations. According to cognitive appraisal theory, an individual's appraisal of a situation shapes their stress response to that situation (5). Primary appraisal refers to the meaning a person gives to a situation. Appraisals of potential future threat, harm, or loss increase the level of stress perceived in a situation. Previous researchers have emphasized the importance of appraisals in shaping the nature and intensity of responses to social situations (5–9). Moreover, appraisals are thought to relate to how individuals emotionally and behaviorally respond to situations (5,10,11).

However, in terms of biological outcomes, research has more traditionally focused on the objective characteristics of situations (e.g., presence or absence of a stressor) rather than perceptions of those situations. For example, a large body of literature has documented that both acute laboratory stressors (12–14) and naturalistic stressors such as exams or caregiving (15,16) are associated with biological responses. A smaller number of studies have examined how appraisals during stressors relate to biological measures (17). For example, greater appraisals of threat were associated with heightened vascular resistance and diastolic blood pressure (DBP) during laboratory tasks (18–20). Greater increases in hostile attributions during a laboratory task also were associated with elevated heart rate (HR) (21). However, a clearer understanding of how appraisals relate to daily life rather than laboratory, physiological indicators is still needed.

The Role of Type of Social Situation in Interpretations and Physiological Responses

This article addresses this gap by investigating social situations in which individual differences in appraisals may be important for daily life physiological outcomes. Social situations that individuals encounter in their daily lives can vary greatly in outcome, some being positive (e.g., being complimented by your boss) and others being negative (e.g., a fight with a good friend). In addition, many of the situations we face in life are fraught with ambiguity. For example, consider a police car pulling up to you as you are sitting in your car. This situation is ambiguous in outcome because it is unclear what is about to happen and what the intent of the police officer is. The police officer might be about to accuse you of a violation of the law (threatening) or might be stopping to ask if you need any help (benign).

Our model starts with the premise that there are individual differences in how people appraise an identical

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situation. In particular, situations that involve ambiguous outcomes may produce the greatest individual differences in responses. For example, one common type of daily life ambiguous event is subtle forms of racism. Adults who perceive greater racism during either their daily lives or ambiguous laboratory situations exhibit greater blood pressure (BP) reactivity in the laboratory (22–25). More generally, negative perceptions of daily social interactions have been associated with increases in ambulatory blood pressure (ABP) among adults (26). In other individual difference research, adults who are high in rejection sensitivity show greater startle responses after viewing rejection-related stimuli, supporting the authors' notion that rejection threats, even if uncertain, activate defensive systems with affective, behavioral, and physiological reactions (27).

Our own previous research has focused on the distinction between ambiguous and negative outcome social situations. We hypothesize that unlike ambiguous situations, those that are clearly negative may result in similar appraisals across people. In contrast, we argue that threat interpretations during ambiguous situations can be conceptualized as an individual difference variable and have focused on factors accounting for differences in interpretations across individuals. For example, we proposed that lower socioeconomic status (SES) individuals, because of the uncertain and unpredictable environments they grow up in, are more likely to interpret ambiguous situations in a threatening manner and consequently to display heightened physiological responses to these situations. We previously documented in a series of laboratory studies that lower SES adolescents reported more threatening interpretations during ambiguous, but not negative, social situations and that these interpretations partially mediated the relationship between low SES and heightened laboratory BP reactivity (28,29).

Another individual difference characteristic closely associated with threat interpretations is hostility. Hostility includes the tendency to view others as provocative and likely to mistreat people (30). In previous work, we demonstrated that although hostility and threat interpretations are significantly correlated, they are not completely overlapping constructs as they correlate at about .3 (31). Hostility may differ from ambiguous threat interpretations in encompassing the tendency to respond more negatively to negative stimuli, such as provocation from others.

Ambulatory Cardiovascular Measures

Physiologically, our previous work has focused on laboratory reactivity studies; in the study presented here, we sought to understand how interpretations during ambiguous situations predict physiological responses in daily life. To test hypotheses about threat interpretations and physiological measures, we relied on ecological momentary assessment—repeated measures throughout the day—of participants' ABP and HR, along with reports about social interactions. Ambulatory cardiovascular measures provide an important, ecologically valid indicator of health, and recent data suggest that other psychological variables such as stress and social support are associated with ambulatory cardiovascular measures (4,32–37).

In general, previous ambulatory studies relied on participants' self-reports of psychological variables, such as perceived stress. With respect to our hypotheses, it would be important to accurately assess the occurrence of *ambiguous* events; however, it may be difficult for participants to self-report accurately on the occurrence of ambiguous events, given that their interpretation could color how they classify an event. Thus, our study combined laboratory measures of appraisals in response to hypothetical situations with ambulatory methods for monitoring BP to best approximate how individual differences in interpretations of ambiguous social situations relate to physiological measures during different types of daily life social situations.

This Study

To assess interpretations specifically during ambiguous situations, we first tested participants in the laboratory on a set of ambiguous social situations. This allowed us to keep the situations constant and thus to rate individual differences in interpretation styles. We then tested the association of these interpretations with ABP/HR.

With respect to daytime readings, our first hypothesis was that relationships of threat interpretation with daytime ABP and HR would be moderated by occasions of social interactions. That is, we hypothesized that individuals who perceived greater threat during ambiguous situations would show higher daytime BP only during times when they were interacting with others, given the importance of social contexts to threat interpretations. Thus we hypothesized that there would be an interaction between threat interpretations and occasions of social interactions in predicting daytime ABP. Note that the advantage of collecting data on social interactions and BP repeatedly throughout the day is that one can compare *within an individual* whether changes in social interactions are associated with changes in BP. We hypothesized that for those participants high in perceived threat, occasions of social interaction would be associated with higher momentary BP than occasions of no social interaction. In contrast, for participants low in perceived threat, social interactions would not produce higher BP than no social interactions.

Our second hypothesis was that participants who perceived threat during ambiguous social situations would show higher ABP and HR at night. Although adolescents are not engaging in social interactions during this time, we hypothesized that a state of heightened vigilance during the day may lead to spillover effects at night, whereby BP and HR at night do not show the typical dipping patterns. Previous research has demonstrated that certain types of stress, such as exposure to violence, job strain, and low

job control, are associated with elevated nighttime ABP and HR (38–41). Thus we tested the hypothesis that greater threat interpretation during ambiguous social situations would also be related to higher nighttime BP and HR. In this case, we hypothesized a main effect of threat interpretations, given that adolescents were asleep and hence there could not be a moderating effect of experiencing social interactions.

Third, we expanded our approach of testing cognitive variables (threat appraisal) to also testing emotional and behavioral responses to ambiguous situations in terms of associations with ABP and HR. This allowed us to test a more comprehensive model of the stress process (42). We hypothesized that the aforementioned patterns would also replicate with emotional (e.g., being scared) and behavioral (e.g., defensiveness) responses to ambiguous situations. We tested these hypotheses in a sample of adolescents, given the importance of social relationships during this formative stage of life, and the relative paucity of data on ambulatory measures in adolescents.

METHOD

Participants

This study consisted of 217 adolescents between the ages of 14 and 16 ($M = 14.56$, $SD = 0.62$) recruited for a study on behavioral risk factors of cardiovascular disease (see Table 1). Adolescents were from two urban high schools. A total of 206 completed both the ambiguous scenarios questionnaire and the ABP monitoring. The University of Pittsburgh Institutional Review Board approved the protocol, and participants and a parent/legal guardian provided written informed consent. Participants were paid $30 for their participation in this component of the project. Parents completed a medical history regarding their child to ensure the child was free of cardiovascular disease, not taking medication affecting cardiovascular function, and within 80% of ideal height and weight for their age and gender group. For further details about the study sample and protocol, please see Matthews et al. (43).

Ambiguous Scenarios Questionnaire

Because our previous research had shown associations of individual difference variables with ambiguous, but not negative, outcome social scenarios (28), we focused on ambiguous scenarios only in this study. Four hypothetical social situations were used to measure responses to ambiguous outcome social situations. Situations involved the adolescent and another individual, with the outcome being ambiguous (both what would happen and the intent of the other individual was unclear). Scenarios included a teacher discussing a cheating incident in class and then asking to speak with you after class; policemen pulling up to you in a car after some commotion on the street nearby; hearing someone coming up to you from behind as you are walking alone down a quiet street; and a saleswoman in a store approaching you after you have been browsing for a while with a backpack. Scenarios were developed from earlier studies on ambiguous situations (28,31). In this previous research, we demonstrated convergent and divergent validity for our ambiguous social scenarios (31).

TABLE 1
Means and Standard Deviations of Study Participant Characteristics

	African American		*European American*		
Characteristics	*Male*	*Female*	*Male*	*Female*	*Significant F Values*
n	52	53	53	53	
Age	14.6 ± 0.6	14.5 ± 0.6	14.5 ± 0.6	14.7 ± 0.6	
Maternal education (years)	13.6 ± 1.7	13.5 ± 1.9	14.4 ± 2.5	15.1 ± 3.0	$R(1, 201) = 13.88$, $p < .0003$
Paternal education (years)	13.3 ± 1.5	13.2 ± 1.8	15.3 ± 3.5	14.8 ± 3.1	$R(1, 189) = 21.39$, $p < .001$
BMI (kg/m^2)	22.8 ± 3.8	23.5 ± 4.8	21.9 ± 3.7	22.9 ± 3.7	
Average Day 1 ambulatory measures (8 a.m.–10 p.m.)					
SBP (mmHg)	129.2 ± 14.1	122.4 ± 15.5	127.3 ± 16.3	120.1 ± 13.4	$G(1, 202) = 11.42$, $p < .001$
DBP (mmHg)	73.3 ± 7.0	74.7 ± 7.8	72.3 ± 7.2	69.9 ± 6.2	$R(1, 202) = 8.65$, $p < .004$; $R \times G(1, 202) = 3.66$, $p < .06$
HR (bpm)	83.7 ± 7.9	92.5 ± 8.4	83.4 ± 9.1	87.4 ± 8.6	$G(1, 202) = 5.34$, $p < .02$

Note. R = race; BMI = body mass index; SBP = systolic blood pressure; G = gender; DBP = diastolic blood pressure; HR = heart rate; bpm = beats per minute.

Scenarios were presented on the computer. After reading each scenario, participants were asked about their responses to the situation. One threatening and one benign/positive interpretation of each situation were presented ("The saleswoman thinks that I shoplifted something into my backpack" vs. "The saleswoman is coming over to ask if she can help me with anything"). Participants rated how likely each interpretation was on a 5-point scale, from *not at all likely (1)* to *very likely (5)*. Threatening and positive interpretations were inversely correlated ($r = -.30$, $p < .001$). Both interpretations were presented so as not to bias participants toward one type of response; however, only threat interpretation scores were used, consistent with our previous studies (28,29,31). Cronbach's alpha across the four scenarios (reliability for a four-item scale) was .58. There were no race differences in threat interpretation scores for any of the stories.

Cognitive interpretations comprised our primary independent variable. However, we also sought to expand previous work by assessing different types of emotional and behavioral responses to ambiguous scenarios. We probed responses likely to arise during threatening situations. Emotionally, participants rated how scared and, conversely, how calm they would feel in the situation on a 5-point scale, ranging from *not at all (1)* to *very (5)*. Cronbach's alpha across the four scenarios for the two emotion questions was .72. Behaviorally, we conceptualized responses to threat as either involving defending oneself or confronting the threat. Participants were asked to rate how likely they would be to engage in each behavioral response on a 5-point scale ranging from *not at all likely (1)* to *very likely (5)*. For each scenario, one response involved a defensive approach to the situation (e.g., "plead my innocence"); another response involved a confrontational approach (e.g., "challenge any accusations and take the matter to a higher authority"). Cronbach's alpha across the four scenarios for the two behavior questions was .55. Finally, participants provided an overall rating of how stressful they would find the situation on a 5-point scale ranging from *not at all stressful (1)* to *very stressful (5)*. Cronbach's alpha across the four scenarios was .64. Across domains of responding (cognitive, emotional, behavioral, and stress), Cronbach's alpha was .84. Scores were created by averaging across the four scenarios for each of the aforementioned questions. See Table 2 for correlations among these measures.

TABLE 2
Correlations Among Cognitive, Emotional, and Behavioral Responses to Ambiguous Social Scenarios

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
(1) Threat interpretation					
(2) Scared	.51**				
(3) Calm	−.30**	−.44**			
(4) Confrontational	.39**	.29**	−.09		
(5) Defensive	.37**	.48**	−.14*	.19**	
(6) Stress	.54**	.76**	−.46**	.27**	.45**

*$p < .05$.
**$p < .01$.

Other Psychosocial Measures

Hostility. Hostility was measured using the cynicism subscale of the Cook-Medley Hostility questionnaire. This measure consisted of 13 items, rated as either true or false (44). Higher scores indicate higher hostility. This scale has good internal consistency ($\alpha = .81$) (45).

Stressful life events. The occurrence of stressful life events was assessed using the Life Events Questionnaire-Adolescents (46). This measure consists of a list of events that were categorized by judges as being ambiguous, positive, or negative. We focused on negative family events because these involved interactions with others (as opposed to negative events that were not interpersonal, such as failing a grade in school). The sum of negative family-related life events was calculated. This scale was significantly associated with an interview rating of stress ($rs = .45$–$.49$) and was found to predict psychological adjustment (47).

Measurement of Ambulatory Blood Pressure and Heart Rate

ABP and HR were obtained using the Accutracker Dx ambulatory monitor (Suntech Medical Instruments Inc., Raleigh, NC). This monitor uses the auscultatory method of BP assessment and is very similar in design to the Accutracker II, which has been validated according to the Association for the Advancement of Medical Instrumentation (AAMI) and British Hypertension Society (BHS) standards. An appropriately-sized cuff was placed on the nondominant arm with the microphone over the inner aspect of the arm. Measures were programmed to be taken during waking hours every 30 min and every 60 min from 10 p.m. until 6 a.m. (or stopped earlier if participants woke up early, as participants were instructed to remove the monitor as soon as they woke up). Measures were taken beginning at 8:30 a.m. of the first day, continuing until 1:30 p.m. of the second day. Data were uploaded to a PC computer using AccuWin software (Suntech Medical Instruments, Inc., Raleigh, NC).

Computerized Diary Questions

Participants were given a handheld computer (Palm Organizers; Palm, Inc., Sunnyvale, CA) that prompted them with 10 questions at each BP assessment during waking hours. (We could not ask more because of the competing demands of school.) Respondents indicated where they were when the BP cuff inflated (school, home, car/bus, other), posture (lying down, sitting down, on my feet), physical activity in the past 10 min (none, mild, moderate, heavy), consumption in the past 10 min (none, food,

caffeine, smoking), mood (angry, calm, interested), whether they had talked to someone in the past 10 min (yes/no), and who they had talked to (friends, parents, school personnel, other relatives, other, no one). Four participants did not complete diary data and were excluded from mixed models analyses.

Body Mass Index

In the laboratory, height was measured with a fixed steel tape in a standing position and weight by a beam scale. The ratio of weight to height squared (kg/m^2) was calculated for each participant as a measure of obesity.

Procedure

Interested participants were sent a letter that provided an overview of the study. Then the research team contacted the student and responsible adult to ask if they had any questions, and parents were asked about the children's eligibility criteria. Eligible students were scheduled for two sessions, one involving two consecutive days of data collection at school and home and another in the psychophysiology laboratory. Prior to testing, informed consent was obtained from the parent and assent from the child.

Research assistants met each scheduled participant at school prior to the beginning of their first class to train them in the use of the ABP monitoring device and the handheld computer diary. Sample BPs were taken until four consecutive readings free of error codes were completed. The participant completed a diary entry on the handheld computer for practice. The monitor was programmed to take readings every 30 min during the day until 10 p.m. and then every 60 min after that. Participants were instructed to complete a diary entry after every reading until 10 p.m.

Participants wore the monitor for the remainder of the school day and night and were instructed to remove it after awakening in the following morning for their morning shower. Participants then returned to school the following morning where a research assistant again met the participant at school and reconnected the ABP monitor. The participant wore the monitor, which resumed readings every 30 min, for the remainder of the second school day. At the end of each day, participants completed an overall assessment of their day.

The laboratory session consisted of completing psychosocial questionnaires, including the ambiguous scenarios questionnaire, the Cook-Medley scale, the Life Events Questionnaire-Adolescents, height and weight, and a set of other measures not reported here.

Data Reduction

Cardiovascular measures. The primary analyses of the BP and HR measures involved Day 1 daytime readings as well as the nighttime readings. Day 2 daytime readings were not used in analyses, given that children were only monitored during school hours until 1:30 p.m. on Day 2, and so there were only 12 readings (as opposed to 29 on Day 1) within a restricted range of locations. Of the Day 1 daytime readings, 4.8% (296 of 6,148) were lost because of either monitor cuff error (cuff not connected, air leak, etc.) or out-of-range values (DBP $<$ 38 mmHg or $>$ 145 mmHg, systolic BP [SBP] $<$ 58 mmHg or $>$ 250 mmHg, or pulse pressure, i.e., the arithmetic difference between SBP and DBP $<$ 10 mmHg). The editing criteria were based on work by Verdecchia et al. (48) of ABP in middle-aged adults and modified for adolescents. It should be noted that if any of these exclusion criteria were met, all data for a particular point in time were excluded. An average participant produced 27.7 ($SD = 3.8$) of 29 valid BP readings, the data overall consisting of 95% (5852 of 6,148) of valid BP readings.

Diary data. Four participants did not have Day 1 diary data because of equipment malfunction or failure to follow instructions. Including those four, ratings were completed for 83% of the diary ratings, with the average participant producing 24.7($SD = 4.0$) of 29 valid diary ratings. Taken together, 80% (4,897 of 6,148) of the BP and all of the diary observations were simultaneously available for the analyses discussed next.

Statistical Analyses

We used covariance pattern models (PROC MIXED, SAS Institute) to test the hypotheses that participants' responses to ambiguous social scenarios would be associated with ABP and HR. Race, sex, body mass index, and the interaction of race and sex were included as between-subject covariates. For each ambulatory measurement point, participants' location; position; physical activity; and consumption of food, beverages, and so on, served as within-subject covariates. Categorical variables were dummy coded so that the following served as referent: Black, female, school, lying down, no physical activity, and consuming nothing. The covariates that were significant in these models have been reported elsewhere (43). Although race and Race $\times$ Sex were not significant predictors of daytime SBP as reported in this earlier article, race was a significant predictor of nighttime DBP and HR, such that Black adolescents had higher DBP/HR than White adolescents (see Table 3). The first order autoregressive error structure was specified to allow for autocorrelation among the sequentially assessed ambulatory readings from the same individuals. To test our first hypothesis about daytime readings, interaction terms of Ambiguous Scenarios (between-person predictor) $\times$ Momentary Social Interactions (within-person predictor) measured simultaneously with daytime BP/HR readings were added to the model including covariates and main effects. One strength of this study design was that each participant provided data at multiple time points throughout the day. Thus we could

TABLE 3
Relationship of Ambiguous Social Scenario Responses With Ambulatory Blood Pressure at Night

	SBP		*DBP*		*HR*	
	B	*p*	*B*	*p*	*B*	*p*
Race: White vs. Black	−0.86	0.78	−2.28	0.05	−4.41	.004
Sex: male vs. female	8.58	0.007	−0.10	0.93	−6.48	<.001
Race × Sex	−3.22	0.47	1.79	0.28	3.78	.08
BMI	−0.01	0.74	−0.35	0.002	0.20	.16
Threat interpretations	−1.46	0.23	−0.06	0.90	1.32	.025
Scared	1.22	0.34	0.19	0.70	1.38	.026
Calm	1.30	0.29	−0.39	0.40	−1.44	.016
Confrontational	−0.30	0.83	−0.17	0.73	1.27	.05
Defensive	−0.32	0.79	−0.26	0.57	0.81	.17
Stress	1.84	0.17	0.15	0.76	1.36	.04

Note. SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate; BMI = body mass index.

ask whether differences from one situation to another relate to differences in outcome within a person (each person serves as their own control). Significant interaction effects were probed by investigating within-person changes across different levels of the between-person predictor. We tested whether occasions of social interaction differed from occasions of no social interaction in BP/HR readings for those high in threat versus those low in threat. To test our second hypothesis about nighttime readings, we added the main effects of ambiguous scenarios to the basic model of covariates in predicting nighttime BP/HR. Effect sizes are reported for categorical variables as *d*s, with .2 representing a small effect, .5 a medium effect, and .8 a large effect (49). Effects sizes are reported for continuous variables as *r*s, with .10 representing a small effect, .24 a medium effect, and .37 a large effect.

RESULTS

Social Contact, Ambiguous Scenarios, and Daytime BP and HR

We investigated our first hypothesis that responses to ambiguous social situations would be associated with daytime BP specifically during times of social contact by testing the interaction between the "talk to someone" variable (*yes/no*) and adolescents' responses to ambiguous social situations. A significant interaction emerged for Talking × Threat Interpretations ($B = -2.69$, $p < .01$) for daytime SBP. The main effect of ambiguous situation responses was not significant for BP or HR (ps > .1). The nature of the interaction was clarified by testing whether differences in the within-person predictor (occasions of social contact) related to differences in outcome (SBP) across levels of the between-person variable (threat interpretations). Thus we compared occasions of talking to someone versus occasions of not talking with anyone for those with threat interpretations above and below the median.

Among adolescents who perceived high threat during ambiguous social situations, talking to someone was associated with higher SBP than not talking with anyone ($B = 2.37$, $p < .05$, effect size $d = 1.45$). In contrast, among those who perceived little threat, talking to someone was associated with lower SBP than not talking with anyone ($B = -2.77$, $p < .01$, $d = 1.55$).

Given the significant interaction with talking to someone, we conducted exploratory analyses to test whether the type of person adolescents were talking to mattered. The majority of interactions involved talking to friends or parents, so we focused on these specific interactions. Among adolescents who perceived high threat during ambiguous social situations, talking to friends was associated with higher SBP than talking to others ($B = 2.05$, $p = .05$, $d = 1.28$). In contrast, among adolescents who perceived low threat during ambiguous social situations, talking to parents was associated with lower SBP than talking to others ($B = -3.18$, $p < .01$, $d = 1.80$).

Ambiguous Scenarios and Nighttime BP and HR

The second hypothesis we tested was whether adolescents' cognitive responses to ambiguous social situations were associated with nighttime ambulatory measures. Main effect analyses revealed that ambiguous situation responses were associated with nighttime HR. Adolescents who made greater threat interpretations of ambiguous situations had higher nighttime HR ($B = 1.32$, $p < .05$, effect size (r) = .17, Figure 1). One question that arises is whether the nighttime hours actually reflect sleeping hours. The following day, participants were asked what time they went to sleep the night before. Ninety-seven percent of participants reported going to sleep before midnight. Analyses were repeated using only nighttime ambulatory measures taken

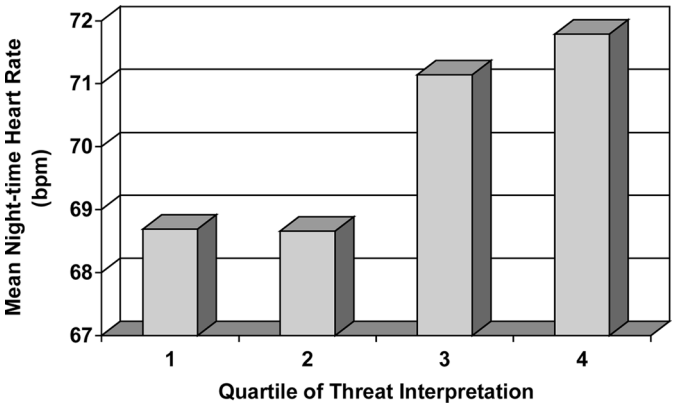

FIGURE 1 Mean nighttime heart rate by quartile of threat interpretation during ambiguous scenarios (1 = lowest threat quartile, 4 = highest threat quartile). *Note*. For the purposes of creating a graphical depiction of these results, we divided the threat interpretation variable into four categories. bpm = beats per minute.

after midnight, and the effect of threat interpretations remained significant.

Analyses With Emotional and Behavioral Variables

Our third hypothesis was that the aforementioned patterns would be replicated with emotional and behavioral responses to ambiguous scenarios. We repeated these daytime analyses with emotional and behavioral responses to ambiguous scenarios. Similar to threat interpretations, talking to someone interacted with defensive behaviors in predicting ambulatory SBP ($B = -1.65$, $p < .05$). Talking to someone also interacted with stress ratings to predict ambulatory SBP ($B = -1.20$, $p < .05$). These interactions followed a similar trend to the one with threat interpretations, although the simple effects tests were not significant. Among adolescents who reported high defensiveness, the coefficient was positive, indicating that talking to someone was associated (though nonsignificantly) with higher SBP ($B = 1.32$, $p = .27$), whereas among adolescents who reported low defensiveness, the coefficient was negative, indicating that talking to someone was marginally associated with lower SBP than talking no one ($B = -1.79$, $p < .07$). Similarly, among adolescents who reported high stress, the coefficient for talking to someone was positive ($B = .65$, $p = .59$), whereas among adolescents who reported low stress, the coefficient was negative ($B = -1.35$, $p = .16$).

We also repeated these nighttime analyses with emotional and behavioral variables. Patterns paralleled those found with threat interpretations. Emotionally, adolescents who reported being more scared and less calm during ambiguous situations had higher nighttime HR (Bs = 1.38 and −1.44, respectively; ps < .05; rs = .17 and .18, respectively). Behaviorally, adolescents who reported that they would be more confrontational during ambiguous situations had higher nighttime HR ($B = 1.27$, $p = .05$, $r = .15$). Last, adolescents who found ambiguous situations to be more stressful had higher nighttime HR ($B = 1.36$, $p < .05$, $r = .16$). See Table 3. When we restricted analyses to only measures taken after midnight, all of the above effects remained significant.

Alternative Explanations

We tested whether moderating variables such as demographics would better explain patterns of associations between ambiguous scenarios and ABP. To address this question, we tested the interaction of race with threat interpretations in predicting both daytime and nighttime BP/HR. We also tested the interaction of sex with threat interpretations in predicting daytime and nighttime BP/HR. There were no significant effects of Race × Threat interpretations on daytime SBP, DBP, or HR, and there were no effects on nighttime SBP, DBP, or HR. There were no significant effects of Sex × Threat Interpretations on daytime SBP, DBP, HR or nighttime DBP, HR. There was a significant Sex × Threat Interpretation interaction on nighttime SBP ($B = 6.84$, $p < .01$), such that among boys, threat interpretations were positively associated with nighttime SBP ($B = 2.33$, $p = .14$), whereas among girls the opposite pattern emerged ($B = -4.74$, $p < .05$).

Second, we examined whether our primary findings could be better accounted for by psychosocial variables that are conceptually similar to threat interpretations. One was hostility, an individual difference variable involving a tendency to mistrust others. The second was the role of momentary emotions, as opposed to cognitions (assessed by measuring negative mood at the time of the BP readings). The third was the occurrence of life stressors rather than appraisals of threat.

Hostility was significantly associated with elevated nighttime HR ($B = 0.52$, $p = .05$); however, the association of threat interpretations with nighttime HR remained significant after controlling for hostility ($B = 1.23$, $p < .05$). Hostility was not associated with daytime SBP ($B = .49$, *ns*), and the interaction between talking to someone and threat interpretations remained significant after controlling for hostility ($B = -2.70$, $p < .01$).

Negative mood (anger at the time of the BP assessment) was not associated with ambulatory SBP during the day ($B = -.05$, *ns*), and the interaction between talking to someone and threat interpretations remained significant after controlling for anger ($B = -2.77$, $p < .01$). In addition, average anger scores across the day were not associated with nighttime HR ($B = .22$, *ns*), and relationship between threat interpretations and nighttime HR remained significant after controlling for anger ($B = 1.33$, $p < .025$).

Negative family-related life events were not associated with daytime SBP ($B = .38$, *ns*), and the interaction between talking to someone and threat interpretations remained significant for SBP after controlling for family events ($B = -2.72$, $p < .01$). Family events were not associated with nighttime HR ($B = -.11$, *ns*), and the relationship between threat interpretations and HR remained significant after controlling for family events ($B = 1.40$, $p = .01$).

DISCUSSION

The results of our study demonstrated that type of social interaction together with ambiguous threat interpretation styles predicted daytime ambulatory SBP responses in adolescents. Occasions of social interaction were associated with higher SBP compared to occasions of no social interaction among adolescents high in threat perception. In contrast, among adolescents low in threat perception, occasions of social interaction were associated with lower SBP compared to occasions of no social interaction. These results provided support for our hypothesis that the relationship between threat perception and daytime ABP depended on whether social interactions had occurred.

Overall, these findings fit with previous research that has demonstrated a link between experimentally induced vigilance for negative words and cardiovascular reactivity in a laboratory setting (50), with other interpersonal ambulatory studies that demonstrated heightened cardiovascular readings when traffic agents interacted with the public (36), and with associations of interpersonally oriented goals with ambulatory measures during times of social interactions (51).

In particular, for adolescents with high threat interpretation styles, interacting with friends was associated with higher SBP. This suggests that although friendships can be a source of social support, these adolescents may also have goals that conflict with the beneficial effects of friendship. For example, adolescents often have goal-oriented strivings, such as striving to defend oneself from criticism or to win sympathy from others. These strivings have been associated with higher levels of ambulatory BP in adolescents (51). It also may be the case that the quality of interactions with friends differs according to whether adolescents have high or low threat interpretation styles. We could not explore this possibility with our data because of limitations in the questions asked simultaneously with the BP/HR assessments.

In contrast, among adolescents who have benign interpretation styles during ambiguous social situations, interacting with others resulted in lower SBP than when alone. For these adolescents who do not perceive threat, social interactions may provide a form of social support, reducing BP levels. The notion of social support reducing BP is consistent with previous research (33,52). In addition, these associations emerged specifically during interactions with parents. This suggests that familiarity may play a role in these adolescents' ambulatory cardiovascular patterns. Being around others that they have known for a long time may promote perceptions of safety and support, thereby lowering SBP in low threat adolescents.

This study also demonstrated that daytime social experiences appear to have spillover effects into the night. Adolescents who perceived greater threat during ambiguous social situations had elevated HR at night. These findings may indicate extended vigilance for or rumination about threat that persists even during sleep. Other studies have demonstrated similar effects of stressful life experiences such as violence, as well as inhibiting anger, on nighttime cardiovascular measures (38,40,53). Future studies that assess factors such as sleep quality, duration, and efficiency would be help elucidate mechanisms behind these effects.

Similar patterns emerged for emotional, behavioral, and stress responses to ambiguous social situations. For example, at night, adolescents with greater threat interpretations exhibited higher HR; similarly, adolescents who felt more scared, less calm, more confrontational, and more stressed during ambiguous social situations also had higher nighttime HR. During the day, the patterns found between threat perception and ambulatory SBP were similar for behavioral (defensiveness) and stress responses. We view these findings as a first step toward broadening our overall model. To date, our work has focused on the role of cognitive interpretations. The current findings reveal that emotional and behavioral reactions to ambiguous situations are also associated with ambulatory SBP/HR. These findings are consistent with previous research on negative emotions and physiological responses to acute laboratory stressors (54). It will be important for future studies to tease apart the temporal ordering of these psychological and physiological responses.

It is important to note that associations with cognitive interpretations could not be explained solely by emotional states, as controlling for momentary negative mood did not diminish the association of cognitive interpretations with ambulatory BP. Similarly, associations with cognitive interpretations persisted after controlling for other similar individual difference variables (hostility) as well as for the occurrence of negative life events, suggesting that there is unique predictive value in cognitive appraisals for understanding adolescents' daily BP responses.

At night, we found that ambiguous scenario responses were associated with HR but not BP. Although we did not predict this divergent pattern, it is of interest to note that low perceived control at work and low social support in borderline and normotensive men were associated with nighttime ambulatory HR but not nighttime SBP (39). Low social support at work was associated with elevated HR during the day and night, and perceived demand and control at work was associated with elevated HR at night, but not during the day, among middle-aged adults (55). Elevated nighttime HR may be a particularly sensitive sign of the beginnings of autonomic dysregulation in healthy adolescents. Elevated nighttime HR may also indicate a slower recovery from stressors, which has been linked to longer term health problems such as hypertension (56,57). Overall, these findings suggest that the health implications of threat interpretations in daily life may begin with effects on nighttime physiology.

In sum, these findings suggest that social interactions produced different patterns of BP responses in different people. That is, in high-threat individuals, social interactions were associated with higher SBP, whereas in low-threat individuals, times of no social interactions were associated with higher SBP. These patterns suggest that it is not the case that one type of social interaction or individual difference variable is always associated with potentially detrimental BP patterns but rather that it is important to understand which situations might be detrimental for which individuals. In turn, health implications may depend on frequency of exposure. For example, if adolescents spend more of their time interacting with others than being alone, this might suggest greater health risk for the profile seen in high-threat adolescents.

This study represents a novel contribution over our previous laboratory-based work (28,29) in that we tested our hypotheses in an ambulatory context, allowing us to investigate how within-person changes in social interactions contribute to within-person changes in BP across different types of threat perceptions, and in beginning to explore the contribution of emotional and behavioral responses to our larger model. Limitations of this study included the inability to assess in detail the types of events that occurred during adolescents' daily lives. We could not ask participants to self-report on the occurrence of ambiguous events (because presumably if they perceive an event as threatening, they may report it as a negative, rather than ambiguous, event). Objectively assessing the types of events that occurred between each BP assessment would have necessitated some type of video or in-person observation of adolescent's entire day, which was not feasible. In addition, we were not able to qualitatively measure what students were talking about during their daily life social interactions, as the time burden of typing in open-ended responses every half hour during the school day would have been too high.

In addition, reliability was modest for the threat interpretation questions. This could be a function of having only four items in this scale or could suggest that cognitive responses are not always consistent across situations. Future studies would need to conduct more comprehensive and validated assessments of emotional and behavioral responses to different types of social situations. Furthermore, the contribution of other individual difference variables such as optimism and perceived control to threat interpretations is an important topic for future research. Finally, future studies are needed to test the replicability of the specific cardiovascular patterns (associations with HR at night vs. SBP during the day).

In sum, we found that perceptions of threat in combination with type of social interaction predicted daytime SBP responses in an ambulatory setting. Adolescents with high-threat perceptions exhibited higher ambulatory SBP when talking to others compared to when not talking with anyone. This association was most pronounced when talking to friends. In contrast, adolescents with low threat perception exhibited lower ambulatory SBP when talking to others than when not talking with anyone. This relationship was most pronounced when talking to parents. Adolescents who perceived greater threat and were more scared, more confrontational, and more stressed during ambiguous social situations also had elevated HR at night. Clinically, these results suggest that how adolescents respond to ambiguous social situations may have implications for later cardiovascular health. Among adolescents, previous research has documented that greater cardiovascular responses to acute stress predict elevated resting blood pressure years later (58–61). If adolescents who perceive greater threat during ambiguous situations do in fact experience more frequent episodes of elevated BP/HR and slower recovery from such episodes, these adolescents may be at risk for developing cardiovascular problems such as hypertension later in life. Overall, our findings suggest that understanding how adolescents perceive different types of social interactions will be important for predicting cardiovascular responses in daily life.

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