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Running Head: STRESS AND COPING IN DIABETES

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Abstract

This study explores the relation of stress and coping style to blood glucose and mood in adolescents with type 1 diabetes. Diabetes is a complex disease to manage due to the daily regimen that each patient must undergo to prevent negative health consequences. The two primary goals of the study were: (1) to examine the relation of stressful daily events to mood and blood glucose levels in adolescents and (2) to examine whether chronic life events and coping styles moderate these relations. To accomplish this, stressors and mood were measured on a daily basis among 20 adolescents with diabetes for one week. At study start, we collected information about coping style and chronic stressors. Results revealed that daily stress did not predict blood glucose levels but did predict mood. Chronic stress did not moderate the relation between daily stress and blood glucose, but did moderate the relation between daily stress and mood. Daily stress was associated to poorer mood but especially so for those with lower chronic stress. Coping style also moderated the relations of daily stress to blood glucose and mood. The findings suggest that individual differences in chronic stress and coping styles moderate the effects of daily stress on adolescents' health.

The Effects of Stress and Coping Styles on Blood Glucose and Mood in Adolescents with Type 1 Diabetes

Type 1 diabetes is a chronic disease that affects the body's ability to produce insulin, a hormone necessary for normal glucose metabolism in the body. It is one of the more common chronic diseases in children and adolescents. About one in every 400 to 600 children and adolescents has type 1 diabetes (American Diabetes Association, 2008). The disease requires the person to take an active role in maintaining blood glucose levels in a normal range. The daily regimen involves administering multiple insulin injections, blood glucose monitoring, maintaining a proper diet, and engaging in regular exercise. Proper adherence to this regimen allows the person to avoid extreme swings in blood glucose that can lead to severe hyperglycemia and ketoacidosis (if too high) or hypoglycemia (if too low).

Low blood glucose levels, or hypoglycemia, if unaddressed can lead to severe headaches, comas and ultimately death. On the other side of the metabolic control spectrum, high blood glucose levels can cause long term complications, which include blindness, kidney disease, and nerve damage (American Diabetes Association, 2008). Because maintaining a healthy blood glucose level is necessary for the prevention of these complications, there has been a large focus on the psychosocial factors that may affect a patient's ability to manage the disease.

Stress

One psychosocial factor that has received a great deal of attention is stress. There are several reviews of the literature that suggest psychological stress can adversely affect glycemic control among individuals with diabetes (Goetsch & Wiebe, 1995). There are two mechanisms by which stress can affect metabolic control. First, stress may directly influence blood glucose levels via physiological mechanisms. It is believed that stressful events can elicit changes in the

body by provoking the body's "fight or flight" response of the autonomic nervous system, and affecting changes in levels of key hormones involved in glucose metabolism. Researchers have identified multiple physiological pathways through which these changes may occur (McCubbin, Surwit, Kuhn, Cochrane, Cochrane, & Feinglos, 1987). Second, researchers have suggested stress may indirectly affect metabolic control by disrupting regimen adherence. That is, stress may detract from self-care behavior which then leads to poor metabolic control (Chase & Jackson, 1981).

Researchers have examined psychological stress in a number of ways, among which include a checklist of major life events (which I term 'chronic stress'), a checklist of daily hassles (which I term 'daily stress'), or by inducing laboratory stressors. Several studies have used checklists of chronic stress with youths with diabetes and found that the frequency of stressful life events is associated with poor metabolic control, specifically higher levels of glycosylated hemoglobin (hba1c; Chase & Jackson 1981; Goldston, Kovacs, Obrosky, & Iyengar, 1995; Hanson, Henggeler, & Burghen, 1987). Others have not found significant relations between chronic stress and metabolic control (Delamater 1987; Griffith, Field & Lustman, 1990). Some argue that this inconsistency is due to methodological reasons, while others argue that measures of chronic stress are insensitive to the potentially acute effects of stress on blood glucose.

In other areas of health, minor daily stressors have been shown to be more predictive of overall health than major life stress (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982). In a daily diary study of 75 married adult couples, it was found that daily stress was related to next-day illness (DeLongis, Folkman, & Lazurus, 1988). In the context of diabetes, where chronic stress has been a primary focus, daily stress has received less attention. In an older study of 59

adult with Type 1 diabetes, more hassles were found to be significantly related to poorer metabolic control (Cox, Taylor, Nowacek, Holley-Wilcox, Pohl, 1984). Another study of 62 adults with Type 1 diabetes showed that it was the variability in daily stress rather than the number of daily stressors that was directly related to poor metabolic control (Aikens, Wallander, Bell, & Cole, 1992).

Several studies have examined daily stress among adolescents with diabetes. One study of adolescents found more daily negative stress was related to higher blood glucose levels (Hanson & Pichert, 1986). In a study of 15 adolescents, daily stress had a significant effect on blood glucose levels independent of diet, exercise, and insulin administration for 7 of the participants, suggesting that a subgroup of patients may be more responsive to stress (Halford, Cuddihy, & Mortimer, 1990). One study examined the relation of daily stress and emotions to blood glucose in 8 adolescents over a 2-month period (Tomakowsky, Delamater, Broadway, & Gutai 1991). They found that only 11% of the variation in blood glucose was accounted for by stress. These two studies suggest that individual differences may be important to understand the relation of stress to blood glucose levels among adolescents. Some patients are more sensitive to stress than others.

Researchers have also investigated the effects of laboratory stressors on metabolic control. Laboratory stressors are more representative of short term daily stressors than long term chronic stressors. In the laboratory, stress is induced by having participants engage in a stressful activity or discussion, and then physiological responses are measured. Results are not consistent across studies. Two studies showed that carefully controlled acute laboratory stressors were not associated with metabolic changes (Kemmer et al., 1986; Gilbert et al., 1989), whereas one study found that adolescents who were in poor metabolic control showed higher physiological

reactivity to stress than adolescents in good control (Delamater et al. 1988). Thus, again, individual differences may play a role in vulnerability to stress.

Taken collectively, it appears that the relation of stress to metabolic control is complicated. First, individual differences may account for some of the inconsistent findings between stress and metabolic control. Second, methodology may also cause some variation in the findings. Most of the studies that examine stress do not measure it on a daily basis. Instead studies rely on daily stress information using questionnaires that ask participants to average their levels of daily stress over a period of time. Daily variability in stress cannot be captured with this method. Examining individuals' stress on a daily basis instead of aggregating across a period of time may lead to a better understanding of the specific effects of daily stress on blood glucose changes.

It also is possible that chronic stress affects the relation between daily stress and metabolic control. However, the pattern of this effect is not clear. One possibility is that chronic stress buffers the relation of daily stress to blood glucose. That is, the relation between daily stress and blood glucose may be weaker among those who have high levels of chronic stress. Those adolescents who have had to undergo many major life events may have learned to cope with these chronic stressors in a way that allows them to cope better with daily stressors. Adolescents who have not had many major life events may have trouble coping with daily stressors because they appraise them quite differently compared to adolescents who have experienced many stressful life events.

Alternatively, chronic stress may amplify the relation between daily stress and metabolic control. That is, chronic stress and daily stress may be related in a more cumulative manner. Adolescents who report more chronic stressors may have more difficulty dealing with daily

stressors because the daily stressors act as additional stressors. Daily stress in the context of chronic stress may make the adolescent feel overwhelmed and less able to control their blood glucose levels. Those who report fewer chronic stressors have less stress with which to cope, so they are less likely to feel overwhelmed and may be better able to cope with minor everyday stressors.

To our knowledge no prior study has examined how chronic stress can influence the relation of daily stress to metabolic control and mood among adolescents with diabetes. This is a primary goal of the present study. Because there are conceptual reasons for two different forms of moderation, we do not make a specific prediction as to how chronic stress will influence the relation of daily stress to metabolic control.

Coping

Another psychosocial factor that may contribute to an individual's blood glucose control is coping style. The way that adolescents cope with stress can influence their metabolic control. Intuitively, it would seem that coping and stress are related; the better one copes with stressors, the greater the reduction in stress. However, not all coping strategies are equally effective.

The literature tends to divide coping into two functions, problem-focused or emotion-focused (Lazarus & Folkman, 1984). Problem-focused coping strategies are those that are aimed at the source of the problem. Emotion-focused coping strategies focus on altering an individual's emotions or responses to the problem. One study of 27 adolescents found that two kinds of emotion-focused strategies—wishful thinking and avoidance—were related to poor metabolic control (Delameter, Kurtz, Bubb, White, & Santiago, 1987). Adolescents were divided into three subgroups based on their level of metabolic control: poor, fair and good. Adolescents in the poor control group scored higher on subscales of wishful thinking and avoidance than the other two

groups. Another study of adolescents found that self blame, keeps to self, wishful thinking, and seeking social support were associated with worse metabolic control (Delamater et al., 1988). Avoidant coping styles have also been found to be associated with poorer metabolic control among adolescents (Hanson, Harris, Carle, Relyea, & Burghen, 1989) and adults (Frenzel, McCaul, Glasgow, & Schafer, 1988). All of these coping styles are part of emotion-based coping, and appear to be related to worse metabolic control.

However this framework for coping strategies is limited in its utility because the categories of problem-focused coping and emotion-focused coping are too broad. For example, emotion-focused coping strategies include both emotional expression and emotional numbing. Emotional expression is when an individual communicates emotion either verbally or nonverbally. Emotional numbing is when individuals try to disassociate themselves with certain emotions. These are not the same. Also there is an inability to distinguish whether these coping responses were automatic or voluntary, which can indicate several individual differences, among which include temperament and stress reactivity.

Another way that coping can be conceptualized is as involuntary and voluntary strategies and as engagement and disengagement coping (Connor-Smith, Compas, Wadsworth, Thomsen, Saltzman, 2000). Voluntary coping strategies are those that are used within conscious awareness. Involuntary coping includes strategies that may not be within conscious awareness. Engagement coping are responses that are directed toward a specific stressor, and disengagement coping are strategies that are directed away from a stressor. This theoretical approach has been suggested as a better method of measuring coping practices in adolescents (Connor-Smith, Compas, Wadsworth, Thomsen, Saltzman, 2000). The specificity of the subscales better reflect individual

differences, and the scales capture the full range and diversity of responses to stress among adolescents, unlike previous theoretical approaches and measures of coping.

Although this conceptual model of coping has not been applied to diabetes, this model has been helpful in understanding the outcomes of children with recurrent abdominal pain. In one study, voluntary engagement styles were associated with less somatic symptoms and with lower levels of anxiety and depression (Thomsen et al., 2002). By contrast, involuntary responses of engagement and disengagement were associated with worse outcomes.

In this present study, we examine how the voluntary and involuntary coping styles of engagement and disengagement might influence the relation of stress to health outcomes. The coping styles that we examine include problem solving (voluntary engagement), emotional expression (voluntary engagement), avoidance (voluntary disengagement), distraction (voluntary disengagement), and rumination (involuntary engagement). We expect that these coping strategies are the ones that adolescents are most likely to use when dealing with stress.

We hypothesize that problem solving and emotional expression (i.e., the two voluntary engagement strategies) will buffer individuals from the impact of daily stress on health. We expect adolescents who engage in these strategies will be more adept at dealing with stress because they involve efforts to reduce the stress. By contrast, we predict that adolescents who employ disengagement strategies, such as avoidance and distraction, or involuntary engagement strategies, such as rumination, will be more strongly affected by stress and have adverse health outcomes. Those who use disengagement strategies may appraise daily stressors as more stressful because they allow stress to accumulate and are less successful at reducing stress levels. In total, we predict that stress will be related to worse blood glucose and poor mood, but the

relation will be weaker for those who use engagement strategies and the relation will be stronger for those who use disengagement strategies.

Introduction to the Study

The literature suggests a relation between major life events and health outcomes among people with diabetes. The relation of more acute stressors such as daily stress and health outcomes is not as consistent. In the present study we examine how daily stress affects blood glucose and mood among adolescents with diabetes. To address this issue, we conducted daily phone interviews with young adolescents with diabetes every day for one week, focusing on daily stressors and blood glucose readings. Because we had measures of stress, mood and blood glucose for seven days, we had the opportunity to see if stress on one day predicted blood glucose and mood on the next day. Thus, we also conducted longitudinal or lagged analyses to test this hypothesis.

We hypothesized that daily stressors would be associated with higher blood glucose and poor mood. We also expected that this relation would be moderated by individual differences in chronic stress levels, although the direction of the moderation is not clear (as described previously). We also expected the relation of stress to blood glucose and mood would be moderated by individual differences in coping strategies, as described above.

Method

Participants

Participants included 11 girls and 9 boys, aged 12 to 16 years (M = 13.3; SD = 1.30). They were recruited from a summer diabetes camp in Western Pennsylvania. To be eligible, participants needed to have met the following criteria: 12 to 16 years old, diagnosed with type 1 diabetes for at least 1 year, and take insulin by pump or injection. Those who were interested and

eligible were contacted by phone. Participants and their parents were told that the participant would be interviewed every day for one week and that interviews would be scheduled in the evening at their convenience. Participants were told that they would be compensated $25 for their participation in the study. After they expressed verbal interest, consent forms were mailed.

Procedure

The study was approved by the Institutional Review Board of Carnegie Mellon University. Parental consent and adolescent assent were obtained through the mail. Adolescents were given a choice to complete the daily surveys online or by phone. All but one participant chose to be interviewed by phone. Adolescents were contacted in the evening of every day for one week. On the first day participants completed measures of coping and chronic stress and were asked a few demographic questions. On that day and each of the next six days, the daily interview was administered. The interview included a daily stress checklist, mood questions, and a request to reveal blood glucose measurements for that day.

The participant who chose to complete the surveys online was emailed links to the interview every day and told to complete it by 8:00 pm. If the survey was not completed by that time, the participant was contacted by phone and reminded.

Of the 20 participants, 15 completed all 7 days, 4 completed 6 days, and only 1 completed 5 days.

Instruments

Chronic stress. We administered an adapted version of the *Adolescent Life Change Event Scale* (Yeaworth, 1980), which consisted of 34 distinct life events. The scale was modified in the following ways: (1) Some items were combined if they encompassed the same basic concept. For example we created a single item "Did a friend or family member die?" by combining 3

items from the original scale (parent dying, sibling dying, close friend dying), (2) Six items were removed because they were irrelevant and unlikely to occur among this age group or did not seem sufficiently stressful (e.g., flunked a grade in school, made new friends), (3) 11 stressful items were added because they seemed sufficiently likely to occur among our age group (e.g., got into an automobile accident, close friend moved away, had difficulties with homework). With these changes and retaining 23 items from the original scale, there were a total of 34 items. Respondents were asked if each item had happened in the past 6 months and, if so, how upsetting it was on a 3-point scale: 1 = not at all, 2 = a little bit, or 3 = very upsetting.

Coping. We used several coping subscales from the *Responses to Stress Questionnaire* (Compas, Connor, Saltzman, Thomsen, & Wadsworth, 1999), including problem solving (α = .64), emotional expression (α = .68), avoidance (α = .60), distraction (α = .54), and rumination (α = .77). Each subscale consisted of three items. Participants were asked to think about how they typically handled stressful events in their life and then asked how often they use each item to cope with stress on a 4-point scale: not at all, a little, some, or a lot. Two items were removed from the scale based on the reliability analysis. One item from the avoidance scale, "I try not to think about it, to forget all about it", and one item from the distraction scale, "I keep my mind off my problems by doing other things. Some examples are: exercise, doing a hobby, watching TV".

Daily stress. We adapted the *Adolescent Perceived Events Scale* (Compas, 1987) for use as a daily stress measure. We shortened the scale to make it more feasible to administer on a daily basis, which also involved removing items that were unlikely to happen on a daily basis (e.g., "change in moral or religious beliefs"). We also added some positive events to the scale to make it seem less negative and to examine whether positive events have a beneficial effect on mood and blood glucose. Items fell into five domains: school stress (e.g. "Did poorly on an

exam or paper", 12 items), peer stress (e.g. "Had fights or problems with a friend", 13 items), family stress (e.g. "Family did not respect your privacy or property", 12 items), personal stress (e.g."Had changes in personal appearance", 4 items), and positive events (e.g. "Received a compliment", 9 items). To ensure that we adequately represented common daily stressors in the lives of adolescents, we administered the questionnaire to several local teenagers to make sure that we captured as many daily stressors as possible.

Mood. We used the Profile of Mood States to assess mood (Usala & Hertzog, 1989). We used four subscales, each consisting of 3 items: anger, anxiety, depression, and happiness.

Blood Glucose

Participants measured their blood glucose several times over the course of the day as part of their regular diabetes care. At the end of the interview, they were asked to tell us the times of each reading and each reading result.

Results

Background Variables

First, we examined whether demographic variables (sex, grade, GPA, age, diabetes age, insulin method, metabolic control [hemoglobin A1c]) were related to our primary variables of interest. Age (r = -.46, p = .04) and length of diabetes (r = -.41, p = .07) were negatively correlated with the number of chronic stressors, such that younger adolescents and adolescents who had had the disease for a shorter period of time reported more chronic stress. None of the other demographic variables were associated with our measures of chronic stress.

GPA was marginally correlated with emotional expression (r = .42, p = .07) and avoidance (r = .08, p = .08), such that adolescents who had higher GPAs reported more emotional expression and more avoidance coping styles. Self-reported A1c levels were found to

be negatively correlated with emotional expression (r = -.54, p = .02), and distraction (r = -.50, p = .04), such that adolescents who reported better metabolic control had higher emotional expression and distraction style coping.

Independent t-tests showed that there were sex differences in emotional expression, $t(18) = 2.01$, $p < .05$, with females reporting higher scores (M = 1.76) than males (M = 1.11). There were no sex differences in the other coping styles.

Independent t-tests also showed that there were significant differences in coping styles between adolescents who used insulin pumps and adolescents who used insulin injections. Those who used pumps reported higher scores for emotional expression (M = 1.75) than those who used injections (M = 1.11), $t(18) = 2.01$, $p < .05$. Those who used pumps also had lower scores on avoidance (M = 1.14) than those who used injections (M = 1.83), $t(18) = -1.86$, $p < .08$.

Relation of Daily Stress to Blood Glucose and Mood

The primary goal of this study was to examine the relation of daily stress to blood glucose levels and mood. Because daily stressors are nested within persons, we used multi-level modeling to examine these relations. Cross-sectional relations of the total daily stress score, as well as the four domains of daily stress, to blood glucose and mood are shown in Table 1.

Blood glucose. There was no relation of total stress to blood glucose. When the four stressor domains were examined, only personal stressors were related to blood glucose. More personal stressors were associated with higher blood glucose.

Mood. Of the four mood variables, total stress was related to more depression and more anger. Of the stressor domains, peer stressors and personal stressors were both associated with more depression and more anger. School stressors were related to more anger and marginally related to more anxiety and depression. Family stressors only revealed one trend toward a

relation to more anger. Positive stressors were not related to any of the mood outcomes. None of the stressor domains were related to happiness.

Chronic Stress as a Moderator of the Relation of Daily Stress to Blood Glucose and Mood

To determine whether chronic stress is a moderator of the relation of daily stress to health outcomes, I computed the interaction between chronic stress and total stress (as well as each of the daily stress domains). Then, I entered the main effects for chronic stress and the daily stressor domain into the first step of the regression and the interaction between the two in the second step. Variables were centered before computing interaction terms.

Blood glucose. Chronic stress did not interact with total stress nor any of the individual domains of stress to predict blood glucose.

Mood. First, we examined whether chronic stress moderated the relation of total stress to mood. Chronic stress interacted with total daily stress to predict depression (B = .19, $p < .05$), anger (B = .20, $p < .05$), and happiness (B = .02, $p < .02$), but not anxiety. As shown in Figure 1, total daily stress was related to more depression—especially so for those who were lower in chronic stress. The same pattern of findings appeared for anger. For happiness, the findings were parallel but reversed. More total daily stress was related to less happiness, and especially so for those who were lower in chronic stress.

Next, we examined whether chronic stress moderated the relation of specific stressor domains to mood. Peer stressors interacted with chronic stressors to predict depression, $B = -.06$, $p < .001$. Similar to the findings for total stress shown in Figure 1, peer stress was related to more depression, and especially so for those low in chronic stress. Peer stress did not interact with chronic stress to predict happiness, anger, or anxiety.

Personal stress interacted with chronic stress to predict anxiety, B = .14, $p < .01$. In contrast to the previous findings, more personal stress was related to more anxiety, and especially so for those who were higher in chronic stress (see Figure 2). Personal stress did not interact with chronic stress to predict happiness, depression, or anger.

Positive stressors interacted with chronic stress to predict anger, B = .019, $p < .05$. As shown in Figure 3, more positive events were related to less anger for those who were low in chronic stress but more anger for those who were high in chronic stress. Positive stress did not interact with chronic stress to predict happiness, depression, or anxiety.

School and family stress did not interact with chronic stress to predict any mood outcomes.

Coping as a Moderator of the Relation of Daily Stress to Blood Glucose and Mood

Blood glucose. To determine whether coping styles moderated the relation of daily stress to blood glucose, the interaction between each coping style and each of the daily stress domains was computed. There were 5 coping styles examined: problem solving, emotional expression, distraction, rumination and avoidance.

First, we examined whether coping styles interacted with total daily stress to predict blood glucose. There was no significant interaction. Next we examined whether coping styles interacted with the different domains of daily stress to predict blood glucose. Rumination interacted with peer stress to predict blood glucose, B = -11.34, $p < .04$. As shown in Figure 4, more peer stress was related to higher blood glucose levels, and especially so for those who scored low in rumination. Avoidance interacted with positive events to predict blood glucose, B = -0.59, $p < .05$. As shown in Figure 5, positive events were related to higher blood glucose for

those who scored low in avoidance and to lower blood glucose levels for those who scored high in avoidance.

Distraction, emotional expression, and problem solving did not interact with any daily stress domain to predict blood glucose.

Mood. To reduce the number of analyses, we only examined whether coping styles interacted with the total daily stress score to predict each of the four mood outcomes.

Total daily stress interacted with **distraction** to predict depression (B = -0.52, $p < .001$) and anger (B = -.06, $p < .02$). As shown in Figure 6, more stress was related to higher depression, especially so for those with high distraction. The same pattern held for the interaction between stress and distraction on anger (see Figure 6). Distraction did not interact with total stress to predict anxiety or happiness.

Total daily stress interacted with **rumination** to predict depression (B = .04, $p < .01$) and happiness (B = -.05, $p < .02$). As shown in Figure 7, there was no relation of total stress to depression for those low in rumination but more stress was related to higher depression for those high in rumination. The findings for happiness were not identical but similar. As shown in Figure 8, more stress was related to lower happiness for those high in rumination, but the reverse occurred for those low in rumination.

Avoidance did not interact with total stress to predict any of the mood outcomes.

Emotional expression interacted with total stress to predict depression (B = .06, $p < .001$) and happiness (B = -.08, $p < .001$). As shown in Figure 9, total stress was related to more depression, and especially so for those high in emotional expression. Stress was related to less happiness for those with high emotional expression and more happiness for those with low

emotional expression, similar to the pattern in Figure 8 with high emotional expression acting as rumination. Emotional expression did not interact with total stress to predict anger and anxiety.

Problem solving interacted with total stress to predict anger, B = -.07, $p < .03$. As shown in Figure 9, total stress was more strongly related to anger for those who scored lower on problem solving. Problem solving did not interact with total stress to predict anxiety, depression, or happiness.

Sex as a Moderator of Daily Stress to Blood Glucose and Mood: Cross-sectional

Although we did not make a specific hypothesis, we took the opportunity to explore whether sex was a moderator of the relation of daily stress to health outcomes. To do so, the interaction between sex and each of the daily stress domains was computed to predict blood glucose and mood.

Blood glucose. Sex interacted with total stress to predict blood glucose (B = -6.59, $p < .03$). More stress was associated with higher blood glucose levels in females but lower blood glucose levels in males (See Figure 10). This same pattern was found for one of the four domains of daily stress—personal stress, B = -77.67, $p < .00$.

Mood. Sex did not interact with total stress to predict mood. The only specific domain of stress that interacted with sex was peer stress. Sex interacted with peer stress to predict depression (B = -.14, $p < .01$) and anger (B = -.23, $p < .01$). The interaction of sex with peer stress to predict depression is shown in Figure 11. The pattern for anger is the same. Peer stress was more strongly associated with more depression and more anger for females than males. Sex also interacted with peer stress to predict happiness, B=.09, $p < .02$. As shown in Figure 12, peer stress was related to less happiness for females and more happiness in males.

Relation of Daily Stressors to Blood Glucose and Mood: Lagged

We also examined whether daily stress on one day predicted blood glucose and mood on the following day controlling for the previous day's mood or blood glucose.

Blood Glucose. Total stress did not predict next day blood glucose levels. Of the specific stress domains, only peer stress predicted next day blood glucose, B=-6.10, $p < .02$, in the direction that more peer stress on one day was associated with a decline in blood glucose on the following day.

Mood. Total stress did not predict any of the next day mood outcomes. Of the stressor domains, peer stress predicted next day anger (B = .15, $p < .24$), such that more stress on one day predicted more anger the following day. Positive events predicted next day happiness (B = .74, $p < .00$), such that more positive events on one day predicted more happiness the following day.

Discussion

The primary purpose of this study was to examine the relation of daily stress to blood glucose. The cross-sectional analyses did not show links of total stress to blood glucose but did show that blood glucose was related to one specific domain of stress, personal stress. Unfortunately, the measure of personal stress included the item, "Did you feel ill or sick today?". Being ill or sick can affect blood glucose levels, and may have significantly contributed to this finding. The lagged analyses did not reveal that total stress was associated with next day blood glucose levels, but one domain of stress was related to next day blood glucose levels—peer stress. However, peer stress on one day was related to a *decline* in blood glucose on the following day. The findings are opposite to prediction.

There are several reasons for these findings (or the lack of findings). First, it could be that daily stress has a negligible effect on blood glucose in adolescents with diabetes. Alternatively, the relation of peer stress on one day to a *decrease* in blood glucose the next day

could be due to a decrease from a relative spike in blood glucose on the previous day. However, we do not have the data to support that interpretation, as peer stress was not related to blood glucose levels within the same day. Another reason for our overall null findings for blood glucose could be that the methodology we used did not allow us to fully capture the effect of daily stress on blood glucose. Our data was limited by the fact that stress and blood glucose measures were daily averages. If the effects of daily stress on blood glucose are more immediate, we would not have captured it with our design. Our design did not take into account temporal proximity.

Our next objective was to determine the relation of daily stress to mood. We had substantial evidence that daily stress was related to mood, in particular depression and anger. Of the specific stressor domains the strongest links were to peer, personal, and academic stressors. This is not surprising because friends begin to play a larger role in the lives of adolescents. Thus, interactions with peers may have more influence on their mood. Personal stressors may have had a greater impact on mood because there is a greater self consciousness or awareness during adolescence, including a concern with body image. It is not a surprise that academic stressors play a role in the mood of these youth as they spend a substantial part of their day in school. Correspondingly during this period, there may be a diminished value of the family to the adolescent. Thus, family stressors do not influence the adolescent's mood to the degree that peer personal, or school problems might.

A second goal of the study was to determine whether chronic stress moderated the relation of daily stress to blood glucose and mood. Although chronic stress did not moderate the relation between daily stress and blood glucose, it did moderate the relation between daily stress and mood. The majority of these findings suggested that adolescents with higher levels of

chronic stress are *less* vulnerable to the effects of daily stress on mood than those with lower levels of chronic stress. This is consistent with our hypothesis that experiences with chronic stress may buffer individuals from the adverse effects of daily stressors. Adolescents who have faced chronic stressors may have developed coping strategies that allow them to be less affected by daily stress. Adolescents who have not faced many chronic stressors in the past may have trouble dealing with everyday stressors due to the lack of experience. Alternatively, in the face of chronic stress, adolescents may appraise daily stressors as less significant and, therefore, be relatively unaffected by them. The result is that those with low chronic stress are more affected by daily stressors.

Our last objective was to determine whether different coping styles moderated the relation of daily stress to blood glucose and mood. None of the coping styles interacted with total stress to predict blood glucose. We did find that rumination interacted with peer stress to predict blood glucose. Peer stress was related to higher blood glucose levels, and especially so for those who scored low in rumination. At first glance, this finding may seem counterintuitive. Rumination is an involuntary engagement strategy, a strategy that we had predicted would magnify the relation of stress to poor blood glucose, However, in the case of blood glucose monitoring, rumination may be an adaptive strategy. These individuals may be more likely to worry about their blood glucose levels, which enables them to monitor it more carefully, and have better regimen adherence as a result. High ruminators may be aware of the effects of stress on blood glucose, so they respond to stress by being more vigilant and taking appropriate precautions. However this interpretation should be taken with caution because rumination did not interact with total stress and it only interacted with one domain of stress.

Many of the coping styles interacted with total daily stress to predict mood outcomes. Overall distraction, rumination, emotional expression, and problem-solving moderated the relation of stress to mood. Relations to stress were generally stronger for individuals who were low in distraction, high in rumination, high in emotional expression, and low in problem-solving. Distraction, in the context of daily stress and mood, may be a beneficial coping strategy in the short run because it allows individuals to avoid the irritation of minor daily stressors. By contrast, those who do not engage in distraction may feel overwhelmed by the same minor daily stressors, leading to poorer mood. While rumination appeared to beneficial in terms of blood glucose, it was not in terms of mood—which is consistent with a large literature on rumination (Nolen-Hoeksema, 1987; 1994). Those who engage in rumination may be constantly thinking and worrying about daily stressors, which leads to poorer mood outcomes.

The findings for emotional expression were surprising, as we expected emotional expression to buffer rather than amplify the effects of stress. Although emotional expression is a voluntary engagement strategy, perhaps it is not the best means of dealing with daily stress. Talking and expressing your feelings to others may serve to reaffirm those feelings and potentially exacerbate them without dealing with the real source of the stress.

The findings for problem-solving were as predicted. This active engagement strategy may serve as a buffer against the effects of daily stress on mood. Those who take a more active role in dealing with stressors may be better off in terms of mood outcomes because they actually reduce the effects of the stressor preventing it from worsening with time.

Collectively in the context of daily stress and mood, rumination and emotional expression are not optimal coping strategies. In contrast problem solving and distraction coping may be more beneficial.

On an exploratory basis, we also examined whether sex moderated the relation of stress to blood glucose and mood. Here we had perhaps the most cohesive set of findings. In all cases, relations of stress to poor health outcomes were stronger among females than males. This suggests a vulnerability to daily stress on the part of female adolescents. Importantly, stress was associated with higher blood glucose in females and lower blood glucose in males. These findings suggest that adolescent girls with diabetes may be more vulnerable than boys to the effects of stress. There could be a fundamental difference in how girls and boys perceive stress. Girls may feel more overwhelmed by stress and have a harder time maintaining their blood glucose. Females also may be more likely than males to respond to stress by neglecting appropriate self-care behaviors which then lead to higher levels of blood glucose. Alternatively, there could be a difference in how males and females cope with daily stress. We found that girls engaged in more emotional expression than boys, and our other findings showed that emotional expression was not an adaptive coping strategy. Thus, coping might explain why daily stress was more strongly related to poor blood glucose in girls than boys.

Sex also moderated the relation of stress to mood, when stress was in the domain of peer stress. Peer stress was more strongly associated with poor mood for females than males. These findings suggest that females may be more vulnerable to a specific domain of stress, peer stress. These findings can be explained by the vital role that peers play during adolescence—especially for females. Adolescent girls may place a higher value on their relationships with their friends and peers than boys do, especially at that age. This finding is consistent with previous research that has shown adolescent girls to have higher stress reactivity to interpersonal stressors than adolescent boys (Nolen-Hoeksema & Girgus, 1994; Rudolph, 2002) As a result, when a conflict or issue arises between friends, girls will be more stressed than boys. Alternatively, conflicts

between girls at that age may be more severe (i.e., relational aggression) than conflicts between boys. Therefore, when these events occur the consequences are much worse for girls than boys.

There are several limitations to the study that we conducted. One potential limitation is that the stress measure was not detailed enough to tell us when the specific stressors were occurring throughout the day. If the effects of stress are more specific and immediate, it would be important to have measures of stress that coincided directly with measures of blood glucose. We may need to assess the more proximal relations of daily stress events to changes in blood glucose. In addition, blood glucose measures were obtained individually by the participant, self-reported, and then averaged across the day. There are several problems with this method. First, the participant may or may not be telling the truth. They may be reporting blood glucose measures that fall within normal range, and not reporting those that are too high or too low. Second, there was no consistency across participants in the number of measurements that were taken every day or in the time that they were taken. This could have significantly affected the average blood glucose we computed. For instance, a participant could have taken one measurement in the morning and then several measurements during the evening when their blood sugar needed to be closely monitored. In this case, there is no record of blood glucose levels in between these two time periods. The average would be more representative of blood glucose levels during the evening rather than over the course of the whole day. Finally, because the measurements were averaged, we could not track specific changes in blood glucose throughout the day. If the relation of stress to blood glucose is more immediate and momentary, this would be a problem.

Another limitation is the size and composition of our sample. We had a small sample size which may have limited out ability to detect significant relations, especially in the case of blood

glucose. The sample was fairly homogenous, as participants were all white and lived in western Pennsylvania, which limits the generalizability of the findings. Due to the small sample size and homogeneity of participants, we might not have captured important individual differences that moderate the relation between stress and blood glucose within our sample. It also was the case that these adolescents did not report many daily stressors in general. Most daily reports of stress ranged from no stressors to a very small number of stressors. Either they were unwilling to disclose daily stressors or they did not have many daily stressors occurring in their life. Thus, these findings do not tell us much about adolescents with diabetes who undergo a relatively great deal of daily stress. If the relation between daily stress and blood glucose exists only for those who have a high degree of stress in their lives, we may have failed to capture this relation.

Future research should include methodologies that involve a more proximal tracking of daily stress and blood glucose, perhaps through daily dairies or palm pilots. Participants could enter the type of stressor as they are experiencing it and blood glucose could be continuously monitored. The time stamp can later be used to associate stress with the corresponding blood glucose readings. By being able to associate specific stressors with blood glucose changes that occur, we may be able to obtain a better understanding of the relation between daily stress and blood glucose, and the individual differences that may moderate that relation.

Taken collectively, these results show that the relation of daily stress to blood glucose and mood is not a simple one. The findings suggest that individual differences may play a significant role in moderating these relations given the number of interactions with the various coping styles, with sex, and with chronic stress. Further research should take into account the importance of individual differences when examining the relation of stress to blood glucose.

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Table 1

Relation of Daily Stress to Blood Glucose and Mood

Stress Type	BG	Happiness	Depression	Anger	Anxiety
Total	-1.02	-0.01	0.45***	0.08***	0.02
Peer	-2.23	-0.07	0.16***	0.21***	0.24
School	-4.86	0.00	0.05+	0.14***	0.06+
Family	-2.05	0.02	0.04	0.10+	0.02
Personal	26.00**	-0.10	0.23**	0.37**	0.15
Positive	0.28	0.04	0.00	0.01	0.02

+ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Note: BG = blood glucose

Figure Captions

Figure 1. The relation of total daily stress to depression for those who are high and low in chronic stress.

Figure 2. The relation of personal to anxiety for those who are high and low in chronic stress.

Figure 3. The relation of positive events to anger for those who are high and low in chronic stress.

Figure 4. The relation of peer stress to blood glucose for those who are high and low in rumination.

Figure 5. The relation of positive events to blood glucose for those who are high and low in avoidance.

Figure 6. The relation of total daily stress to depression for those who are high and low in chronic stress.

Figure 7. The relation of total daily stress to depression for those who are high and low in rumination.

Figure 8. The relation of total daily stress to happiness for those who are high and low in rumination

Figure 9. The relation of total daily stress to depression for those who are high and low in emotional expression.

Figure 10 . The relation of total daily stress to anger for those who are high and low in problem solving

Figure 11. The relation of total daily stress to blood glucose for males and females.

Figure 12. The relation of peer stress to depression for males and females.

Figure 13. The relation of peer stress to happiness for males and females.

Figure 1

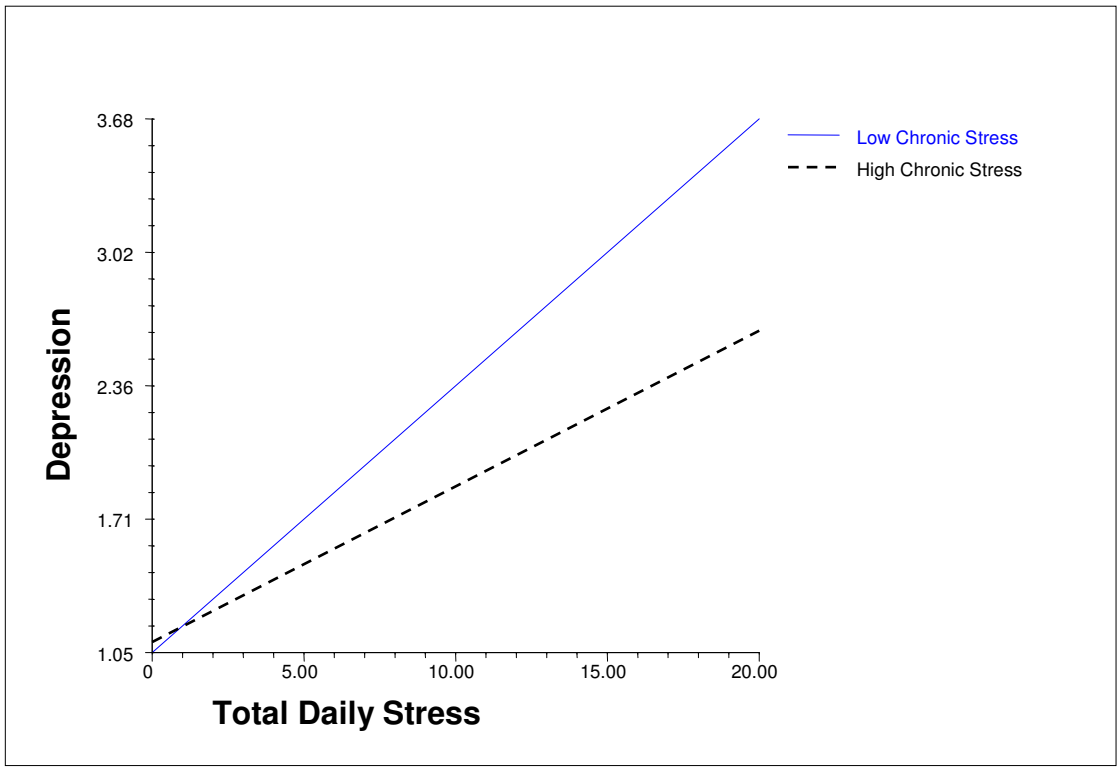

3.68
3.02
2.36
1.71
1.05
Depression
0
5.00
10.00
15.00
20.00
Total Daily Stress
Low Chronic Stress
High Chronic Stress

Figure 2

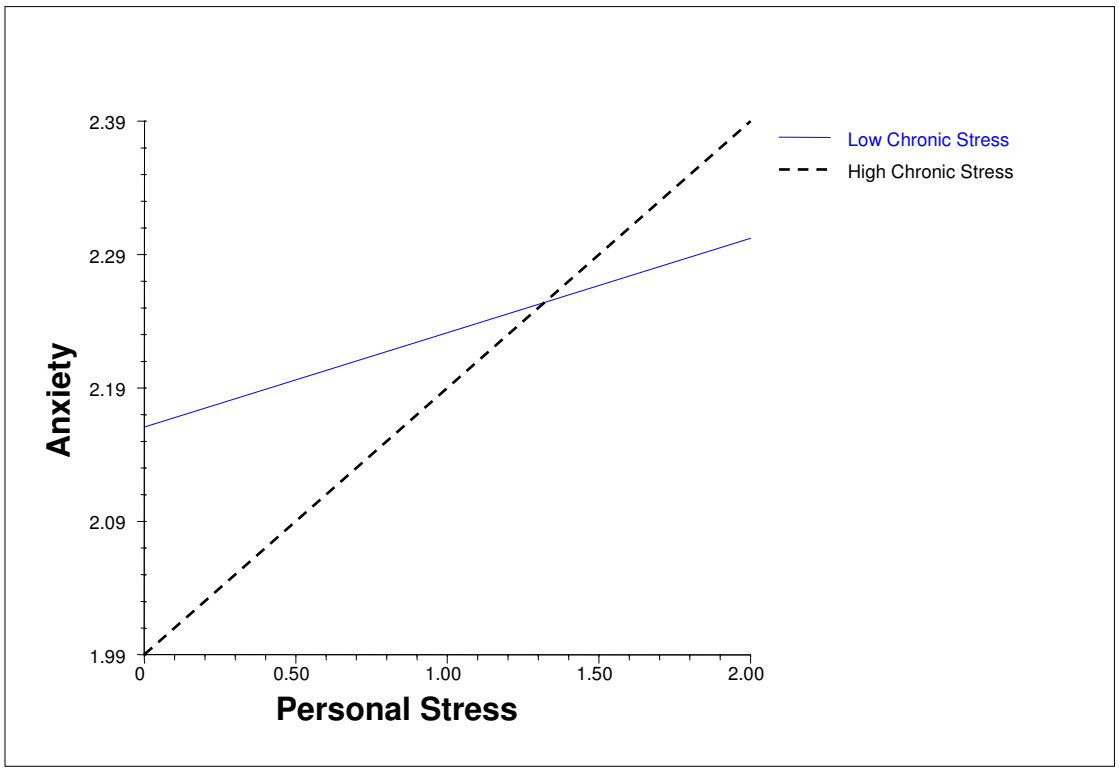

2.39
2.29
2.19
2.09
1.99
Anxiety
0
0.50
1.00
1.50
2.00
Personal Stress
Low Chronic Stress
High Chronic Stress

Figure 3

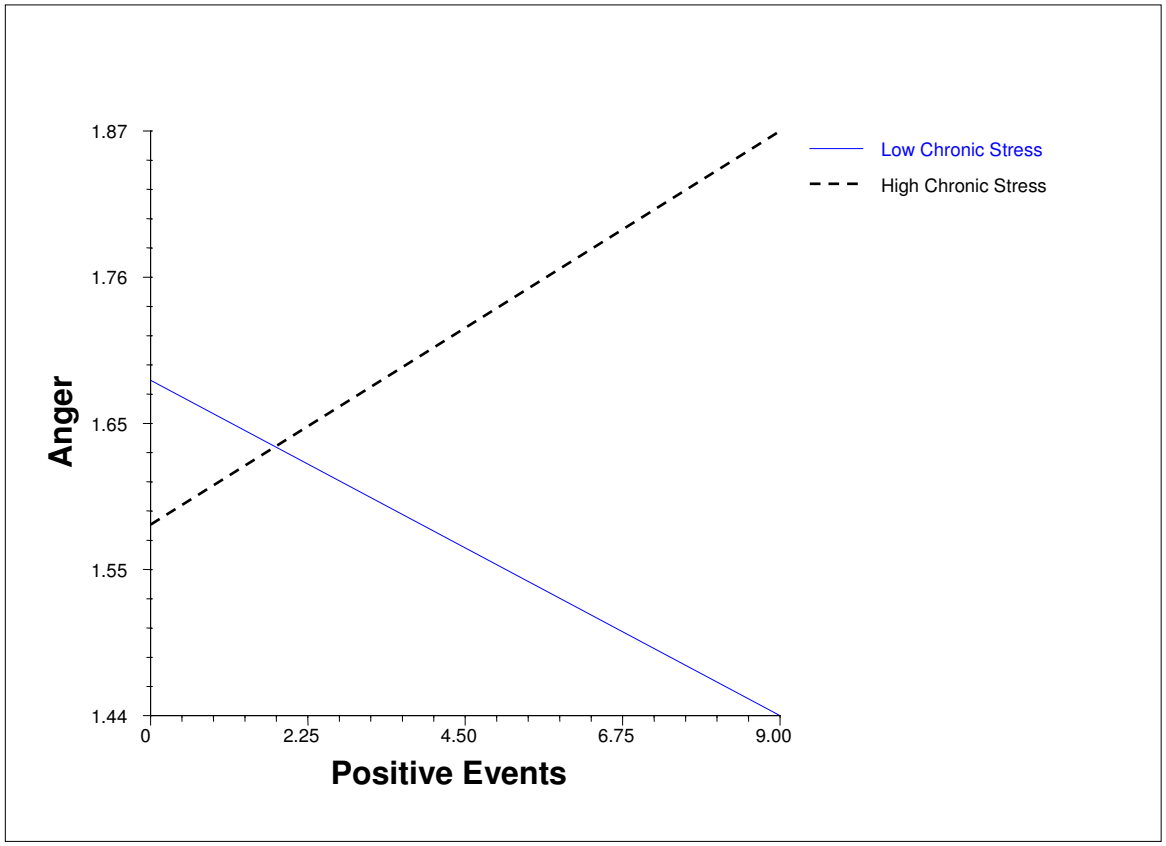

1.87
1.76
1.65
1.55
1.44
Anger
0
2.25
4.50
6.75
9.00
Positive Events
Low Chronic Stress
High Chronic Stress

Figure 4

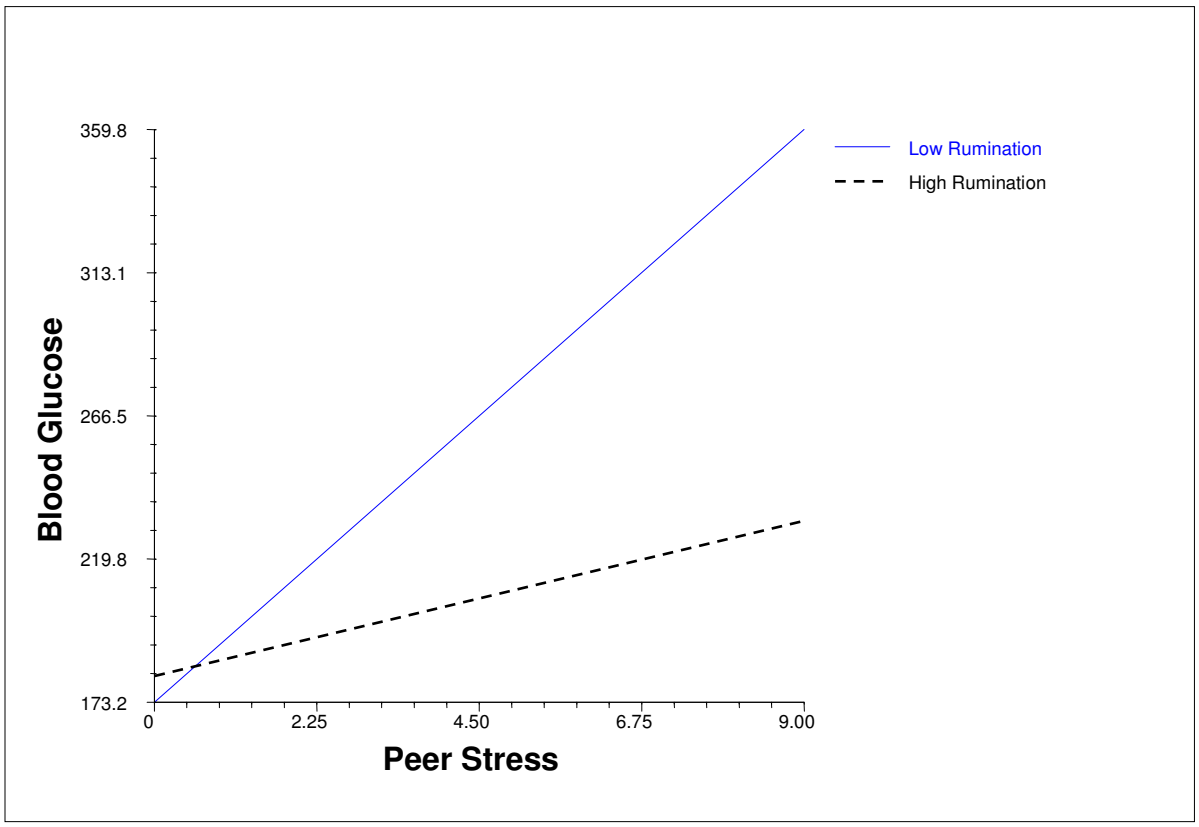

359.8
313.1
266.5
219.8
173.2
Blood Glucose
0
2.25
4.50
6.75
9.00
Peer Stress
Low Rumination
High Rumination

Figure 5

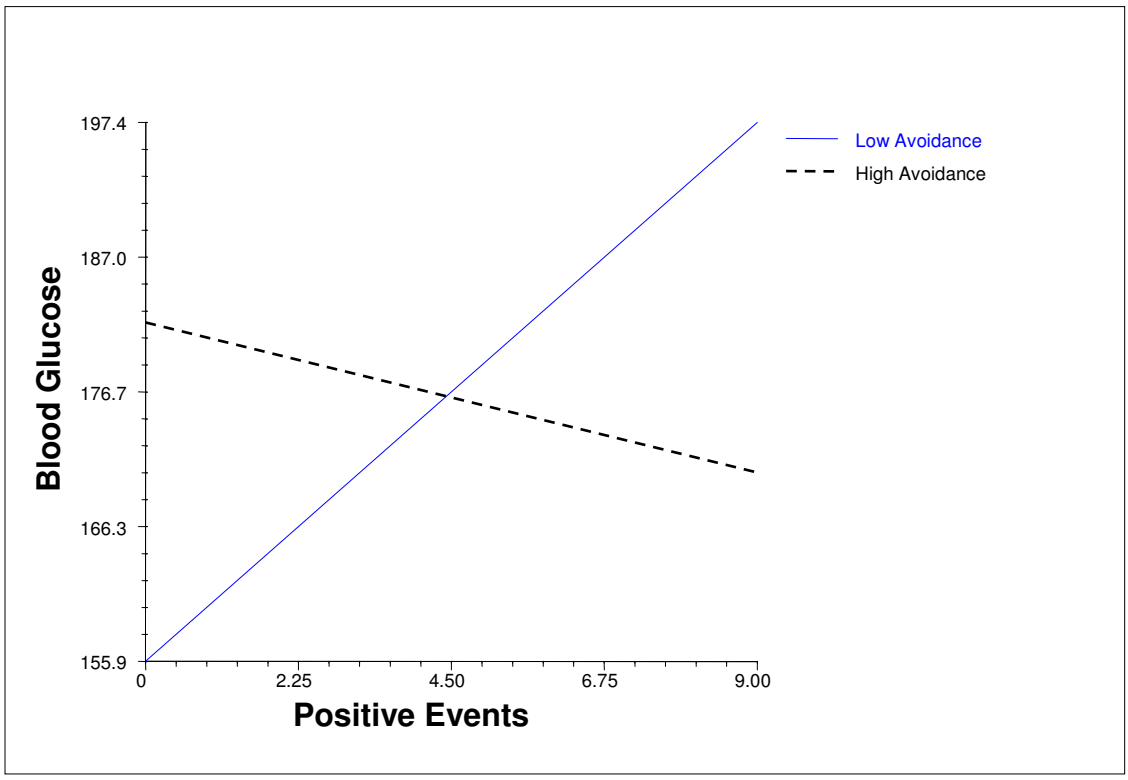

197.4
187.0
176.7
166.3
155.9
Blood Glucose
0
2.25
4.50
6.75
9.00
Positive Events
Low Avoidance
High Avoidance

Figure 6

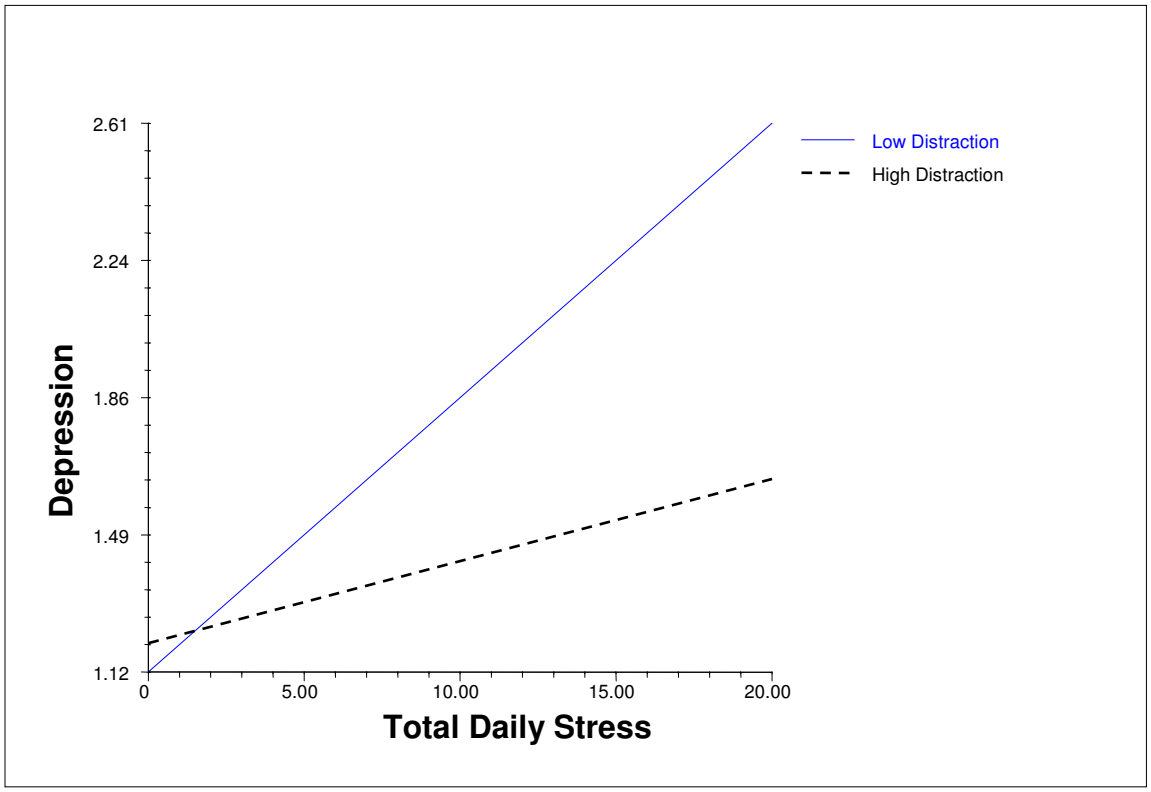

2.61
2.24
1.86
1.49
1.12
Depression
0
5.00
10.00
15.00
20.00
Total Daily Stress
Low Distraction
High Distraction

Figure 7

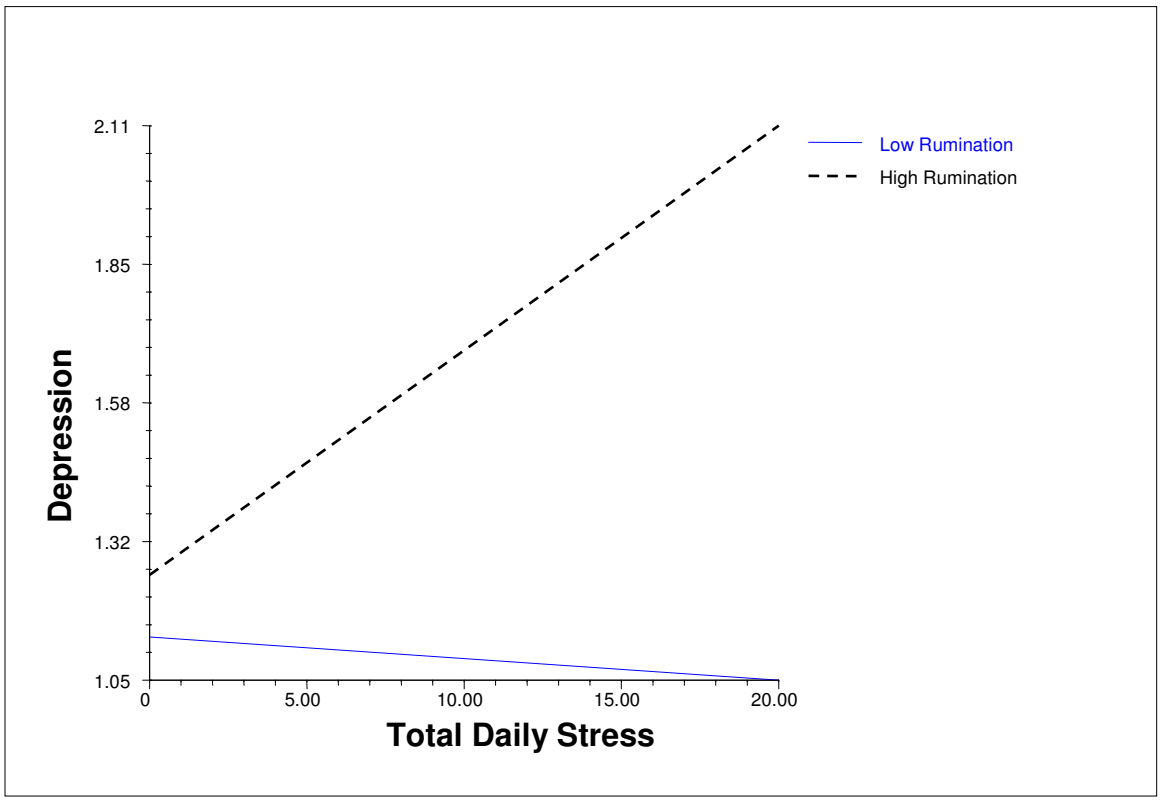

2.11
1.85
1.58
1.32
1.05
Depression
0
5.00
10.00
15.00
20.00
Total Daily Stress
Low Rumination
High Rumination

Figure 8

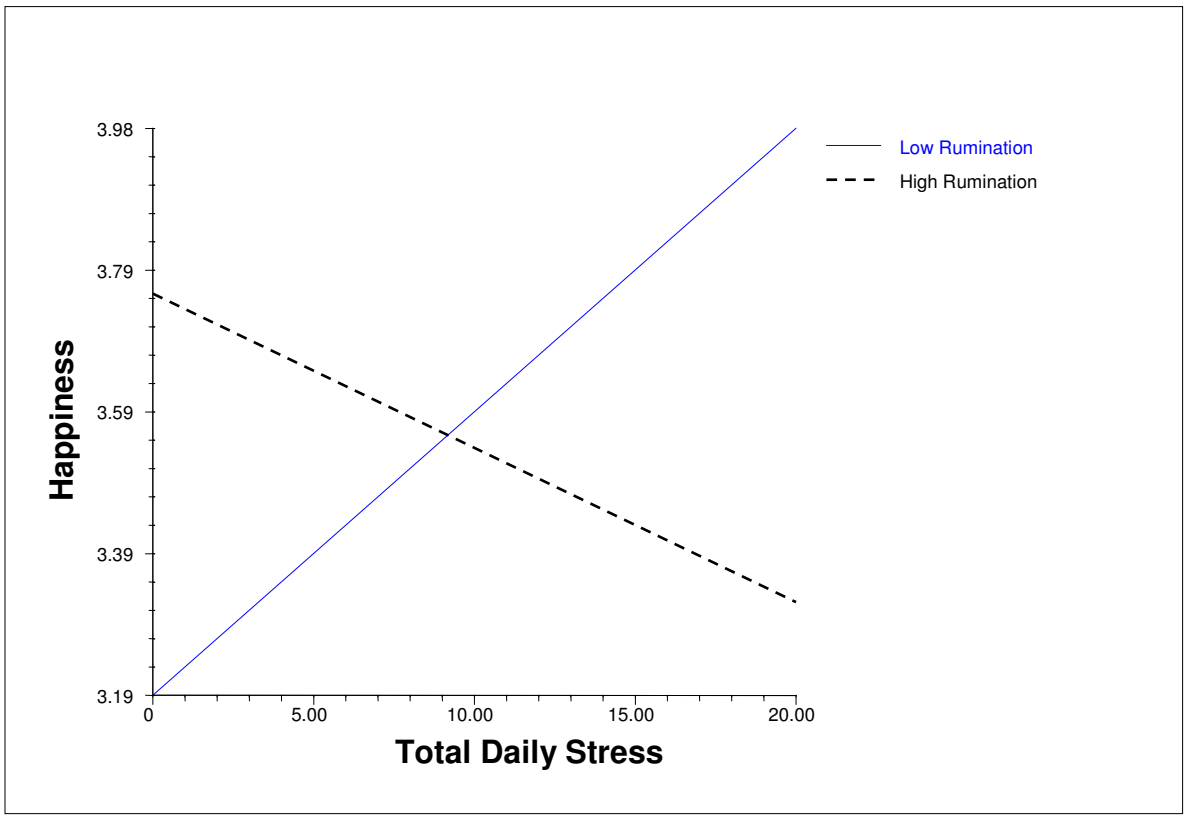

3.98
3.79
3.59
3.39
3.19
Happiness
0
5.00
10.00
15.00
20.00
Total Daily Stress
Low Rumination
High Rumination

Figure 9

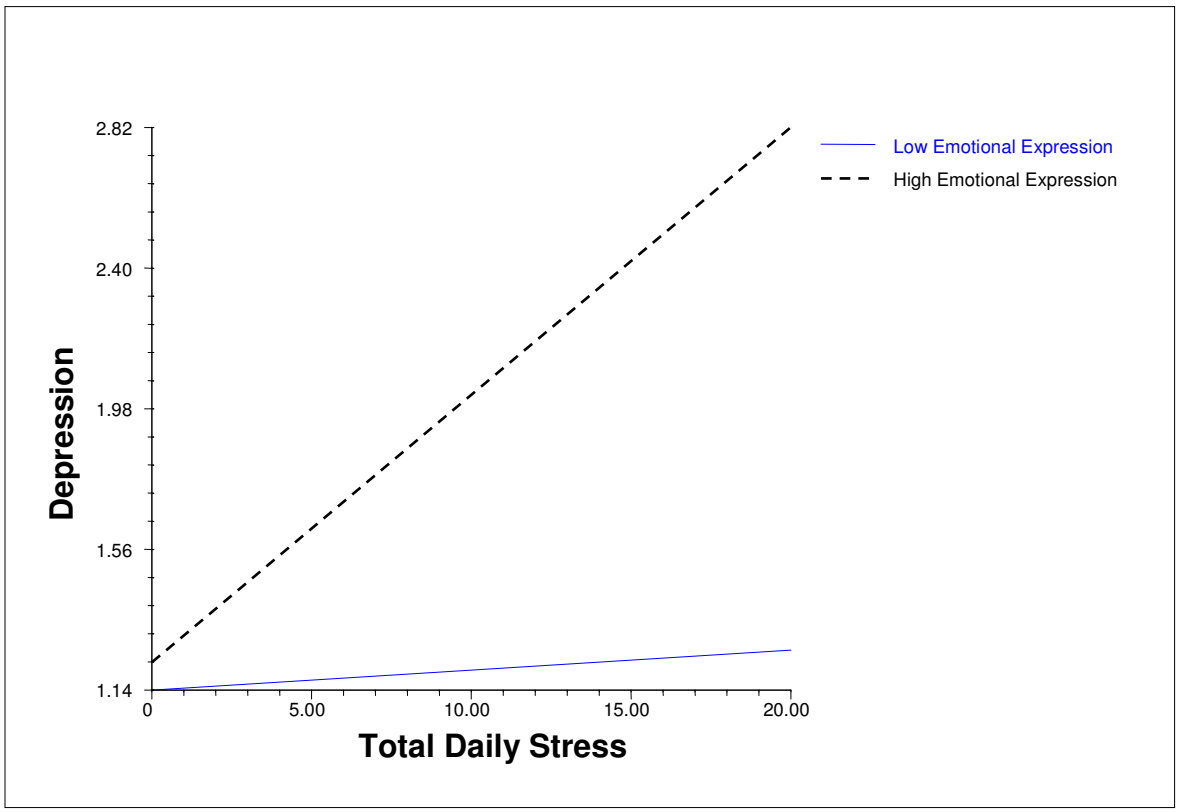

2.82
2.40
1.98
1.56
1.14
Depression
0
5.00
10.00
15.00
20.00
Total Daily Stress
Low Emotional Expression
High Emotional Expression

Figure 10

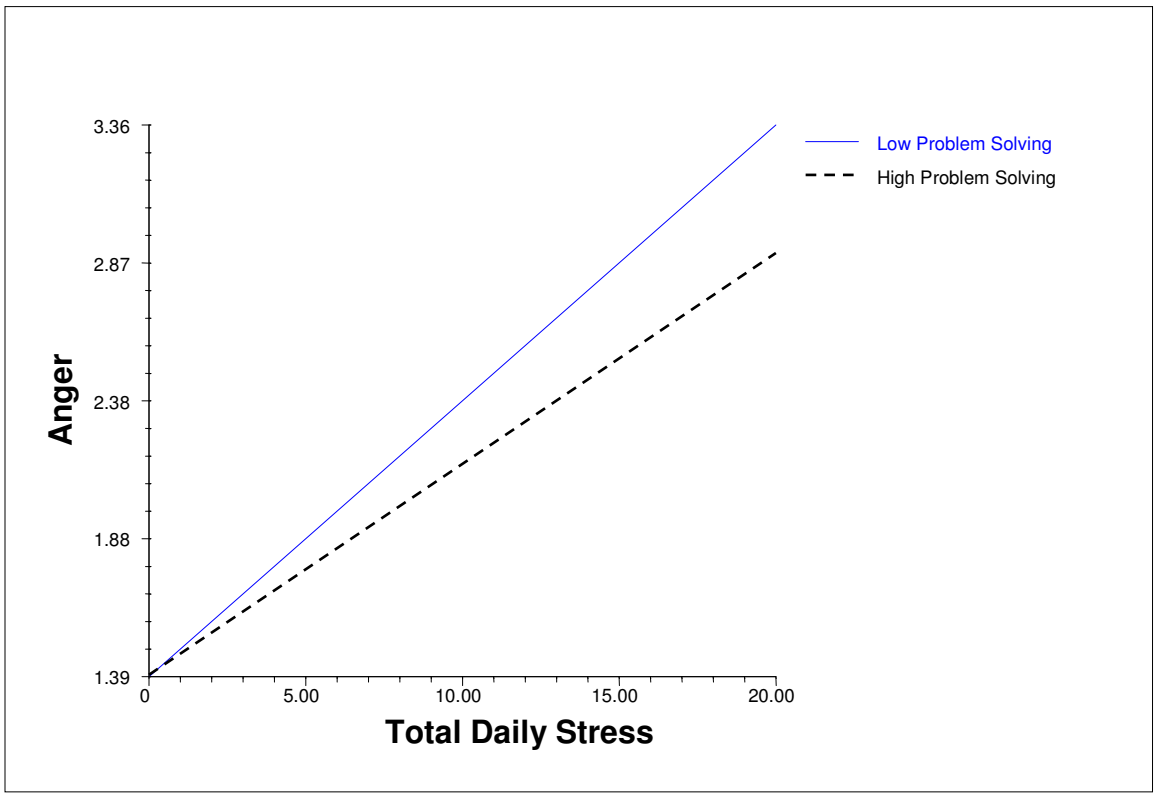

3.36
2.87
2.38
1.88
1.39
Anger
0
5.00
10.00
15.00
20.00
Total Daily Stress
Low Problem Solving
High Problem Solving

Figure 11

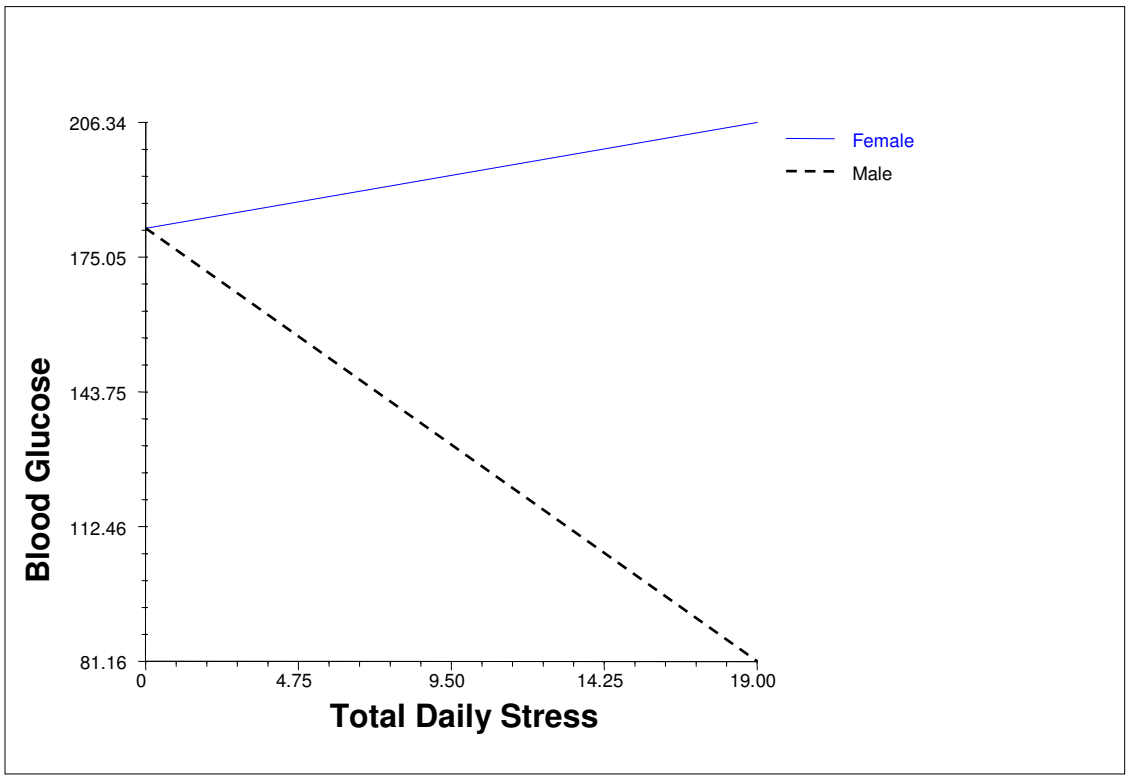

206.34
175.05
143.75
112.46
81.16
Blood Glucose
0
4.75
9.50
14.25
19.00
Total Daily Stress
Female
Male

Figure 12

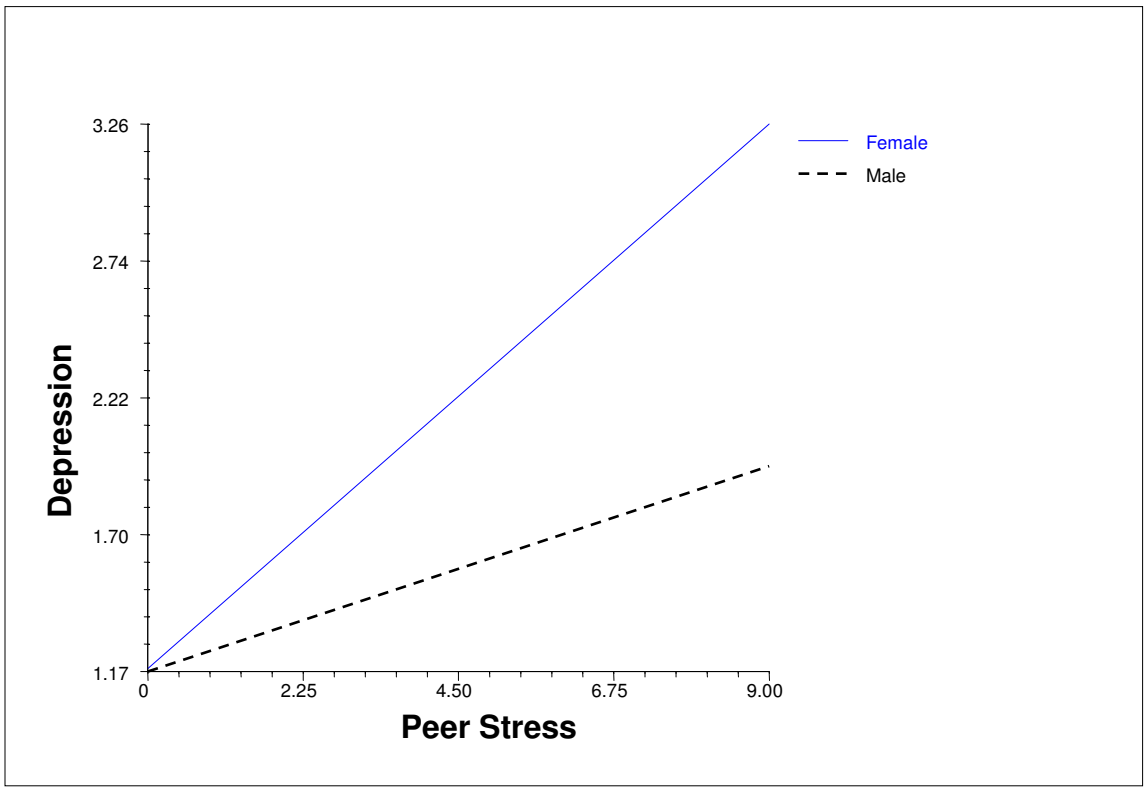
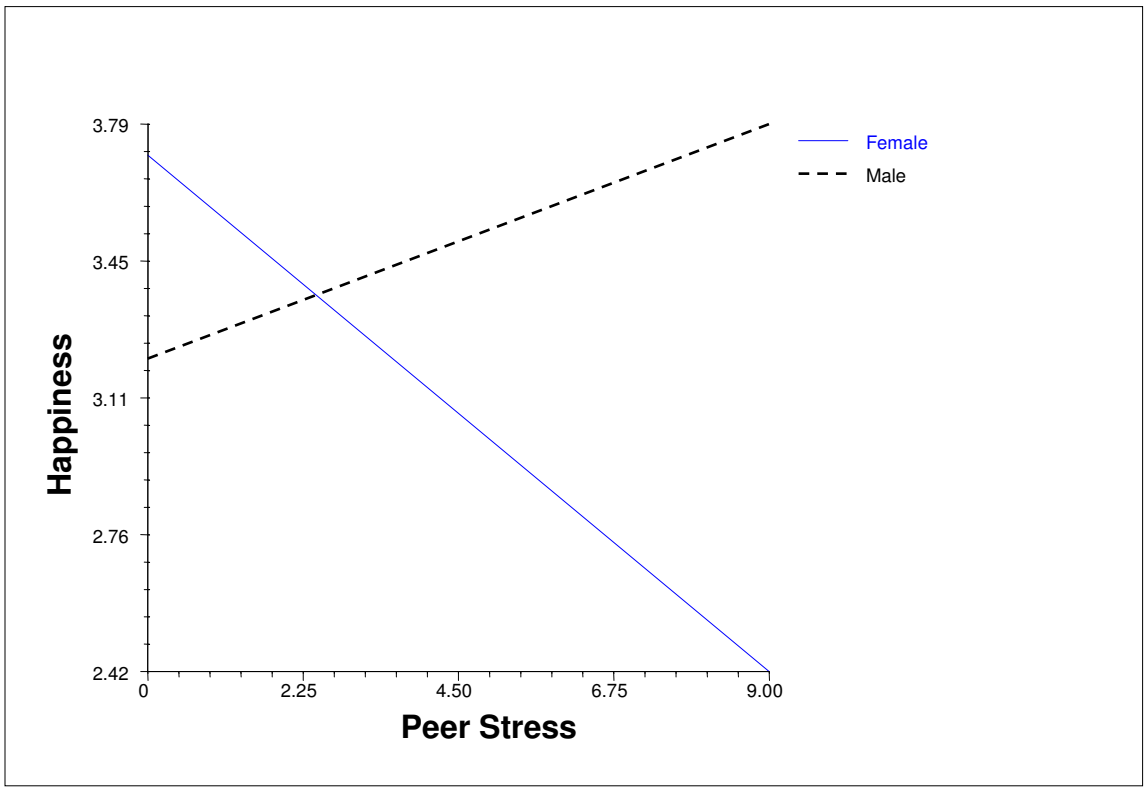

3.26
2.74
2.22
1.70
1.17
Depression
0
2.25
4.50
6.75
9.00
Peer Stress
Female
Male

Figure 13


3.79
3.45
3.11
2.76
2.42
Happiness
0
2.25
4.50
6.75
9.00
Peer Stress
Female
Male