# REGULATORY BENEFITS OF EMOTIONAL PROCESSING AND SELF-CONTROL IN ADOLESCENTS WITH TYPE 1 DIABETES

by

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## STATEMENT OF THESIS APPROVAL

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ABSTRACT

The objective of this study was to examine how emotional processing (i.e., understanding, acknowledging, and accepting emotions) moderated self-control (i.e., regulation of thoughts, emotion, and behavior) in explaining diabetes-specific self-regulation and metabolic control in adolescents with type 1 diabetes. Strong emotional processing was expected to confer regulatory benefit and promote adaptive outcomes, especially so for adolescents with poor self-control. General self-control capacity, and particularly self-control combined with emotional processing, may also underlie the relation of diabetes-specific management self-competence, negative affect, and adherence, and metabolic control. Self-report measures of self-control, emotional processing, diabetes management self-competence, diabetes-specific negative affect, adherence, and measured HbA1c were obtained from 137 adolescents with type 1 diabetes (M age = 13.48 years). Emotional processing significantly moderated the relation of self-control and metabolic control. Adolescents with high emotional processing were buffered from the effects of poor self-control. Adolescents with low self-control and low emotional processing had the poorest metabolic control. This interaction predicted metabolic control better than diabetes-specific self-regulatory constructs, and mediated the relations between those constructs and metabolic control. These findings suggest the importance of considering strength of emotional processing and self-control in the study of diabetes-specific self-regulation and health outcomes in adolescents with type 1 diabetes.

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## ACKNOWLEDGEMENTS

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# INTRODUCTION

For those with type 1 diabetes, adolescence, compared with middle childhood and adulthood, is marked by struggles to maintain sufficient metabolic control to avoid long-term health consequences (Silverstein, et al., 2005). Diabetes management requires self-control, such as inhibiting impulsive behavior (e.g., overeating pizza) in the service of completing adherence behaviors associated with the delayed reward of health in later adulthood (Kross & Ochsner, 2010). Adolescents must manage their diabetes more independently than younger children (Palmer, et al., 2008); yet they lack the self-control maturity of adults (Steinberg, 2008). Further, the immature self-regulatory capacity of adolescents is exacerbated by increased social and emotional influences on self-control (Cole, Martin, & Dennis, 2004; Dennis, 2010; Ordaz, 2010; Stanton, Parsa, & Austenfeld, 2002; Steinberg, 2008, 2010). For adolescents poor in self-control, lower capacity for emotional processing (i.e. acknowledging, understanding, and accepting emotions) may amplify maladaptive outcomes. In contrast, higher capacity for emotional processing may confer regulatory benefit, promoting adaptive outcomes in spite of limited self-control (Austenfeld & Stanton, 2004; Cole, Michel, & Teti, 1994; Gratz & Roemer, 2004). Therefore, processing of emotional information may greatly affect self-control capacity in explaining diabetes-specific self-regulation and health outcomes. Further, self-control combined with emotional processing may underlie diabetes-specific self-regulatory capacities, such as diabetes management self-competence, diabetes-specific negative affect, and adherence. This study seeks to clarify the regulatory role of emotional processing in adolescents with type 1 diabetes by examining how emotional processing moderates the relations of self-control and metabolic control and how this relation may act as a mediator of diabetes-specific self-regulation and metabolic control.

Self-control and emotional processing are unique constructs that each contribute to effective self-regulation (Dennis, 2010; Diamond & Aspinwall, 2003) and are proposed to be central to disease management in adolescents with type 1 diabetes. Self-control is defined as the regulation and modulation of thoughts, emotions, and behavior in the service of goal pursuit (Finkenauer, Engels, & Baumeister, 2005; Kross & Ochsner, 2010). Self-control in adolescents predicts academic success above and beyond the contribution of intelligence (Duckworth & Seligman, 2005), and better self-control is correlated with decreased rule-breaking and decreased engagement in risky behaviors and greater interpersonal success (Tangney, Baumeister, & Boone, 2004). In adolescents with type 1 diabetes, self-control is related to both adherence and metabolic control (Hughes, Berg, & Wiebe, 2010). Emotional processing is defined as the ability to understand, acknowledge, and accept emotions, and is related to increased adaptation and positive psychosocial functioning (Cole, et al., 2004; Stanton, Kirk, Cameron, & Danoff-Burg, 2000; Stanton, et al., 2002). While self-control is predictive of outcomes, research has suggested that emotional processing also serves to regulate emotions, thoughts and behavior (Austenfeld & Stanton, 2004; Cole, et al., 1994; Gratz & Roemer, 2004).

Given the increased social and emotional influences on self-control during adolescence (Dennis, 2010; Ordaz, 2010; Steinberg, 2005), the interaction of self-control and emotional processing may be especially important in explaining adolescent outcomes

(Cole, et al., 2004; Dennis, 2010; Gray, 2004; Steinberg, 2008). Research suggests that a self-regulation construct integrating emotion and self-control more accurately reflects developmental processes and neural circuitry activation and signaling that occurs during acts of self-regulation than more limited self-control constructs (Dennis, 2010; Diamond & Aspinwall, 2003; Gray, 2004). Further, the capacity to process emotions is a crucial aspect of development (Blakemore & Choudhury, 2006; Campos, Campos, & Barrett, 2010; Cole, et al., 1994; Grazicino, 2006; Lamm & Lewis, 2010; Posner & Rothbart, 2000) that is important to the regulation of emotion, thoughts, and behavior (Cole, et al., 2004; Cole, et al., 1994; Gratz & Roemer, 2004). Based on these findings, we expect that emotional processing will be integral to understanding self-regulation and disease management in adolescents with type 1 diabetes. We theorize that the interaction of emotional processing and self-control will be a better predictor of metabolic control than self-control studied independently. Emotional processing will moderate self-control such that for adolescents poor in self-control, lower capacity for emotional processing may amplify negative health outcomes. In contrast, higher capacity for emotional processing may confer regulatory benefit, promoting positive health outcomes in spite of limited self-control.

As a broad self-regulatory capacity, self-control combined with emotional processing may be central in explaining adolescents' diabetes management. General self-regulation is related to daily management of social and emotional events that indirectly influence diabetes care as well as diabetes-specific self-regulation that directly influences diabetes care. For that reason, this study examines how this interaction may be involved in the benefits to metabolic control of key aspects of diabetes-specific self-regulation, diabetes management self-competence, diabetes-specific negative affect, and adherence to the medical regimen. Diabetes management self-competence is an adolescent's perception of their ability to self-regulate in the face of diabetes-specific barriers or setbacks and to persist with effective diabetes management (Iannotti, et al., 2006). Research has found that increased diabetes management self-competence is related to increased adherence and metabolic control and mediates relations between family and psychosocial variables and metabolic control in adolescents with type 1 diabetes (Berg, et al., 2010; Chih, Jan, Shu, & Lue, 2010; Iannotti, et al., 2006). Diabetes specific negative affect is defined as adolescents' perception of their ability to regulate negative emotions related to diabetes (Moss-Morris, 2002), with lower negative affect indicating better regulation. Increased diabetes specific negative affect is related to decreases in adherence, daily blood glucose testing, and worse metabolic control (Fortenberry, et al., 2009). Adherence is defined as the extent to which an adolescent completes the behaviors and tasks required for type 1 diabetes management including blood glucose testing, insulin administration, diet, and exercise, among other restrictions and guidelines (La Greca, et al., 1995; Lewin, et al., 2009). Adherence is an important correlate and determinant of metabolic control (Hood, Peterson, Rohan, & Drotar, 2009) and problematically, adherence declines across adolescence for those with type 1 diabetes(Hoffman, 2002; King, Berg, Butler, & Wiebe, 2010).

Each diabetes-specific self-regulatory construct has received considerable study in adolescents with type 1 diabetes, but we do not yet know whether these diabetes self-regulatory constructs reflect a more general regulatory construct that draws on general self-control and emotional processing. General self-regulatory constructs predict a range of youth outcomes (e.g. externalizing and risk behaviors, academic success, and social functioning) that are also related to diabetes behavior and health outcomes (Berg, et al., 2010; Horton, Berg, Butner, & Wiebe, 2009; Steinberg, 2010; Tangney, et al., 2004). Due to the broad influence of self-control in a variety of contexts and the importance of integrating emotional processing in explaining self-regulation, we expected that the interaction of emotional processing and self-control would uniquely predict metabolic control beyond diabetes-specific self-regulatory constructs. Moreover, it is theorized that the interaction of self-control and emotional processing represents a general capacity that may explain, in part, the mechanisms through which diabetes-specific self-regulation affects metabolic control in adolescents with type 1 diabetes.

In all, this study examined the importance of emotional processing in moderating the benefit of self-control on metabolic control, and the centrality of the interaction of self-control and emotional processing to diabetes-specific self-regulation for adolescents with type 1 diabetes. First, it was hypothesized that the interaction of self-control and emotional processing would significantly predict metabolic control beyond self-control as an independent predictor. Emotional processing was expected to confer regulatory benefit and buffer poor self-control, such that adolescents with high emotional processing would be less affected by low self-control. We also hypothesized that the interaction of self-control and emotional processing would predict metabolic control above and beyond diabetes management self-competency, diabetes-specific negative affect, and adherence. Finally, we hypothesized that the interaction of self-control and emotional processing would mediate the relations of diabetes management self-competence, diabetes-specific negative affect, and adherence to metabolic control.

# METHODS

## Participants

The University of Utah Institutional Review Board approved the study. Parents gave written informed consent and adolescents gave written assent. Participants included 137 adolescents (*M* Age= 13.48 years, *SD* = 1.51, 54% females) diagnosed with type 1 diabetes mellitus who completed all necessary measures for this study. Families were recruited from both a university/ private partnership clinic (76%) and a community-based private practice (24%) that each followed similar treatment regimens and clinic procedures. Eligibility criteria included adolescent age between 10 and 14 years, diabetes diagnosis for more than 1 year (*M* = 5.43 years), and parent and child ability to read and write either English or Spanish. Approximately half (63%) of adolescents were on an insulin pump, with the remainder prescribed multiple daily injections (MDI). Mothers reported physicians recommended an average of 3.98 insulin injections, for those adolescents on MDI (*SD* =1.65, range = 1 to 8 injections), and 5.58 blood glucose checks per day (*SD* = 1.65, range = 1 to 11 checks). Families were largely Caucasian (95%) and middle class, with approximately half (53%) reporting household incomes averaging $50,000 or more annually.

This sample includes a portion of participants participating in the third wave of a 3-year longitudinal study. In this third wave 194 of the 254 participants remained in the study. There were no significant differences in child gender or age between families still participating at time 3 and families that were no longer participating. There was however, a significant difference, $t(247) = 3.73$, $p < .001$, in metabolic control, such that teens remaining in the study had lower glycosolated hemoglobin percentages (HbA1c; $M$ = 8.30) than those teens who had left the study ($M$ = 10.26). A subset of the adolescents in the third wave were not included in this study because some measures used were included after data collection had begun, and those adolescents did not differ from the participants in this study in any key variables including, gender, age, or HbA1c.

## Procedure

Participants were recruited from diabetes clinics and they individually completed three of this study's questionnaires at home and returned those at a laboratory appointment, with the other two questionnaires completed during the laboratory appointment. For questionnaires completed at home, adolescents were instructed to complete separately without their parents. A cover sheet reiterated the importance of completing the questionnaires separately and asked that questions be directed to the investigators rather than family members.

## Measures

Self-control. Adolescents completed a self-control scale that consisted of 11-items designed to tap aspects of the ability to regulate emotions, behaviors, and impulses (Finkenauer, et al., 2005). The scale is a shortened version of a 36-item scale created by Tangney, Baumeister, and Boone(2004) but distinct from their Brief Self-Control Scale. Adolescents rated their identification with statements about self-control (e.g. "I wish I had more self-discipline") on a 5-point Likert scale (1= Not at all like me to 5= Very much like me). Finkenauer, et al. (2005) reported adequate reliability, (α = .67); in the present study reliability was good (α = .73).

Emotional processing. The Emotional Processing subscale of the Emotional Approach Coping Scale (Stanton, et al., 2000) measured the degree to which one actively attempts to understand, acknowledge, and accept one's emotions (i.e. "I explore my feelings to really understand them."). The scale included four items that were rated on a 5-point Likert scale (1= Never to 5= Always). The measure has been used successfully with an adolescent population (Diamond & Fagundes, 2008) and was initially validated on college-aged students. Reliability in the present study was good (α = .70).

Diabetes management self-competency. The Diabetes Management Self-Competency Scale (Iannotti, et al., 2006) assessed adolescents' perceptions of their competence and resourcefulness in being able to manage diabetes across 10 problematic situations (e.g. "How sure are you that you can manage your diabetes even when you feel overwhelmed?"). Adolescents rated items on a 10-point Likert scale (1=Not at all sure to 10= Completely sure). This scale had excellent reliability in our sample (α = .90).

Diabetes-specific negative affect. An index of negative affect linked to diabetes was measured with the Negative Consequences and Emotional Representation scales from the Revised Illness Perceptions Questionnaire (Moss-Morris, 2002). This 6-item scale measured the child's worries and negative emotions about the consequences of diabetes (e.g. "When I think about my diabetes I get upset"). Adolescents rated agreement with each item on a 5-point Likert scale (1= Strongly disagree to 5= Strongly agree). The scale had excellent reliability (α = .89).

Adherence. Adherence was assessed using a 16-item Self Care Inventory (adapted from (La Greca, et al., 1995)(Berg, et al., 2008)to assess adherence to the diabetes regimen over the preceding month (1 = never to 5 = always did this as recommended without fail). Items reflected current standards of diabetes care around blood glucose testing, insulin management, diet, and exercise (e.g. "Calculating insulin doses based on carbohydrate content of meals or snacks?"). The scale had excellent reliability in our sample ($\alpha = .83$).

Metabolic control. Metabolic control was assessed using glycosolated hemoglobin percentages (HbA1c) obtained from the child's routine clinic visit.HbA1c provides information on average blood glucose levels over the preceding three or four months. Lower HbA1c levels reflect better metabolic control. At all clinic sites, HbA1c was obtained using the Bayer DCA2000 by clinic staff. Participant authorization provided access to adolescents' medical records to obtain HbA1c and other illness information (e.g. duration of diabetes, pump vs. no pump treatment, etc.). The mean HbA1c for this study was 8.6%.

## Statistical Analyses

The interaction of emotional processing and metabolic control and its relations with diabetes-specific self-regulation constructs and metabolic control were examined through a series of hierarchical linear regressions. Prior analyses were also conducted to determine whether household income, pump status, and time since diagnosis should be covaried out in the following analyses. Pump status (i.e., dichotomous uses a pump or not) was correlated with metabolic control and then controlled for in further analyses. Length of diagnosis was also controlled for in analyses due to its theoretical importance to diabetes management. The effects of age and gender were analyzed through regression in separate three-way interactions with self-control and emotional processing, and two-way interactions with diabetes management self-competence, diabetes-specific negative affect, and adherence predicting metabolic control. For both age and gender neither the three-way interactions nor the two-way interactions including age and gender were significant for any of the variables. Thus, the following findings were representative of males and females and within the age range of adolescents in the study, 11.0- 16.2 years.

All study variables were examined graphically and statistically for outliers and normality. No outliers were found and each variable, except for metabolic control (skewness = 1.525, $p < .01$), had a sufficiently normal distribution. Metabolic control was not transformed to correct the skew and kurtosis in the distribution, as HbA1c percentages are not expected to produce a completely normal distribution in a sample of adolescents with type 1 diabetes.

# RESULTS

Correlations among study variables revealed that higher self-control, emotional processing, diabetes management self-competence, and adherence and lower diabetes-specific negative affect were each significantly correlated with lower HbA1c as expected (see Table 1). Higher self-control was also associated with each of the diabetes-specific self-regulation variables, higher management self-competence, lower negative affect, and higher adherence. Supporting our operationalization of emotional processing as distinct from self-control, emotional processing was not correlated with self-control.

## Emotional Processing as a Moderator of the Effects of Self-Control on Metabolic Control

Hierarchical regression was used to examine the interaction of self-control and emotional processing on metabolic control. Covariates, as discussed above, were entered on step 1, self-control and emotional processing, centered around their mean (Aiken & West, 1991), on step 2, and the interaction of self-control and emotional processing on step 3.

The results indicated that self-control continued to significantly predict metabolic control while emotional processing did not (see Table 2). The interaction of self-control and emotional processing significantly predicted metabolic control (see Figure 1, plotting results for emotional processing at 1 SD above the mean, at the mean, and at 1 SD below the mean), $b = .24$, $t(124) = 3.04$, $p = .003$, $\Delta R^2$ at step 3 = .06, $p = .003$, and the full model accounted for a significant amount of variance in metabolic control, $F$ (5, 124) = 7.07, $R^2$ = .22, $p$< .001 (see Table 2). Through simple slopes testing (Preacher, Curran, & Bauer, 2006) it was determined that the slope was significant for adolescents with low and average emotional processing, respectively, slope = -1.35, $t$ = -4.08 , $p$< .001; slope = -.626, $t$ = -2.42, $p$ = .02, but not for adolescents with high emotional processing, slope = .098, $t$ = .27, $p$ = .79. Thus, at low and average levels of emotional processing, adolescents with low self-control experienced poor metabolic control; however, high levels of emotional processing buffered the detrimental effects of low self-control on metabolic control.

These results indicate that the interaction of self-control and emotional processing was a significant predictor of metabolic control, and that higher emotional processing was especially beneficial for adolescents with low self-control.

Predictive Utility of Emotional Processing Moderating Self-Control versus Diabetes-Specific Self-Regulation for Metabolic Control

To assess the centrality of the interaction of self-control and emotional processing in predicting diabetes outcomes, we examined its predictive utility versus diabetes-specific self-regulation for metabolic control. Three analogous hierarchical regressions were run, with covariates entered on step 1, and the diabetes-specific self-regulatory construct, self-control and emotional processing, centered around their mean (Aiken & West, 1991), and the interaction of self-control and emotional processing on step 2.

The interaction of self-control and emotional processing predicted metabolic control, $b$ = .23, $t$(125) = 2.92, $p$ = .004, above and beyond diabetes management self-competence, $b$ = -.18, $t$(125) = -1.80, $p$ = .08, and the entire model predicted significant variance in metabolic control, $F(6, 125) = 6.54$, $R^2 = .24$, $p < .001$ (see Table 2).

Results from the second regression testing diabetes-specific negative affect followed the same pattern as the above analysis. The interaction of self-control and emotional processing predicted metabolic control, $b = .24$, $t(125) = 3.00$, $p = .003$, above and beyond diabetes-specific negative affect, $b = .29$, $t(125) = 1.51$, $p = .13$, and the entire model predicted a significant amount of variance in metabolic control, $F(6, 125) = 6.33$, $R^2 = .24$, $p < .001$ (see Table 2).

Results from the third regression testing adherence followed the same pattern as the above analyses. The interaction of self-control and emotional processing predicted metabolic control, $b = .24$, $t(124) = 3.00$, $p = .003$, above and beyond adherence, $b = -.36$, $t(124) = -1.25$, $p = .22$, and the entire model predicted a significant amount of variance in metabolic control, $F(6, 124) = 6.28$, $R^2 = .23$, $p < .001$ (see Table 2).

In sum, these results indicate that a general, self-regulatory construct was particularly useful, even in comparison to diabetes-specific regulatory constructs, in predicting health outcomes in adolescents with type 1 diabetes.

Interaction of Self-Control by Emotional Processing as a Mediator of Diabetes-Specific Self-Regulation and Metabolic Control Relations

The above analyses also support the argument that the interaction of self-control and emotional processing mediated the relations of each diabetes-specific self-regulation construct on metabolic control. All five associations necessary for a moderated mediation effect to be present were met (Baron & Kenny, 1986). The first two criteria, that the diabetes-specific self-regulatory construct predicted self-control and metabolic control were supported. Diabetes management self-competence predicted self-control, $b = .14$, *t*(125) = 5.21, *p*< .001, and metabolic control, *b* = -.31, *t*(125) = -3.15, *p* = .001. Similarly, diabetes-specific negative affect predicted self-control, *b* = -.30, *t*(125) = -5.63, *p*< .001, and metabolic control, *b* = .49, *t*(125) = 2.75, *p* = .007. Adherence also significantly predicted self-control, *b* = .31, *t*(124) = 3.684, *p*< .001, and metabolic control, *b* = -.73, *t*(124) = -2.69, *p* = .008. Support for the third criteria, that the interaction of self-control and emotional processing significantly predicted metabolic control, as well as the fourth and fifth criteria, that when both the predictor and interaction were entered into the equation, the interaction of self-control and emotional processing continued to significantly predict metabolic control while the diabetes-specific self-regulatory constructs did not, were presented above (see Table 2). Accordingly, the interaction of self-control and emotional processing significantly mediated the relations of diabetes management self-competence, diabetes-specific negative affect, and adherence on metabolic control.

<u>Self-Control as a Mediator of Diabetes-Specific Self-Regulation and Metabolic Control at Differing Levels of Emotional Processing</u>

Acknowledging from the above analyses that the interaction of self-control and emotional processing mediated the relation between diabetes-specific regulation and metabolic control, we further examined the conditional indirect effects of these relations. The conditional indirect effects indicate the levels of emotional processing at which self-control significantly mediates the relation between diabetes-specific regulation and metabolic control. Three analogous bootstrapped linear regressions using Preacher, Rucker, and Hayes (2007) moderated mediation macro for the Statistical Package for the Social Sciences (SPSS) were used to analyze the conditional indirect effects. The model tested (see Figure 2) is best described as: the predictor's (diabetes-specific self-regulation construct) relation with metabolic control was mediated by self-control and the relation between self-control and metabolic control was further moderated by emotional processing.

Determined through bootstrapping, the conditional indirect effect of diabetes management self-efficacy on metabolic control through self-control was significant ($p < .05$) at less than -.64 mean-centered values of emotional processing. This was such that the variance predicted in metabolic control by diabetes management self-competence was only accounted for by self-control at low to low-average values of emotional processing.

The conditional indirect effect of diabetes-specific negative affect on metabolic control through self-control was significant ($p < .05$) from -7.84 to -1.44 and at greater than 7.36 mean-centered values of emotional processing. This latter significant conditional indirect effect was driven by only 3 participants who received a score of 20 (maximum score = 20) on the emotional processing measure. This was such that the variance predicted in metabolic control by diabetes-specific negative affect was accounted for by self-control at low to low-average values and at extremely high values of emotional processing.

The conditional indirect effect of adherence on metabolic control through self-control was significant ($p < .05$) at less than -.43 mean-centered values of emotional processing. Thus, the variance predicted in metabolic control by adherence is only accounted for by self-control at low to low-average values of emotional processing.

In all, these conditional indirect effect findings suggest that self-control may function as a mechanism in the relation between diabetes-specific self-regulation and metabolic control primarily when emotional processing is low. This further confirms the added utility of a self-regulation construct that integrates self-control and emotional processing in understanding diabetes-specific health outcomes.

Table 1

Means, Standard Deviations, and Correlations of Key Study Variables

| | M | SD | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| 1. HbA1c | 8.60 | 1.75 | | | | | |
| 2. Self-Control | 3.51 | .60 | -.22** | | | | |
| 3. Emotional Processing | 11.81 | 3.02 | -.17* | .01 | | | |
| 4. Diabetes Management Self-competency | 6.90 | 1.78 | -.28** | .41** | .29** | | |
| 5. Diabetes-Specific Negative Affect | 2.47 | .92 | .21** | -.37** | -.10 | -.36** | |
| 6. Adherence | 3.91 | .57 | -.25** | .38** | .23** | .56** | -.24** |

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

Table 2

Hierarchical Regressions of the Interaction of Self-Control and Emotional Processing and Diabetes-Specific Self-Regulation Predicting HbA1c

| Model | Step | Variable(s) | $R^2$ | $\Delta R$ | $F$ | $b$ |
|---|---|---|---|---|---|---|
| Emotional Processing Moderating Self-Control | 1 | | .09 | .09 | 6.1 | |
| | | Pump Status | | | | -.84* |
| | | Length Since Diagnosis | | | | .10* |
| | 2 | | .16 | .07 | 6.1 | |
| | | Self-Control | | | | -.63* |
| | | Emotional Processing | | | | -.091 |
| | 3 | | .22 | .06 | 7.0 | |
| | | Self-Control ×Emotional | | | | .24** |
| Predictive Utility vs. Diabetes Management Self-Competence | 1 | | .09 | .09 | 6.1 | |
| | | Pump Status | | | | -.81* |
| | | Length Since Diagnosis | | | | .11* |
| | 2 | | .24 | .15 | 6.5 | |
| | | Diabetes Management Self- | | | | -.18 |
| | | Self-Control | | | | -.41 |
| | | Emotional Processing | | | | -.06 |
| | | Self-Control ×Emotional | | | | .23** |
| Predictive Utility vs. Diabetes-Specific Negative Affect | 1 | | .09 | .09 | 6.1 | |
| | | Pump Status | | | | -.79* |
| | | Length Since Diagnosis | | | | .11* |
| | 2 | | .24 | .15 | 6.3 | |
| | | Diabetes-Specific Negative | | | | .29 |
| | | Self-Control | | | | -.44 |
| | | Emotional Processing | | | | -.09 |
| | | Self-Control ×Emotional | | | | .24** |
| Predictive Utility vs. Adherence | 1 | | .09 | .09 | 6.1 | |
| | | Pump Status | | | | -.75* |
| | | Length Since Diagnosis | | | | .10 |
| | 2 | | .23 | .14 | 6.2 | |
| | | Adherence | | | | -.36 |
| | | Self-Control | | | | -.55* |
| | | Emotional Processing | | | | -.07 |
| | | Self-Control ×Emotional | | | | .24** |

All regression coefficients are from the final block of the regression.
* $p < .05$, ** $p < .01$

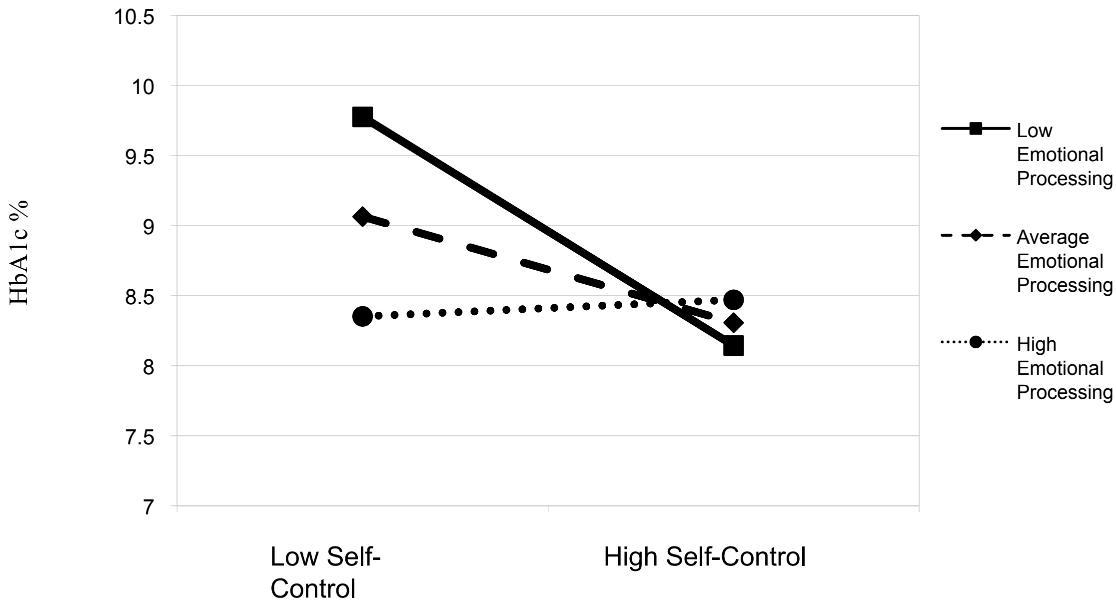
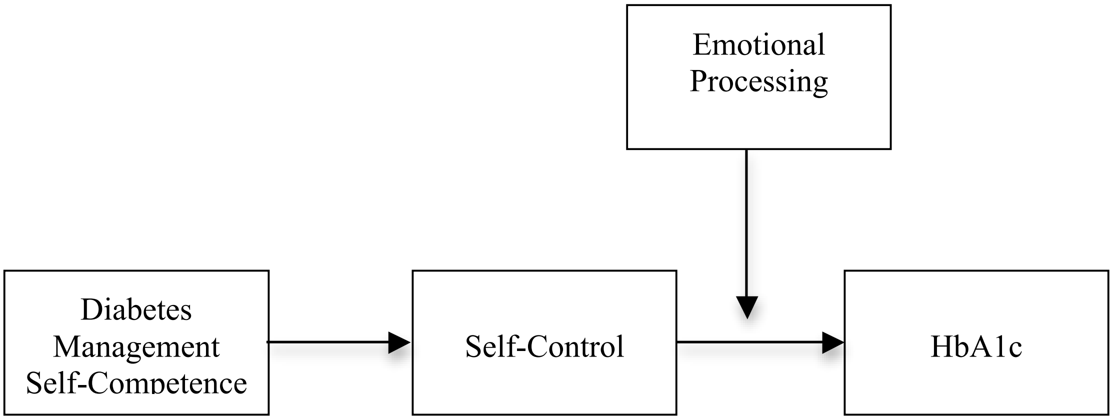
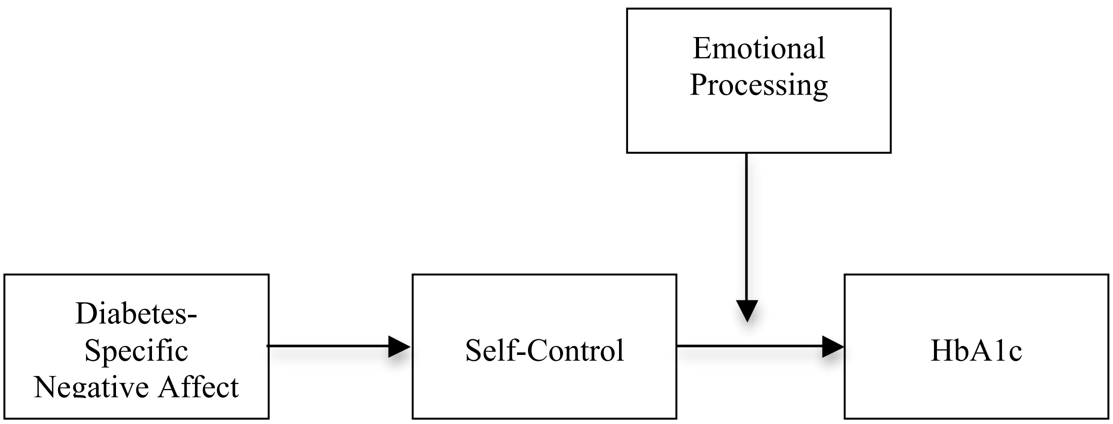


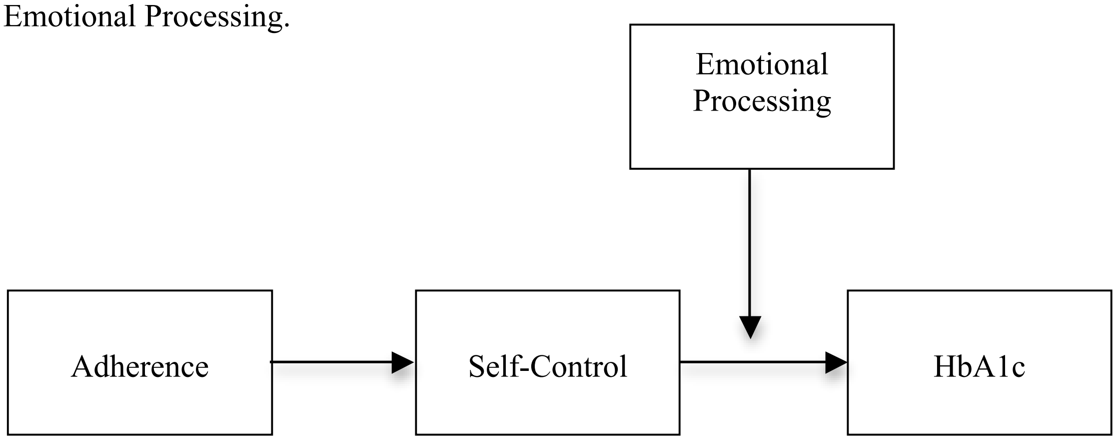

*Figure 1.*Simple slopes of the interaction of self-control and emotional processing predicting HbA1c at 1 SD below the mean, at the mean, and at 1 SD above the mean of emotional processing.




This model was significant ($p < .05$) at only low to low-average levels (less than -.64 mean-centered values) of Emotional Processing.




This model was significant ($p < .05$) at low to low-average (-7.84 to -1.44 mean-centered values), and high levels (greater than 7.36 mean-centered values) of Emotional Processing.




This model was significant ($p < .05$) at only low to-low average levels (less than -.43 mean-centered values) of Emotional Processing.

*Figure 2.* Models testing the conditional indirect effects of the relation between diabetes-specific self-regulation constructs and metabolic control that are explained by the interaction between self-control and emotional processing.

# DISCUSSION

These results highlight the regulatory effect of emotional processing on self-control and the centrality of emotional processing combined with self-control to diabetes-specific self-regulation and metabolic control in adolescents with type 1 diabetes. In alignment with developmental and psychobiological research arguing for the integration of self-control and emotion (Dennis, 2010; Diamond & Aspinwall, 2003; Gray, 2004), the interaction of emotional processing and self-control functioned as a unique predictor of metabolic control beyond self-control alone as an independent predictor. Further, the interaction of self-control and emotional processing predicted metabolic control above and beyond diabetes-specific self-regulation constructs and mediated the relation of diabetes-specific self-regulation and metabolic control. While the study of diabetes-specific constructs is an important focus of research and intervention for adolescents with type 1 diabetes (Weissberg-Benchell, et al., 2009; Wysocki, 2006; Wysocki, et al., 2008), our research also points to the benefits of exploring non-diabetes-specific constructs that might underlie diabetes-specific capacities.

Emotional processing significantly moderated the relation between self-control and metabolic control, allowing for adolescents low in self-control but high in emotional processing to be buffered from the negative effects of low self-control on metabolic control. Strong emotional processing conferred considerable regulatory benefit for adolescents low in self-control, with metabolic control in these adolescents being similar to those adolescents with high self-control. In contrast, limited emotional processing capacity exacerbated the detrimental effects of low self-control on metabolic control. As such, emotional processing was essential to explain self-regulation for metabolic control in adolescents with type 1 diabetes. This is in agreement with research on emotional processing and its capacity to regulate emotion, thought, and behavior (Cole, et al., 2004; Cole, et al., 1994; Gratz & Roemer, 2004).

Developmentally, emotional processing is integral to self-regulation, as regulatory capacity is developed through an interrelation of attachment, emotion and emotional processing, and behavioral control (Coan, 2008, 2010; Diamond & Fagundes, 2008; Diamond & Aspinwall, 2003; Hughes, Crowell, Uyeji, & Coan, in press). Across the lifespan the ability to regulate in social and emotional contexts involves the activation and connectivity of the neural substrate underlying both self-control and emotion (Bechara, Damasio, & Damasio, 2000; Goldin, McRae, Ramel, & Gross, 2008; Lamm & Lewis, 2010; Steinberg, 2008; Taylor & Liberzon, 2007). In both children and adults, research has found that an understanding of one's emotions can be used to further regulate one's thoughts, emotions, and behaviors, and that such an integration of emotions as "regulating" with self-control is adaptive when appropriately activated (Dennis, 2010; Diamond & Aspinwall, 2003; Gray, 2004). As emotional processing conferred regulatory benefit, moderating self-control in explaining metabolic control, our research suggests that in adolescents with type 1 diabetes, as well, emotional processing and self-control should be integrated to better explain self-regulation.

Our findings also argue that in adolescents the benefit to health outcomes of diabetes-specific self-regulation arises from broader regulatory constructs involved in the integration of emotional processing and self-control. The general capacity for self-regulation, as described in the interaction of emotional processing and self-control, functioned as a mechanism that explained the relation between diabetes-specific self-regulation and metabolic control. Thus, self-control combined with emotional processing may be a common resource that underlies the benefits of diabetes-specific self-regulation for diabetes health outcomes. Further, this general self-regulatory construct may be useful in understanding other risk behaviors that adolescents engage in (Steinberg, 2005) that may also affect diabetes outcomes (e.g., externalizing behaviors, risky driving).The study of non diabetes-specific self-regulation not only helps to better explain health outcomes, but also provides valuable insight into the measurement of diabetes-specific self-regulatory constructs.

Research has shown that diabetes-specific measures and interventions targeting these constructs are essential to understanding health outcomes in adolescents with type 1 diabetes (Nansel, Weisberg-Benchell, Wysocki, Laffel, & Anderson, 2008; Weissberg-Benchell, et al., 2009; Wysocki, et al., 2008) and thus, improving diabetes-specific construct measurement is essential. Across our findings we found evidence that a diabetes-specific self-regulatory construct would benefit from the integration of emotional processing, just as the predictive utility of self-control on metabolic control was shown in this study to benefit from the addition of emotional processing. Primary support for this argument comes from our finding that the interaction of self-control and emotional processing predicted metabolic control above and beyond each diabetes-specific self-regulatory construct. The better predictive utility of the general construct was likely due, in part, to the inclusion of emotional processing, an important regulatory construct. Further support was found in the conditional indirect effects of diabetes management self-competence and adherence on metabolic control through self-control that were insignificant at high levels of emotional processing. Thus, the inclusion of emotional processing in a diabetes-specific self-regulatory measure might allow for increased utility of diabetes-specific self-regulatory constructs in explaining behavior and health outcomes in adolescents with type 1 diabetes. Our recommendation is not to abandon the diabetes-specific self-regulatory measures currently in use, but to develop a diabetes-specific self-regulation measure that integrates diabetes-specific items of emotion, emotional processing, and self-control in explaining behavior and health outcomes in adolescents with type 1 diabetes.

These findings also highlight multiple areas of research that need further exploration and should also be considered in the context of some limitations. This sample is made up of primarily Caucasian participants and cultural differences seen in the development of self-regulatory capacity (Posner & Rothbart, 2007) should be considered in generalizing these findings. Additionally, this study used a cross-sectional design with self-regulatory measures composed of only adolescent self-report. Accordingly, the inclusion of parent and teacher report measures of adolescent self-regulation, as well as behavioral measures such as neurocognitive tests that tap facets of self-regulation in the study of self-control in adolescents with type 1 diabetes are needed. Further, although the results are consistent with mediation, the cross-sectional design limits the determination of temporal precedence in the moderated mediation models. While self-control likely underlies diabetes-specific self-regulation, determining causal relations is complicated as both general and diabetes-specific self-regulatory skills are developing across adolescence.

Also of note, there are many different constructs studied in self-regulation and emotion research (e.g., cognitive control, effortful control, emotional regulation, and coping; (Austenfeld & Stanton, 2004; Baumeister, Vohs, & Tice, 2007; Gray, 2004; Gross, 2002; Lamm & Lewis, 2010; Ordaz, 2010; Posner & Rothbart, 2000), and these constructs deserve consideration along with the self-control construct explored in this study. Future research should continue to explore how understanding general self-regulatory capacity, especially a capacity that integrates emotion and self-control, can help explain diabetes-specific behaviors and health outcomes. This research should also examine further how emotional processing and self-control develop both as separate and as integrated capacities from infancy through adulthood. Finally, our findings suggest that assessing both adolescent self-control and emotional processing capacity will be important when developing and determining appropriate interventions.

In summary, this research found that a high capacity for emotional processing served a regulatory benefit for positive health outcomes, especially for adolescents poor in self-control. Further, this general self-regulatory capacity predicted metabolic control above and beyond typical diabetes-specific regulatory constructs in this study, a quite stringent test of the utility of a general self-regulatory construct in explaining adolescent diabetes health outcomes. These results suggest the inclusion of emotional processing will be essential to understanding the functioning of adolescents who are struggling to self-regulate and manage type 1 diabetes care. This research also suggests that adolescents identified as low in self-control may benefit from interventions that serve to increase their skills in emotional processing, such as acceptance and commitment therapy, which has a strong focus on mindfulness and acceptance of emotion (Hayes, Luoma, Bond, Masuda, & Lillis, 2006). Thus, research and clinical efforts aimed at improving metabolic control in adolescents with type 1 diabetes will benefit from consideration of emotional processing and its regulatory function.

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