Control-value appraisals, enjoyment, and boredom in mathematics:

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Running Head: CONTROL-VALUE INTERACTIONS

Control-Value Appraisals, Enjoyment, and Boredom in Mathematics: A Longitudinal Latent Interaction Analysis

Abstract

Based on the control-value theory of achievement emotions, this longitudinal study examined students’ control-value appraisals as antecedents of their enjoyment and boredom in mathematics. Self-report data for appraisals and emotions were collected from 579 students in their final year of primary schooling over three waves. Data were analyzed using latent interaction structural equation modeling. Control-value appraisals predicted emotions interactively depending on which specific subjective value was paired with perceived control. Achievement value amplified the positive relation between perceived control and enjoyment, and intrinsic value reduced the negative relation between perceived control and boredom. These longitudinal findings demonstrate that control and value appraisals, and their interaction, are critically important for the development of students’ enjoyment and boredom over time.

Keywords: Enjoyment, boredom, perceived control, value, control-value theory

This study examines control and value appraisals, and their interaction, as proximal antecedents of two critically important achievement emotions: enjoyment and boredom. Academic emotions, such as enjoyment and boredom, are important educational outcomes in their own right, providing insight into the learning experiences of students (e.g., Ruddock, 2007). Academic emotions are also indicators of engagement (e.g., Skinner, Furrer, Marchand, & Kinderman, 2008), relate to motivational and cognitive mechanisms that can help or hinder learning (e.g., King, McInerney, Ganotice, & Villarosa, 2015), and predict academic achievement, physical health, and wellbeing (e.g., Humphrey, 2013; Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017; Putwain, Larkin, & Sander, 2013; Steinmayr, Crede, McElvany, & Wirthwein, 2016). Thus, an appreciation of academic emotions and why they arise offers an opportunity to deepen understanding of the learning experiences, processes, and outcomes, of students.

The present study was focused on enjoyment and boredom in the learning of mathematics. Mathematics learning has been the focus of international research efforts due to the importance of preparing a competent workforce in the science, engineering and mathematics (STEM) subjects and to ensure adequate preparation for university level study in these subjects (e.g., Kärkkäinen & Vincent-Lancrin, 2013; Wai, Lubinski, Benbow, & Steiger, 2010). The foundation of successful learning of mathematics during secondary school education is effective mathematics learning during earlier stages of schooling (Clements & Samara, 2004, 2011). Learning of core mathematical concepts in primary education predicts achievement in secondary school after controlling for intellectual ability, working memory, and family background (Siegler et al., 2012). However, despite the importance of mathematics education in the primary school years, studies of enjoyment and boredom in the learning process have focused on older populations of students. To redress this imbalance, in the present study the focus was on students in primary education.

According to the control-value theory (CVT; Pekrun, 2006; Pekrun & Perry, 2014), achievement emotions arise as a result of control appraisals, value appraisals, and the interaction of these appraisals. Empirical studies, however, have typically used cross-sectional designs measuring control and value appraisals at the same point in time as emotions. Moreover, they have not tested for the interactions between control and value appraisals predicted by CVT. We set out to address these limitations in the present study by using a longitudinal design to separate measurements of control and value appraisals from emotions over time and by testing for interactions between control and value appraisals. Furthermore, by utilizing a prior measurement of enjoyment and boredom we were able to establish whether control and value appraisals prospectively predict subsequent enjoyment and boredom, over and above the variance accounted for by prior enjoyment and boredom (i.e., we controlled for autoregressive effects).

CVT is one of several contemporary educational psychology theories that address the network of factors related to optimal academic development in students. Other notable theories include Eccles's expectancy-value theory (EEVT; e.g., Eccles, 2005; Wigfield, Tonks, & Klauda, 2016) and self-determination theory (SDT; e.g., Ryan & Deci, 2016; Ryan & Moller, 2017). CVT differs from EEVT and SDT by addressing the functional importance of emotions, but nevertheless shares some common features with these theories. CVT, EEVT, and SDT, all distinguish between intrinsic and extrinsic forms of values and motivation. SDT explains how different forms of motivation and value, intrinsic and extrinsic, are generated; related to how basic needs for competence, autonomy, and relatedness are fulfilled and whether one can exercise choice over educational decisions and activities. CVT and EEVT, in turn, explain how value interacts with control and expectancy to generate emotions and motivation, respectively. Thus, SDT addresses an earlier stage of emotion and motivation generation than CVT and EEVT. CVT is most obviously differentiated from EEVT and SDT with the central role played by emotions in the theory, and the role of emotions for motivation to learn, information processing, and, achievement. The three theories are complementary rather than oppositional and can be integrated (for CVT and EEVT see Lauerman, Eccles, & Pekrun, 2017). There are, however, more subtle ways that CVT and EEVT differ in their conceptualization of task values and these are explored more fully in the Supplementary Materials.

Achievement Emotions: Enjoyment and Boredom

Achievement emotion is an omnibus term referring to the varying and many emotions experienced by students related to achievement activities or achievement outcomes (Pekrun & Perry, 2014). Thus, achievement emotions can be differentiated from other types of emotions that occur in academic settings, such as epistemic emotions (e.g., Muis et al., 2015), and from other types of affect such as moods, which do not have a specific referent and are less intense (Forgas, 2000; Linnenbrink, 2006; Linnenbrink-Garcia & Barger, 2014). In CVT, discrete learning-related emotions are differentiated by their valence, level of activation, and object focus (Pekrun, 2006; Pekrun & Perry, 2014). Valence refers to whether the emotion is pleasant or unpleasant, activation to the degree of physiological arousal, and object focus to whether the emotion is activity-related or outcome-related. The present study was concerned with students' experiences of mathematics learning in the classroom and so we chose to focus on the two most frequently and intensely reported emotions referring to achievement activities; namely enjoyment and boredom (e.g., Goetz, Frenzel, Pekrun, Hall, & Lüdtke, 2007; Nett, Goetz, & Hall, 2011). In this way, enjoyment and boredom can be differentiated from outcome emotions, such as hope and anxiety (pleasant and unpleasant outcome emotions, respectively).

Enjoyment and boredom are critically important for self-regulation of learning, adoption of learning strategies, motivation, and academic achievement (e.g., Ahmed, can der

Werf, Kuyper, & Minnaert, 2013; Artino & Jones, 2012; Goetz, Frenzel, Hall, & Pekrun, 2008; Pekrun, Goetz, Daniels, Stupinsky, & Perry, 2010; Ruthig, Perry, Hladkyj, Hall, Pekrun, & Chipperfield, 2008; Villavicencio & Baernardo, 2013). Enjoyment and boredom were conceptualized as trait-like emotions. That is, in the present research they did not refer to momentary affective experiences during mathematics lessons, or the experience of a single mathematics lesson, but the typical affective experience of mathematics lessons.

Control-Value Theory of Achievement Emotions

According to CVT (Pekrun, 2006; Pekrun & Perry, 2014), the proximal antecedents of achievement emotions comprise appraisals of task demands, personal competencies, the likelihood of success and failure, and the perceived value of an achievement activity or outcome. The two most pertinent types of appraisals relevant to achievement emotions are one's sense of perceived control over achievement activities and outcomes and the perceived value (or importance) of these activities and outcomes. Distal personal antecedents, such as achievement goals or gender, and situational features of the achievement environment, such as feedback, goal structures, and teacher behavior, influence achievement emotions indirectly through control and value appraisals (e.g., Frenzel, Pekrun, & Goetz, 2007; Putwain et al., 2013). Each component of CVT is linked reciprocally so that over time, environments, appraisals, emotions, and achievement, will influence each other and unfold in a dynamic cycle of feedback loops. Thus, not only would appraisals give rise to emotions, but emotions would also strengthen or weaken subsequent appraisals.

Perceived control. Perceived control refers to action-control beliefs and action-outcome beliefs (Skinner, 1996). Action-control beliefs refer to judgments of one's capacity to initiate and perform an action (e.g., completing homework), whereas action-outcome beliefs refer to judgments that an action will bring about the desired outcome (e.g., success in a forthcoming test). Action-control beliefs are similar to self-efficacy beliefs but are focused on performance of an activity (e.g., investing effort during learning) rather than success at solving a problem. Congruent with the focus of the present study on emotions during learning activities, rather than outcomes, we specifically measured action-control beliefs. We would expect outcome beliefs to be more germane to emotions focused on learning outcomes. A belief that one is capable to successfully initiate and perform academic activities in a given domain (e.g., mathematics) will shape and lay the foundation for the perception of greater control in that domain (Pekrun & Perry, 2014). Hence, many studies (e.g., Frenzel et al., 2007; Goetz, Frenzel, Stoeger, & Hall, 2010), including ours, utilize or adapt measures of domain-specific competence beliefs such as academic self-concept to measure control.

Perceived value. Achievement activities and outcomes can be subjectively valued for different reasons. Intrinsic value is when an activity or outcome is judged to be interesting and meaningful in its own right. Achievement value refers to the perceived importance of achievement for one's sense of self-identity or self-worth. Utility value is when an activity or outcome is judged to be instrumental in obtaining a desired outcome (Eccles, 2005). Several empirical CVT studies have investigated the role of achievement value (e.g., Frenzel et al., 2007; Goetz, Pekrun, Hall, & Haag, 2006), defined as the personal importance of gaining good marks or good grades.

Domain specificity. Emotions, and their antecedent appraisals, can be represented at varying levels of granularity, ranging from generalized to context-specific and task- and moment-specific (Goetz, Hall, Frenzel, & Pekrun, 2006; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). The present study is focused on domain-level emotions in mathematics, which is a core subject in the science, technology, engineering, and mathematics (STEM) fields and critically important for students' academic performance, educational attainment, and career choices. In order to ensure that antecedent emotions are matched to subsequent emotions at the appropriate level of specificity (see Swann, Chang-Schneider, & McClarty, 2007), it is necessary to also represent control and value at the domain level. Perceived control and value are, therefore, defined and operationalized in the present study as being domain, rather that task, specific. Recent empirical studies of EEVT have operationalized expectancy and value in a similar way; using measures of generalized competence and value beliefs rather than task specific beliefs (e.g., Guo, Marsh, Parker, Morin, & Yeung, 2015; for a discussion of the differences between CVT and EEVT, see Supplementary Materials).

Control-value appraisals as antecedents of enjoyment and boredom. Different activity-related emotions, such as enjoyment and boredom, are thought to arise from differing combinations of control and value appraisals (Pekrun, 2006). Enjoyment is thought to arise from the combination of control and positive value. When a task or learning material is appraised as being controllable, a student will perceive the learning situation as providing the opportunity to develop competence and mastery, and experiences enjoyment on the condition that the material is sufficiently valuable and interesting. Enjoyment is further enhanced when the task or learning material is highly valued (e.g., a subject in which the student is very interested). Thus, an interaction would be expected between perceived control and value whereby the enjoyment experienced from undertaking a controllable task is enhanced when that task is valued. If a task is positively valued, but is appraised as being uncontrollable, an alternative emotion such as frustration will result. Whereas CVT is concerned with how control and value generate enjoyment, SDT is focused on how underlying needs for competence, autonomy, and relatedness, generate different forms of motivation (Ryan & Deci, 2016; Ryan & Moller, 2017). Enjoyment, in SDT, is one of the conditions that may give rise to intrinsic motivations, along with interest.

Boredom arises when a task is not valued (either positively or negatively), or from very high or low levels of perceived control resulting in mismatched task demands (tasks are too easy or too hard). An interaction is not necessarily implied for boredom, as very high or low perceived control and non-value could induce boredom independently. However, we speculate that high control would further increase boredom in a non-valued task. In a compulsory school environment, where the student has no choice whether to undertake a lesson task (without being non-compliant with the teacher's instruction), a non-valued task might be experienced as more monotonous and boring by a student with higher perceived control due to a lack of challenge. Such students might believe they are capable of learning and progressing in a particular subject but are given tasks that are not perceived to assist learning and judged as having little or no personal relevance.

CVT delineates how subjective values might contribute to different achievement emotions. We would anticipate that values would relate more strongly to discrete activity or outcome emotions with a congruent activity or outcome focus. Intrinsic value, with a focus on learning activities, would relate more strongly to activity emotions, namely enjoyment and boredom during learning, than to outcome emotions. Utility value, focused on learning outcomes rather than activities, would relate more strongly to outcome emotions such as pride and shame. The strong connection between interest, a central component of intrinsic value, and enjoyment (e.g., Ainley, 2007; Ainley & Ainley, 2011; Ainley & Hidi, 2014) further supports that enjoyment should relate positively to intrinsic value. Furthermore, boredom has been found to be more closely associated with lack of intrinsic motivation than with external motivation (e.g., Ntoumanis, 2001).

What of achievement value? Achievement need not be related to instrumental outcomes that are the extrinsic focus of utility value. Achievement can be valued in its own right if it is related to one's identity and to developing mastery and competence (see Eccles, 2005). As such, achievement value may have intrinsic properties, similar to other intrinsic forms of motivation that relate to developing competence, such as curiosity (e.g., Carbonneau, Vallerand, & Lafrenière, 2012). Furthermore, since one can derive enjoyment from achievement (Pekrun, 2006), it would be likely that learning activities and materials that contribute to mastery and competence (i.e., activities that have high achievement value), would also be experienced as enjoyable. Accordingly, we expect that high achievement value would be positively related to enjoyment, and negatively related to boredom.

Empirical Evidence for the Role of Control-Value Appraisals in Enjoyment and Boredom

Empirical evidence has largely supported the proposition that stronger perceived control is associated with higher enjoyment and lower boredom. For instance, control has been shown, using cross-sectional designs, to positively correlate with enjoyment and negatively correlate with boredom in undergraduate (Artino & Jones, 2012; Hall, Sampasivam, Muis, & Ranellucci, 2016; Pekrun et al., 2010, 2011; Pekrun, Goetz, Perry, Kramer, Hochstadt, & Molfenter, 2004) and secondary school students (Frenzel et al., 2007). Perry, Hladkyj, Pekrun, and Pelletier (2001) showed that control predicted higher subsequent enjoyment and lower subsequent boredom in a prospective design using undergraduate students. However, prior levels of enjoyment and boredom were not controlled for in this study. In a cross-sectional study, Goetz et al. (2010) showed that higher control was positively correlated with enjoyment in a sample of undergraduate students using within-person analysis and a single-item measure of control. Furthermore, academic self-concept, which would be expected to give rise to strong perceived control, has been shown, using cross-sectional designs, to positively correlate with enjoyment and negatively correlate with boredom in university (Pekrun et al., 2004, 2011; Pekrun, Goetz, Daniels, Stupinsky, & Perry, 2010) and secondary school students (Bieg, Goetz, & Hubbard, 2013; Goetz, Frenzel, Hall, & Pekrun, 2008; Goetz, Pekrun, Hall, & Haag, 2006).

Evidence has also supported the proposed role of perceived value in enjoyment and boredom. Enjoyment has been shown to correlate positively, and boredom negatively, with intrinsic value in cross-sectional designs with university (Noteborn, Carbonell, Dailey-Hebert, & Gijselaers, 2012; Pekrun et al., 2010, 2011) and secondary school students (Goetz et al., 2006). In cross-sectional designs with secondary school students, achievement value has also been shown to correlate positively with enjoyment and negatively with boredom (Frenzel et al., 2007; Goetz et al., 2006), and utility value has correlated positively with enjoyment (Ainley & Ainley, 2011). A combined measure of intrinsic, achievement, and utility value was also shown to correlate positively with enjoyment and negatively with boredom in a cross-sectional design with undergraduate students (Hall et al., 2016). Furthermore, Dettmers, Trautwein, Lüdtke, Goetz, Frenzel, and Pekrun (2011) found higher utility value to predict lower negative homework emotions (using a composite measure including boredom and reverse scored enjoyment) while controlling for prior negative homework emotions in secondary school students. Using a single-item measure of value, Goetz et al. (2010) found value to be positively correlated with enjoyment in undergraduate students, and Bieg et al. (2013) found value to be negatively correlated with boredom in secondary school students.

Despite the available evidence supporting the role of perceived control and value, there are four limitations that should be highlighted. First, the vast majority of studies have relied on cross-sectional designs where appraisals and emotions were measured concurrently (the Dettmers et al., 2011, study is a notable exception). As appraisals and emotions operate in a feedback loop, it is likely that coefficients from cross-sectional studies reflect effects of appraisals on emotions as well as effects of emotions on appraisals. In order to specifically establish how appraisals predict emotions, a longitudinal design is required that temporally separates appraisals from emotions and controls for prior levels of emotions (i.e., autoregressive effects). To address this concern, the present study utilized a longitudinal design measuring emotions subsequent to appraisals and controlling for autoregressive effects of emotion.

Second, as noted, CVT predicts that achievement emotions arise from combinations of perceived control and value appraisals, implying that these appraisals should interact in predicting emotions. However, unlike recent EEVT studies (e.g., Guo et al., 2015), research on achievement emotions has not typically examined such interactions. The extant literature has either reported bivariate correlations of perceived control and value with emotions (e.g., Pekrun et al., 2011) or included perceived control and value as additive predictors in regression analysis (e.g., Frenzel et al., 2007). The studies by Goetz et al. (2010) and Bieg et al. (2013) are notable exceptions. Goetz et al. (2010) found that high scores on a global measure of value amplified positive relations between control and enjoyment. Bieg et al. (2013) found a positive relation between control and boredom at low achievement value, and a negative relation between control and boredom at high achievement value. However, these two studies did not temporally separate appraisals from emotions; they did not examine the effects of control-value interactions on emotion over time. Furthermore, both studies used ordinary least squares regression analysis with manifest variables, thus not controlling for measurement error and possibly underestimating the strength of interactive effects. In the present study, we used longitudinal data and latent variable interaction analysis to redress these deficits.

Third, the extant literature has used samples of secondary school and university students. In order to further understanding of emotions in the mathematics learning of children in early stages of education, and widen the literature base for CVT and achievement emotions in general, it is necessary to ensure generalizability to a wider age range of students by including samples of younger students in earlier stages of schooling. In the present study, we address this point by including students from the final year of primary schooling (Year 6).

Fourth, CVT studies have typically included only a single value at a time, or used an undifferentiated measure of value. Thus, it is not possible to examine how different values relate to enjoyment and boredom. In the present study, we address this limitation by including intrinsic, achievement, and utility value.

Aims and Hypotheses of the Present Study

The present study aimed to examine the role of perceived control and value as proximal antecedents of enjoyment and boredom in primary school children (see Figure 1). Mindful of the limitations highlighted above, data on control and value appraisals were measured mid-way through the school year (March) and emotions were measured three months later (June). A prior measure of emotions was taken three months before the assessment of perceived control and value (November of the preceding calendar year) allowing us to control for autoregressive effects of emotions. It is possible, therefore, to establish if control and value appraisals predict subsequent emotions over and above the variance accounted for by prior emotions. As perceived control and value, and emotions, are domain specific (see Brunner, Keller, Dierendonck, Reichert, Ugen, Fischbach, & Martin, 2010; Goetz, Haag, Lipnevich, Keller, Frenzel, & Collier, 2014; Gogol, Brunner, Preckel, Goetz, & Martin, 2016), they were measured in relation to a single academic subject: Mathematics.

Based on CVT, we hypothesized that perceived control and value have positive effects on enjoyment, and that the two appraisals interact such that the positive effects of perceived control on enjoyment are amplified by value. We further hypothesized that lack of value predicts boredom. In addition, we hypothesized that control and value interact such that high perceived control (i.e., lack of challenge) would increase the effects of lack of value on boredom, and that high value would reduce the effects of high perceived control on boredom (i.e., protect against the effects of high control). Given that enjoyment and boredom are activity-related emotions, we expect these relations to be stronger for intrinsic and achievement value rather than utility value. Regarding perceived control, although a curvilinear U-shaped relation is proposed by CVT (with very high and very low control instigating boredom), empirical studies have typically found a negative relation between control and boredom (e.g., Pekrun et al., 2010, 2011). As such, we expected this relation to be negative in this study as well. Nonetheless, we checked for a curvilinear relation between perceived control and boredom. Succinctly stated, the primary hypotheses we tested in our research are as follows:

Hypothesis 1. Control, value, and their interaction positively predict enjoyment. In the interaction, value amplifies the positive relation between control and enjoyment. Relations will be stronger for intrinsic and achievement value than utility value.

Hypothesis 2. Control, value, and their interaction negatively predict boredom. In the interaction, control amplifies the relation between lack of value and boredom. Relations will be stronger for intrinsic and achievement value than utility value.

The longitudinal design also allows for the possibility to examine relations from the initial measurement of emotions to subsequent control and value appraisals. We did not include a specific hypothesis pertaining to these relations, as they were not the substantive focus of this study. Prior emotions were primarily included to control for autoregressive relations with subsequent emotion. Nonetheless, we anticipate that relations with subsequent control/ value would be positive for prior enjoyment and negative for prior boredom.

Method

Participants

At the first wave of data collection (November), there were 579 participants (50.3% female) in 27 classes (*M* = 21.4 students per class) drawn from 21 English primary schools. Participants were in Year 6 (the final year of primary schooling), with a mean age of 10.1

years (*SD* = .51). All primary schools in England follow a prescribed National Curriculum where students follow the same program of learning during a particular phase of education (Department of Education, 2015a). The schools represented a wide range of neighborhoods and were located in areas of both high, mid, and low social and economic deprivation. The majority of participants were from a Caucasian ethnic background (*n* = 482, 83.2%) with small numbers from Asian (*n* = 7, 1.2%), Black (*n* = 34, 5.9%), other (*n* = 17, 2.9%), and mixed heritage (*n* = 39, 6.7%).

Participating schools were drawn from a broad socio-demographic that included schools located in the least and most deprived deciles of England and the majority around the median (see Department for Communities and Local Government, 2015). Furthermore, the sample was broadly representative in terms of gender and ethnic heritage. English primary schools in 2015 (the point of final data collection) had 51% male students aged 10-11 years, and 79.1% students from a Caucasian background (Department of Education, 2015b).

There was some participant attrition at the second (*n* = 445 remaining students) and third waves of data collection (*n* = 437 remaining students) due to students being absent from class or exercising their right for non-participation. Attrition was not significantly related to any substantive study variables or covariates and handled using full information maximum likelihood (FIML) in M*plus* 7.4 (Muthén & Muthén, 2012). Rather than imputing missing data prior to analysis, FIML incorporates information from the analytic model to estimate population-based parameters from the data in the sample. This approach, commonly used in longitudinal structural equation modeling, is an effective approach to reduce bias resulting from missing data and restore loss of power resulting from attrition (Graham, Van Horn, & Taylor, 2012).

Measures

Participants responded to all measures on a five-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). A full list of all items is reproduced in the Supplementary Materials.

Learning-related emotions in mathematics. Enjoyment was measured using the eight enjoyment items from the *Achievement Emotions Questionnaire-Mathematics* (AEQ-M; Frenzel, Thrash, et al., 2007; Pekrun et al., 2011) that assess trait-like learning-related enjoyment (e.g., “I look forward to my maths lessons”[2]). Boredom was measured using the boredom scale of the AEQ-M (e.g., “I think that maths lessons are boring”) Internal reliability coefficients in the present study were excellent (see Table 1; α range = .88 – .93).

Control-value appraisals in mathematics. Perceived control was measured using four items adapted from the *Self-description Questionnaire II* (Marsh, 1990). Items were modified to reflect a student’s belief that they were capable of performing actions required in learning mathematics specifically (e.g., ‘I can learn things quickly in maths lessons‘). Intrinsic (e.g., ‘I find maths lessons interesting‘), achievement (e.g., ‘Getting good marks on maths tests is important to me‘), and utility value (e.g., ‘Maths can help with things in everyday life‘) were measured using items (four per scale) adapted from the *Michigan Study of Adolescent Life Transitions* scales (Eccles et al., 2005). Internal reliability coefficients in the present study were acceptable to good (Table 1; α range = .69 – .85).

Procedure

Invitations to participate in a study of classroom learning in mathematics were sent to the Head Teacher of partnership primary schools of the institution where the third author was employed. These were schools that had an ongoing relationship with the University for research or initial teacher education purposes. No incentives were offered to schools. Data were collected in three waves, at three-month intervals, over the course of a single school year. Learning-related enjoyment and boredom were measured at the first (T_1) and third (T_3)

waves mid-way through the first and third terms of the school year, respectively. Perceived control and subjective values were measured at the second wave (T_2) mid-way through the second term. Due to restrictions on administration time imposed by participating schools, it was not possible to assess all emotion and appraisal variables at each wave. Students completed measures during regular classroom instruction time using a digital personal assistant that was used for routine instructional purposes. Teachers read out standardized instructions that explained to students the purpose of the study, that items were not part of a test (there were no right or wrong answers), that teachers would not see individual students' responses, and other ethical aspects (anonymity, right to non-participation, and how to withdraw data). Written consent was obtained from the school head teacher, and passive consent from parents/ carers (parents/ carers were invited to opt-out children), at the outset of the study. Verbal assent was obtained from students at each wave of data collection. Students were asked to generate a code from letters of their name and numbers of their birthday to match responses anonymously over the three waves. The project was approved by an institutional research ethics committee.

Analytic Approach

Data were analyzed in two stages using a latent variable modeling approach. First, a series of preliminary analyses were performed to check the measurement properties of each construct, test for measurement invariance in enjoyment and boredom over time, and estimate latent bivariate correlations in a single measurement model (see Supplementary Materials for details). Second, a series of latent interaction structural equation models, using the unconstrained approach (Marsh, Wen, & Hau, 2004, 2006), were performed to model predictive effects of perceived control, value, and the interaction between perceived control and value on emotion, and of emotion on the appraisals. All analyses were performed in M*plus* 7.4 (Muthén & Muthén, 2012) using the cluster/ complex commands to control for the nestedness of the data within classrooms, and maximum likelihood estimation with robust standard errors to account for violations to the normal distribution of data. Negative leptokurtic distributions were shown for T_1 enjoyment, T_2 intrinsic value, T_2 attainment value, and T_3 utility value, and positive leptokurtic distributions were shown for T_1 and T_3 boredom (see Table S3 in the Supplementary Materials for details about the descriptive characteristics of data, including the distribution, and proportion of variance occurring at the classroom level).

Results

Preliminary Analyses

Preliminary analyses were conducted to: (i) Check for a curvilinear relation between perceived control and subsequent boredom, (ii), check the measurement properties of each construct separately using confirmatory factor analyses, (iii), check measurement invariance over time for enjoyment and boredom, and (iv), estimate latent bivariate relations between substantive constructs and possible covariates (gender and age). A regression curve analysis showed that a quadratic relation between perceived control and boredom did not account for a substantial proportion of variance (0.6%) beyond the linear relation and was not statistically significant (p >.05). Accordingly, relations between perceived control and boredom were modeled in subsequent analyses as linear.

Good fitting measurement models were shown for each construct and were used to estimate descriptive data. Measurement invariance for enjoyment and boredom over time was tested by constraining various parameters to be equal over time. No deterioration of model fit indices was shown for configural, metric, scalar, and residual invariance, indicating that there was robust measurement invariance of enjoyment and boredom over time. A measurement model including all substantive constructs, along with gender (0 = male, 1 = female) and age as possible covariates, showed a good fit and was used to estimate descriptive statistics and latent bivariate correlations (see Table 1). Perceived control and value correlated positively with enjoyment and negatively with boredom (additional details can be found in Supplementary Materials).

Latent Interaction Structural Equation Models

Interactions between perceived control and value were examined in a series of six latent interaction structural equation models (LI-SEMs) following a common structure (see Figure 1). This is one model for each of the three two-way interactions between perceived control and value (intrinsic, achievement, and utility) for enjoyment and again for boredom. Separate models were estimated for each of the interactions, and for the two emotions, to reduce problems due to multicollinearity of predictors. In each model, paths were specified from T_2 perceived control and value, and their interaction, to T_3 enjoyment/ boredom. Furthermore, autoregressive paths were specified from T_1 to T_3 enjoyment/ boredom, and paths were estimated from T_1 enjoyment/ boredom to T_2 perceived control and value. As gender and age did not significantly correlate with any of the substantive study variables, they were not included as covariates. All models showed a good fit (see Table 2) and showed no obvious sources of misspecification. When interpreting standardized regression coefficients, Keith (2006) recommends $\beta < .10$ as small, $\beta > .10$ and $< .25$ as moderate, and $\beta > .25$ as large. For expedience, *p* values are reported in Figures 2 and 3, and the Supplementary Materials.

Predicting Enjoyment from Control-value Appraisals and their Interaction

We hypothesized that perceived control and value would be positively related to subsequent enjoyment, and value would amplify the relation between control and enjoyment.

Perceived control × intrinsic value on enjoyment. T_2 intrinsic value was a positive predictor of T_3 enjoyment ($\beta = .31$) over and above the autoregressive effect of T_1 enjoyment (β = .52; Figure 2). T_2 perceived control (β = .12) and the intrinsic value × perceived control interaction (β = -.01) were not statistically significant predictors of T_3 enjoyment.

Perceived control × achievement value on enjoyment. T_2 perceived control (β = .25), T_2 achievement value (β = .11), and the perceived control × achievement value interaction (β = .16), were positive predictors of T_3 enjoyment over and above the autoregressive effect of T_1 enjoyment (β = .64; Figure 2). Simple slope analyses for the control × achievement value interaction showed that for high (+1SD) achievement value, the relationship between perceived control and enjoyment was amplified (*B* = .93), compared to mean achievement value (*B* = .47) and low (-1SD) achievement value (*B* = .01; see Figure 4).

Perceived control × utility value on enjoyment. T_2 perceived control (β = .20) and utility value (β = .19) were positive predictors of T_3 enjoyment over and above the autoregressive effect of T_1 enjoyment (β = .60; Figure 2). The perceived control × utility value interaction was not a statistically significant predictor of T_3 enjoyment (β = .09).

Predicting Boredom from Control-value Appraisals and their Interaction

We hypothesized that perceived control and value would be negatively related to subsequent boredom, and control would amplify the relation between lack of value and boredom.

Perceived control × intrinsic value on boredom. T_2 intrinsic value was a negative predictor of T_3 boredom (β = -.51) over and above the autoregressive effect of T_1 boredom (β = .43; Figure 3). T_2 perceived control (β = .11) was not a statistically significant predictor of T_3 boredom. Perceived control did, however, interact with intrinsic value (β = -.16). Simple slope analyses for the perceived control × intrinsic value interaction showed that at high value (+1SD), the relationship between control and boredom was negligible (*B* = .07; Figure 4). At mean (*B* = .26) and low (-1SD) value, the positive relation between control and boredom was amplified (*B* = .44).

Perceived control × achievement value on boredom. T_2 perceived control (β = -.10), T_2 achievement value (β = -.10) and the perceived control × achievement value interaction (β = -.08), did not predict T_3 boredom over and above the autoregressive effect of T_1 boredom (β = .56; Figure 3).

Perceived control × utility value on boredom. T_2 perceived control (β = -.01), T_2 utility value (β = -.23), and the perceived control × utility value interaction (β = .07), did not predict T_3 boredom over and above the autoregressive effect of T_1 boredom (β = .50; Figure 3).

Predicting Control and Value appraisals from Enjoyment and Boredom

T_2 perceived control was positively predicted by T_1 enjoyment across models (βs = .59), and negatively predicted by T_1 boredom (βs = -.38). T_2 intrinsic value was positively predicted by T_1 enjoyment (β = .63) and negatively predicted by T_1 boredom (β = -.54). T_2 achievement value was positively predicted by T_1 enjoyment (β = .46) and negatively predicted by T_1 boredom (β = -.41). T_2 utility value was positively predicted by T_1 enjoyment (β = .50) and negatively predicted by T_1 boredom (β = -.41).

Discussion

The aim of this study was to examine the role of control and value appraisals as antecedents of two activity-focused achievement emotions, enjoyment and boredom, as predicted by CVT, in a sample of primary school students. Data were collected over three waves separated by three-month intervals. Enjoyment and boredom were measured in the first and third waves and appraisals in the second wave. This allowed us to overcome one of the principle limitations of previous studies examining control-value antecedents, namely the use of cross-sectional designs which did not prospectively predict emotions from control-value appraisals, or control for autoregressive effects of emotions.

Control and Value Appraisals as Antecedents of Enjoyment and Boredom

Control and value appraisals were, in general, shown to be antecedents of enjoyment and boredom. This is consistent with previous cross-sectional studies that have shown control and value appraisals to positively predict enjoyment and negatively predict boredom (Pekrun & Perry, 2014). The finding that high achievement value amplified the relation between perceived control and enjoyment supports the previous findings of Goetz et al. (2010; undergraduate students). Notably, our study found the relation between control and enjoyment to be negligible at low value. In contrast, using an undifferentiated measure of value, Goetz et al. (2010) found that a positive relation remained at low value. In line with CVT, the present findings suggest that students with high control perceive their learning experiences as more enjoyable. It would seem likely that students with high control perceive such learning experiences as providing an opportunity to develop competence and mastery, hence are experienced as enjoyable. When students value achievement those learning experiences are experienced as even more enjoyable.

One contextual factor may partly explain the finding that achievement value in particular interacted with control. Students take National Curriculum Tests at the end of primary schooling in Year 6. It is common practice in many schools for children to be coached or hot-housed during Year 6 where much of the school timetable is devoted to test practice and feedback (e.g., Boyle & Bragg, 2006; Hutchings, 2015; Troman, 2008). Thus, the experience of mastery and competence becomes amplified by achievement value, rather than intrinsic or utility value, as student attention and activities are directed towards their forthcoming tests. Those students with high achievement value, who also have perceived control over the learning materials indicating likely success on the forthcoming tests, will experience their learning materials and activities as being more enjoyable.

The finding that the relation between perceived control and boredom is moderated by intrinsic value is in line with Bieg et al. (2013; secondary school students). Theoretically speaking, very high or low control might be expected to result in greater boredom (although empirically speaking it was only low control in this study). High intrinsic value in mathematics, that is, an interest and curiosity in the subject matter, sustained low levels of boredom regardless of the level of perceived control, even when students experienced very high control. In contrast, when intrinsic value was low, a positive relation was shown between perceived control and boredom, consistent with the cross-sectional findings by Bieg et al. (2013) who also found that perceived control was positively related to boredom at low achievement value. In the absence of the protective role of high intrinsic value (i.e., students do not find lessons interesting or stimulating), students who believe in their ability to successfully learn become increasingly bored. This could be a result of students with stronger perceived control experiencing lessons as monotonous, under-challenging, and of a mismatch between their perceived ability to learn with the perceived lack of meaning of lesson material (also see Daschmann, Goetz, & Stupnisky, 2011).

When interpreting specific control-value interactions, it is important to bear in mind that first-order effects of the predictor variables (control and value) cannot be interpreted as analogous to main effects in an analysis of variance (e.g., Hayes, Glynn, & Huge, 2012; Kam & Franzese, 2007). Rather, they are conditional, or simple, effects[3] in that the size and statistical significance of the coefficients is dependent on the effect of the interaction term. As such, the likelihood of control and value appraisals predicting emotion depends on the variance they share with each other and with the interaction term. For instance, in the LI-SEM examining effects of perceived control and intrinsic value on enjoyment it would appear that intrinsic value is the only statistically significant predictor. This should not be taken to imply that perceived control does not play a substantive role for enjoyment (the bivariate correlation between the two variables is r = .64; Table 1). Rather, it implies that the influence of control, when controlling for shared variance and the interaction with intrinsic value, is not statistically significant. In contrast, when conditional on achievement value, control is a statistically significant predictor of enjoyment. Therefore, it would appear that control-value appraisals significantly predicted enjoyment and boredom depending on which type of value was paired with perceived control.

Limitations and Suggestions for Future Research

The findings show how control and value appraisals predict subsequent emotions. They are robust methodologically, using a longitudinal design controlling for autoregressive effects and a latent variable modeling approach correcting for measurement error. However, it is important to bear several limitations in mind when interpreting the findings. First, CVT suggests that appraisals and emotions could be related in a bidirectional fashion. As control and value appraisals were measured only once in our design we were unable to examine effects of emotions on appraisals controlling for autoregressive effects of appraisals. To provide a more robust assessment of the relations from emotions to subsequent appraisals, and a formal test of the reciprocal nature of emotions and appraisals, future research should measure both appraisals and emotions on at least two measurement occasions in a cross-lagged design.

Second, despite using measures designed to assess typical appraisals, it is possible that the three month-interval between the measurement of appraisals and subsequent emotions resulted in small changes in the appraisals. These changes could have weakened the relations between the appraisals and subsequent emotions. Future research should investigate this possibility by using multiple assessments of perceived control and value with the intervals calibrated in various ways and in relation to the achievement situation. For example, one-month intervals with multiple-item assessments might be optimally suited to assess emotions related to learning a specific subject over the course of a term. For a specific task or lesson, single-item assessments administered every few minutes might be more appropriate for emotions conceptualized as being more state-like

Finally, our analysis did not include any learning outcomes. Although enjoyment and boredom represent important outcomes in their own right and have been shown in other studies to be reliable predictors of educational achievement (e.g., Pekrun et al., 2014, 2017; Pinxten, Marsh, De Fraine, Noortgate, & Dame, 2014; Putwain, Becker, Symes, & Pekrun, 2017), our findings cannot show if the experience of higher enjoyment, and lower boredom, translated into learning outcomes. Future research could examine how emotions mediate the relations from control value appraisals to achievement as predicted by CVT. Specifically, interactions between control and value appraisals and the potentially mediating role of emotions could be combined in a single moderated meditational model (see Preacher, Rucker, Hayes, 2007). In such a model, the relations between control and achievement, as mediated by emotions, could be examined at different levels of value.

There are also a number of useful directions for future research to follow. First, the effects of the perceived control-intrinsic value interaction on boredom demand more attention. We speculated that in the absence of protective intrinsic value, high-control students could become bored because they could perceive lessons as monotonous, under-challenging, and not meeting their needs (a mismatch between high control and the level of challenge). Empirical research is required to further examine these, and other, reasons for the interaction. Second, this study examined three different types of values as antecedents of enjoyment and boredom. Future research could consider how different types of perceived control (e.g., action-control vs. action-outcome) may differentially interact with subjective values to predict subsequent emotions not included in this study. For example, CVT predicts that outcome-related appraisals are more important for outcome-focused emotions (e.g., hope and pride) than for activity focused emotions (e.g., enjoyment and boredom).

Third, while our study utilized a longitudinal design to measure emotions in the first and third waves of data collection, and appraisals in the second wave, a stronger design could measure appraisals and emotions over all waves of data collection. In such a design it would be possible to examine how control-value appraisals predicted subsequent emotions controlling not only for prior emotions, but also emotions measured concurrently with appraisals. Finally, the extant research has relied on naturalistic, ecologically valid designs to examine the control-value antecedents of emotions. There is a need for lab and field experiments to provide robust evidence for the causal role of control-value antecedents. Recent EEVT interventions have shown innovative approaches to experimentally manipulating value in field settings (e.g., Gaspard et al., 2015; Hulleman, & Harackiewicz, 2009) that could be applied to test CVT. Control can be directly manipulated in lab settings using instructions (e.g., Turner, Jones, Sheffield, Barker, & Coffee, 2014) or indirectly through feedback on performance tasks (e.g., Quigley, Lindquist, & Barrett, 2014). Studies using experimental designs would offer a complimentary approach to those using naturalistic designs to broaden the evidence base for the role of appraisals in achievement emotions.

Implications for Educational Practice

Control and value appraisals are inherently malleable constructs (Aronson & Steele, 2005; Magidson, Roberts, Collado-Rodriguez, & Lejuez, 2014; Vrugt, Langereis & Hoogstraten, 1997). They are formed from interpretations of one's experiences with learning materials, interactions with others, feedback on one's learning, attributions, and the beliefs of key socializers such as parents and teachers (Eccles, 2005; Pekrun, 2006; Pekrun & Perry, 2014). The malleability of control and value appraisals offers the possibility for teachers to influence them in a positive way. Incorporating attributional principles into student feedback to focus student attention on strategy, effort, and mastery-development can be a powerful way to build a student's sense of control (e.g., strategy-focused feedback; Perry, Chipperfield, Hladkyj, Pekrun, & Hamm, 2014). Similarly, creating lessons and activities based on stimulating situational experiences of curiosity and interest can help students to develop a more stable sense of intrinsic value over time (e.g., Rotgans & Schmidt, 2010). Teachers can employ these and other principles to facilitate positive emotions such as enjoyment that have been shown to relate to a network of adaptive learning outcomes (e.g.,Ahmed et al., 2013; Artino & Jones, 2012; Goetz et al., 2008; Pekrun et al., 2010; 2017; Ruthig et al., 2008; Villavicencio & Baernardo, 2013). Given the associations between enjoyment, boredom, and subsequent academic achievement and progression (e.g., Pekrun et al., 2014; Pintxen et al., 2014; Putwain et al., 2017), we would anticipate that increases in enjoyment and/ or reductions in boredom would lead to improved educational achievement for students.

Conclusion

In general, the results supported the role of control-value appraisals as antecedents of enjoyment and boredom, over and above the autoregressive relations with prior emotion. In addition to first-order effects of control and value, two interactions were found; control interacted with achievement value to predict enjoyment, and with intrinsic value to predict boredom. Thus, appraisals can predict emotions uniquely or interactively depending on specific perceived control-value combinations. Enjoyment was related to all three types of subjective value, but it was specifically achievement value that amplified the positive relation between control and enjoyment. Boredom was most strongly related to intrinsic value, which protected against the boredom-inducing effects of high control.

Footnotes

[1] 32,844 English boroughs (each based on an approximate number of 1,500 residents) are ranked on multiple indices of deprivation (income, health, education, crime, employment, environment, and housing).

[2] In the UK, mathematics is colloquially referred to as ‘maths’.

[3] Although the term simple or conditional ‘effects’ is used, this does not imply causality in the design we use.

References

Ahmed, W., can der Werf, G., Kuyper, H., & Minnaert, A. (2013). Emotions, self-regulated learning, and achievement in mathematics: A growth curve analysis. *Journal of Educational Psychology*, *105*, 150–161. doi: 10.1037/a0030160

Ainley, M. (2007). Being and feeling Interested. Transient State, Mood, and Disposition. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 147–164). San Diego, CA: Academic Press.

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology*, *36*, 4-12.doi: 10.1016/j.cedpsych.2010.08.001

Ainley, M., & Hidi, S. (2014). Interest and enjoyment. In R. Pekrun and L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 205-227). New York, NY: Routledge.

Aronson, J., & Steele, C.N. (2005). Stereotypes and the fragility of academic competence, motivation, and self-concept. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 436–456). New York, NY: Guildford Press.

Artino, A. R., & Jones, K. D. (2012). Exploring the complex relations between achievement emotions and self-regulated learning behaviors in online learning. *The Internet and Higher Education*, *15*, 170-175. doi: 10.1016/j.iheduc.2012.01.006

Bieg, M., Goetz, T., & Hubbard, K. (2013). Can I master it and does it matter? An intraindividual analysis on control–value antecedents of trait and state academic emotions. *Learning and Individual Differences, 28*, 102-108. doi: 10.1016/j.lindif.2013.09.006

Boyle, B., & Bragg, J. (2006). A curriculum without foundation. *British Educational Research Journal*, 32, 569-582. doi: 10.1080/01411920600775225

Brunner, M., Keller, U., Dierendonck, C., Reichert, M., Ugen, S., Fischbach, A., & Martin, R. (2010). The structure of academic self-concepts revisited: The nested Marsh/Shavelson model. *Journal of Educational Psychology, 102*, 964-981. doi:10.1037/a0019644

Carbonneau, N., Vallerand, R.J., & Lafrenière, M.K. (2012) Toward a tripartite model of intrinsic motivation. *Journal of Personality, 80*, 1147-1178.doi: 10.1111/j.1467-6494.2011.00757.x

Cheung, D. (2009). Using think-aloud protocols to investigate secondary school chemistry teachers' misconceptions about chemical equilibrium. *Chemistry Education Research and Practice, 10*, 97-108. doi: 10.1039/B908247F

Clements, D.H., & Samara, J. (2004). Learning trajectories in mathematics education. *Mathematical Thinking and Learning, 6,* 81-89. doi: 10.1207/s15327833mtl0602_1

Clements, D.H., & Samara, J. (2011). Early childhood mathematics intervention. *Science, 333,* 968-970. doi: 10.1126/science.1204537

Daschmann, E. C., Goetz, T., & Stupnisky, R. H. (2011). Testing the predictors of boredom at school: Development and validation of the precursors to boredom scales. *British Journal of Educational Psychology, 81,* 421-440. doi: 10.1348/000709910X526038

Department for Communities and Local Government (2015). *The English indices of deprivation*. London: HMSO.

Department for Education. (2015a). *2010 to 2015 Government policy: School and college qualifications and curriculum*. London: HMSO.

Department for Education. (2015b). *Schools, pupils and their characteristics: January 2015*. London: HMSO.Denissen, J. J., Zarrett, N. R., & Eccles, J. S. (2007). I like to do it, I'm able, and I know I am: Longitudinal couplings between domain-specific achievement, self-concept, and interest. *Child Development*, *78*, 430-447. doi: 10.1111/j.1467-8624.2007.01007.x

Dettmers, S., Trautwein, U., Lüdtke, O., Goetz, T., Frenzel, A. C., & Pekrun, R. (2011). Students' emotions during homework in mathematics: Testing a theoretical model of antecedents and achievement outcomes. *Contemporary Educational Psychology*, *36*, 25-35. doi: 10.1016/j.cedpsych.2010.10.001

Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement-related choices. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 105–121). New York, NY: Guildford Press.

Eccles, J. S., O'Neill, S. A., & Wigfield, A. (2005). Ability self-perceptions and subjective task-values in adolescents and children. In K.A. Moore & L.H. Lippman (Eds.) *What do children need to flourish? Conceptualizing and measuring indicators of positive development*. (pp. 239-247). NY, New York: Springer.

Forgas, J. P. (2001). *Feeling and thinking: The role of affect in social cognition*. Cambridge : Cambridge University Press.

Gaspard, H., Dicke, A. L., Flunger, B., Schreier, B., Häfner, I., Trautwein, U., & Nagengast, B (2015). More value through greater differentiation: Gender differences in value beliefs about math. *Journal of Educational Psychology*, *107*, 663-677. doi: 10.1037/edu0000003

Goetz, T., Frenzel, A. C., Hall, N. C., & Pekrun, R. (2008). Antecedents of academic emotions: Testing the internal/external frame of reference model for academic enjoyment. *Contemporary Educational Psychology*, *33*, 9-33. doi: 10.1016/j.cedpsych.2006.12.002

Goetz, T., Frenzel, A. C., Pekrun, R., Hall, N. C., & Lüdtke, O. (2007). Between- and within-domain relations of students' academic emotions. *Journal of Educational Psychology, 99*, 715-733. doi: 10.1037/0022-0663.99.4.715

Goetz, T., Frenzel, A. C., Stoeger, H., & Hall, N. C. (2010). Antecedents of everyday positive emotions: An experience sampling analysis. *Motivation and Emotion*, *34*, 49-62. doi:10.1007/s11031-009-9152-2

Goetz, T., Hall, N. C., Frenzel, A. C., & Pekrun, R. (2006). A hierarchical conceptualization of enjoyment in students. *Learning and Instruction*, *16*, 323–338. doi: 10.1016/j.learninstruc.2006.07.004

Goetz, T., Haag, L., Lipnevich, A. A., Keller, M. M., Frenzel, A. C., & Collier, A. P. M. (2014). Between-domain relations of students' academic emotions and their judgments of school domain similarity. *Frontiers in Psychology, 5*, 1153. doi:10.3389/fpsyg.2014.01153

Goetz, T., Pekrun, R., Hall, N., & Haag, L. (2006). Academic emotions from a social-cognitive perspective: Antecedents and domain specificity of students' affect in the context of Latin instruction. *British Journal of Educational Psychology*, *76*, 289-308. doi: 10.1348/000709905X42860

Gogol, K., Brunner, M., Preckel, F., Goetz, T., & Martin, R. (2016). Developmental dynamics of general and school-subject-specific components of academic self-concept, academic interest, and academic anxiety. *Frontiers in Psychology*, *7*, 356. doi:10.3389/fpsyg.2016.00356

Graham, J.W., Van Horn, M., & Taylor, B.J. (2012). Dealing with the problem of having too many variables in the imputation model. In J. W. Graham (Ed.) *Missing data: Design and analysis*. New York, NY: Springer.

Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S., & Yeung, A. S. (2015). Expectancy-value in mathematics, gender and socioeconomic background as predictors of achievement and aspirations: A multi-cohort study. *Learning and Individual Differences, 37,* 161-168. doi: 10.1016/j.lindif.2015.01.008.

Hayes, A. F., Glynn, C. J., & Huge, M. E. (2012). Cautions regarding the interpretation of regression coefficients and hypothesis tests in linear models with interactions. *Communication Methods and Measures, 6,* 1-11. doi: 10.1080/19312458.2012.651415

Hall, N. C., Perry, R. P., Ruthig, J. C., Hladkyj, S., & Chipperfield, J. G. (2006). Primary and secondary control in achievement settings: A longitudinal field study of academic motivation, emotions, and performance. *Journal of Applied Social Psychology*, *36*, 1430-1470. doi: 10.1111/j.0021-9029.2006.00067.x

Hall, N. C., Sampasivam, L., Muis, K. R., & Ranellucci, J. (2016). Achievement goals and emotions: The mediational roles of perceived progress, control, and value. *British Journal of Educational Psychology*, *86*, 313-330. doi: 10.1111/bjep.12108

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326*, 1410–1412. doi: 10.1126/science.1177067

Humphrey, N. 92013). *Social and emotional learning: A critical approach*. London: Sage.

Husman, J., Derryberry, W. P., Crowson, H. M., & Lomax, R. (2004). Instrumentality, task value, and intrinsic motivation: Making sense of their independent interdependence. *Contemporary Educational Psychology, 29*, 63-76. doi:10.1016/S0361-476X(03)00019-5

Hutchings, M. (2015). *Exam factories: The impact of accountability measures on children and young people*. Chelmsford: Ruskin Press.

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children's self competence and values: Gender and domain differences across grades one through twelve.*Child Development, 73*, 509–527. doi:10.1111/1467-8624.00421

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology, 102*, 588-600. doi: 10.1037/a0019682

Kam, C. D., & Franzese, R. J. (2007). *Modeling and interpreting interactive hypotheses in regression analysis*. Ann Arbor, MI: University of Michigan Press.

Kärkkäinen, K. & Vincent-Lancrin, S. (2013). *Sparking Innovation in STEM Education with Technology and Collaboration: A Case Study of the HP Catalyst Initiative. OECD Education Working Papers, No. 91*. Paris: OECD Publishing. doi:10.1787/5k480sj9k442-en.

Keith, T. Z. (2006). *Multiple regression and beyond*. Boston, MA: Pearson Education

King, R. B., McInerney, D. M., Ganotice, F. A., & Villarosa, J. B. (2015). Positive affect catalyzes academic engagement: Cross-sectional, longitudinal, and experimental evidence. *Learning and Individual Differences*, *39*, 64–72. doi: 10.1016/j.lindif.2015.03.005Lauerman, F., Eccles, J.S., & Pekrun, R. (2017). Why do children worry about their academic achievement? An expectancy-value perspective on elementary students' worries about their mathematics and reading performance. *ZDM Mathematics Education*, *49*, 339-354. doi: 10.1007/s11858-017-0832-1

Linnenbrink, E. A. (2006). Emotion research in education: theoretical and methodological perspectives on the integration of affect, motivation and cognition. *Educational Psychology Review, 18*, 307-314. doi: 10.1007/s10648-006-9028-x

Linnenbrink-Garcia, L. & Barger, M. M. (2014). Achievement goals and emotions. In R. Pekrun and L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 142-161). New York, NY: Routledge.

Loose, F., Régner, I., Morin, A.J.S., & Dumas, F. (2012). Are academic discounting and devaluing double-edged swords? Their relations to global self-esteem, achievement goals and performance among stigmatized students. *Journal of Educational Psychology, 104*, 713-725. doi: 10.1037/a0027799Magidson, J. F., Roberts, B. W., Collado-Rodriguez, A., & Lejuez, C. W. (2014). Theory-driven intervention for changing personality: Expectancy value theory, behavioral activation, and conscientiousness. *Developmental Psychology, 50*, 1442-1450. doi: 10.1037/a0030583

Marsh, H. W. (1990). *The self description questionnaire (SDQ) II: a theoretical and empirical basis for the measurement of multiple dimensions of adolescent self-concept. A test manual and research monograph*. Macarthur, New South Wales: University of Western Australia.

Marsh, H. W., Wen, Z. & Hau, K. (2004). Structural equation models of latent interactions: Evaluation of alternative estimation strategies and indicator construction. *Psychological Methods, 9,* 275-300. doi: 10.1037/1082-989X.9.3.275

Marsh, H. W., Wen, Z., & Hau, K. T. (2006). Structural equation models of latent interaction and quadratic effects. In G. Hancock & R. Mueller (Eds.), *A second course in structural equation modeling* (pp. 225–265). Greenwich, CT: Information Age.

Meredith, W. (1993). Measurement invariance, factor analysis and factorial invariance. *Psychometrika, 58,* 525–543. doi:10.1007/BF02294825

Muis, K. R., Pekrun, R., Sinatra, G. M., Azevedo, R., Trevors, G., Meier, E., & Heddy, B. C. (2015). The curious case of climate change: Testing a theoretical model of epistemic belief, epistemic emotions, and complex learning. *Learning and Instruction*, *39*, 168-183. doi: 10.1016/j.learninstruc.2015.06.003

Muthén, L. K., & Muthén, B. O. (2012). *Mplus user's guide* (7th ed.). Los Angeles, CA: Muthén & Muthén.

Nett, U. E., Goetz, T., & Hall, N. C. (2011). Coping with boredom in school: An experience sampling perspective. *Contemporary Educational Psychology*, *36*, 49-59. doi: 10.1016/j.cedpsych.2010.10.003

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice. *Theory and Research in Education*, *7*, 133-144. doi: 10.1177/1477878509104318

Noteborn, G., Carbonell, K. B., Dailey-Hebert, A., & Gijselaers, W. (2012). The role of emotions and task significance in virtual education. *The Internet and Higher Education, 15*, 176-183. doi: 10.1016/j.iheduc.2012.03.002

Ntoumanis, N. (2001). A self-determination approach to the understanding of motivation in physical education. *British Journal of Educational Psychology*, *71*, 225-242. doi: 10.1348/000709901158497

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, *18,* 315–341. doi: 10.1007/s10648-006-9029-9

Pekrun, R., Goetz, T., Daniels, L. M., Stupinsky, R.H., & Perry, R.P. (2010). Boredom in achievement settings: Exploring control-value antecedents and performance outcomes of a neglected emotion. *Journal of Educational Psychology, 102*, 531–549. doi: 10.1037/a0019243

Pekrun, R., Goetz, T., Frenzel, A.C., Barchfeld, P., & Perry, R. P (2011). Measuring emotions in students' learning and performance: The Achievement Emotions

Questionnaire (AEQ). *Contemporary Educational Psychology, 36*, 36-48. doi: 10.1016/j.cedpsych.2010.10.002

Pekrun, R., Goetz, T., Perry, R. P., Kramer, K., Hochstadt, M., & Molfenter, S. (2004). Beyond test anxiety: development of the test emotions questionnaire (TEQ). *Anxiety, Stress and Coping, 17*, 287-316. doi: 10.1080/10615800412331303847

Pekrun, R., Hall, N. C., Goetz, T., & Perry, R. P. (2014). Boredom and academic achievement: Testing a model of reciprocal causation. *Journal of Educational Psychology, 106*, 696-710. doi: 10.1037/a0036006

Pekrun, R., Lichtenfeld, S., Marsh, H. W., Murayama, K., & Goetz, T. (2017). Achievement emotions and academic performance: Longitudinal models of reciprocal effects. *Child Development, 88*, 1653-1670. Doi: 10.1111/cdev12704

Pekrun, R. & Perry, R.P. (2014). Control-value theory of achievement emotions. In R. Pekrun and L. Linnenbrink-Garcia (Eds.). *International handbook of emotions in education* (pp. 120-141). New York, NY: Routledge.

Perry, R. P., Hladkyj, S., Pekrun, R. H., & Pelletier, S. T. (2001). Academic control and action control in the achievement of college students: A longitudinal field study. *Journal of Educational Psychology, 93*, 776-789. doi: 10.1037/0022-0663.93.4.776

Perry, R. P., Chipperfield, J. G., Hladkyj, S., Pekrun, R., & Hamm, J. M. (2014). Attribution-based treatment interventions in some achievement settings. In S. Karabenick & T. C. Urdan (Eds.), *Advances in motivation and achievement* (Vol 18, pp. 1-35). Bingley, UK: Emerald.

Pinxten, M., Marsh, H.W., De Fraine, B., Noortgate, W.V.D., & Dame, J.V. (2014). Enjoying mathematics or feeling competent in mathematics? Reciprocal effects on mathematics achievement and perceived math effort expenditure. *British Journal of Educational Psychology, 84*, 152-174.doi: 10.1111/bjep.12028

Preacher, K.J., Rucker, D.D., Hayes, A.F. (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. Multivariate Behavioral Research, 42, 185-227. doi: 10.1080/00273170701341316

Putwain, D.W., Becker, S., Symes, W., & Pekrun, R. (2017). Reciprocal relations between academic Enjoyment, boredom, and achievement over time. *Learning and Instruction*. Advance online publication, doi: 10.1016/j.learninstruc.2017.08.004

Putwain, D. W., Larkin, D., & Sander, P. (2013). A reciprocal model of achievement goals and learning related emotions in the first year of undergraduate study. *Contemporary Educational Psychology, 38*, 361-374. doi: 10.1016/j.cedpsych.2013.07.003

Quigley, K. S., Lindquist, K. A., & Barrett, L. F. (2014). Inducing and measuring emotion and affect: Tips, tricks, and secrets. In H.T. Reis & C.M. Judd (Eds.) *Handbook of research methods in social and personality psychology* (pp. 220-252). New York, NY: Cambridge University Press.

Régner, I., & Loose, F. (2006). Relationship of socio-cultural factors and academic self-esteem to school grades and school disengagement in North African French adolescents. *British Journal of Social Psychology, 45*, 777–797. doi:10.1348/014466605X83610

Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology, 98*, 209-218. doi: 0.1037/0022-0663.98.1.209Rotgans, J.I., & Schmidt, H.G. (2011). The role of teachers in facilitating situational interest in an active-learning classroom. *Teaching and Teacher Education, 27*, 37-42. doi: 10.1016/j.tate.2010.06.025

Rudduck, J. (2007). Student voice, student engagement, and school reform. In D. Thiessen & A. Cook-Sather (Eds.) *International handbook of student experience in elementary and secondary school* (pp. 587-610). Dordrecht, Netherlands: Springer.

Ruthig, J. C., Perry, R. P., Hladkyj, S., Hall, N. C., Pekrun, R., & Chipperfield, J. G. (2008). Perceived control and emotions: Interactive effects on performance in achievement settings. *Social Psychology of Education*, *11,* 161-180. doi: 10.1007/s11218-007-9040-0

Ryan, R.M., & Deci, E.L. (2016). Facilitating and hindering motivation, learning, and well-being in schools: Research and observations from self-determination theory. In K.R. Wentzel & D. B. Miele (Eds.) *Handbook of motivation at school* (pp. 96-119). Oxon: Routledge.

Ryan, R.M., & Moller, A.C. (2017). Competence and central, but not sufficient, for high quality motivation: A self-determination theory perspective. In Elliot, A.J., Dweck, C.S. & Yeager D.S. (Eds.) *Handbook of Competence and Motivation, 2nd Edition* (pp. 214-231); New York: NY: Guildford Press.

Sahin, A., & Gulum, G. (2008). Sixth grade mathematics teachers' intentions and use of probing, guiding, and factual questions. *Journal of Mathematics Teacher Education, 11*, 221-241. doi: 10.1007/s10857-008-9071-2

Siegler, R.S., Duncan, G.J., Davis-Kean, P.E., Duckworth, K., Claessens, A., Engel, M., Susperreguy, M.I., & Chen, M. (2012). Early predictors of high school mathematics achievement. *Psychological Science, 23*, 691-697. doi: 0.1177/0956797612440101

Skinner, E. A. (1996). A guide to constructs of control. *Journal of Personality and Social Psychology, 71*, 549–570. doi: 10.1037/0022-3514.71.3.549

Skinner, E. A., Furrer, C., Marchand, G., & Kinderman, T. (2008). Engagement and disaffection in the classroom: Part of a larger motivational dynamic? *Journal of Educational Psychology, 100*, 765–781. doi: 10.1037/a0012840

Steinmayr, R., Crede, J., McElvany, N., & Wirthwein, L. (2016). Subjective well-being, test anxiety, academic achievement: Testing for reciprocal effects. *Frontiers in Psychology, 6*, 1994.doi: 10.3389/fpsyg.2015.01994

Swann, W., Chang-Schneider, C., & McClarty, K. (2007). Do people's self-views matter? Self-concept and self-esteem in everyday life. *American Psychologist, 62*, 84–94. doi:10.1037/0003-066X.62.2.84

Troman, G. (2008) Primary teacher identity, commitment and career in performative school cultures. *British Educational Research Journal, 34*, 619-633. doi: 10.1080/01411920802223925

Turner, M.J., Jones, M.V., Sheffield, D., Barker, J., & Coffee, P. (2014) Manipulating cardiovascular indices of challenge and threat using resource appraisals. *International Journal of Psychophysiology, 94*, 9-18. doi: 10.1016/j.ijpsycho.2014.07.004

Villavicencio, F.T., & Baernardo, A.B.I. (2013) Positive academic emotions moderate the relationship between self-regulation and academic achievement. *British Journal of Educational Psychology, 83*, 329-340. doi: 10.1111/j.2044-8279.2012.02064.x

Vrugt, A.J., Langereis, M.P., & Hoogstraten, J. (1997). Academic Self-Efficacy and Malleability of Relevant Capabilities as Predictors of Exam Performance. *The Journal of Experimental Education, 66*, 61-72. doi: 10.1080/00220979709601395

Wai, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2010). Accomplishment in science, technology, engineering, and mathematics (STEM) and its relation to STEM educational dose: A 25-year longitudinal study. *Journal of Educational Psychology, 102,* 860.doi: 10.1037/a0019454

Wigfield, A., Tonks, S., & Klauda, S. L. (2016). Expectancy-value theory. In K.R. Wentzel & D. B. Miele (Eds.) *Handbook of motivation at school* (pp. 55-74). Oxon: Routledge.

Table 1

Bivariate Correlations and Descriptive Statistics Between the Study Variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	W_1 Enjoyment	—	.79***	-.62***	-.47***	.59***	.62***	.45***	.51***	.06	-.01
2.	W_3 Enjoyment	.71***	—	-.47***	-.67***	.63***	.73***	.42***	.59***	.08	-.02
3.	W_1 Boredom	-.56***	-.50***	—	.60***	-.28**	-.47***	-.37***	-.35***	.06	.06
4.	W_3 Boredom	-.44***	-.62***	.54***	—	-.32***	-.58***	-.31***	-.45***	.01	.01
5.	W_2 Perceived Control	.51***	.57***	-.30***	-.31***	—	.66***	.46***	.61***	.01	.02
6.	W_2 Intrinsic Value	.56***	.67***	-.49***	-.59***	.58***	—	.47***	.66***	-.02	-.10
7.	W_2 Achievement Value	.39***	.37***	-.36***	-.32***	.44***	.49***	—	.59***	-.04	-.09
8.	W_2 Utility Value	.42***	.49***	-.31***	-.40***	.49***	.54***	.57***	—	.10	-.01
9.	Gender	.07	.04	.06	.11	.02	.05	-.01	.07	—	—
10.	Age	-.01	-.04	.06	.02	.04	-..07	-.04	-.01	—	—

Note. Latent bivariate correlations above, and manifest variables below, the diagonal.

**p* < .05. ***p* < .01. ****p* < .001.

Table 2

Model Fit Indices for Latent Interaction Structural Equation Models

	χ^2(df)	RMSEA	SRMR	CFI	TLI
Enjoyment					
Perceived Control × Intrinsic Value	663.83 (332) ***	.037	.053	.943	.935
Perceived Control × Achievement Value	755.17 (332) ***	.042	.070	.925	.915
Perceived Control × Utility Value	828.75 (332) ***	.042	.070	.921	.909
Boredom					
Perceived Control × Intrinsic Value	493.35 (236) ***	.033	.058	.963	.957
Perceived Control × Achievement Value	412.19 (236) ***	.036	.061	.951	.942
Perceived Control × Utility Value	501.77 (236) ***	.044	.070	.924	.911

*p < .05. **p < .01. ***p < .001.

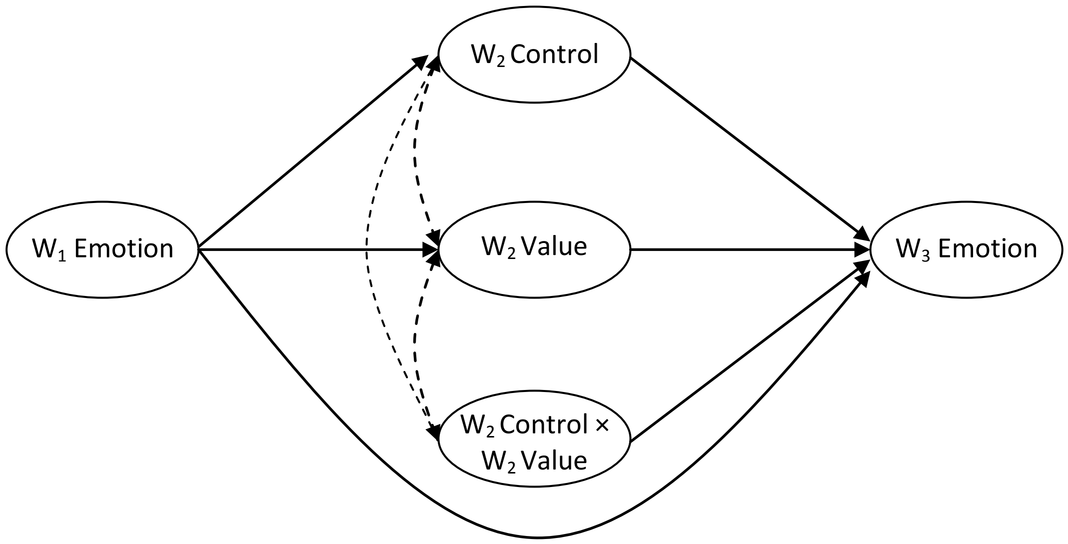


Figure 1. LI-SEM to examine the relations between appraisals and emotion. Solid lines represent structural paths and dashed lines represent correlations.

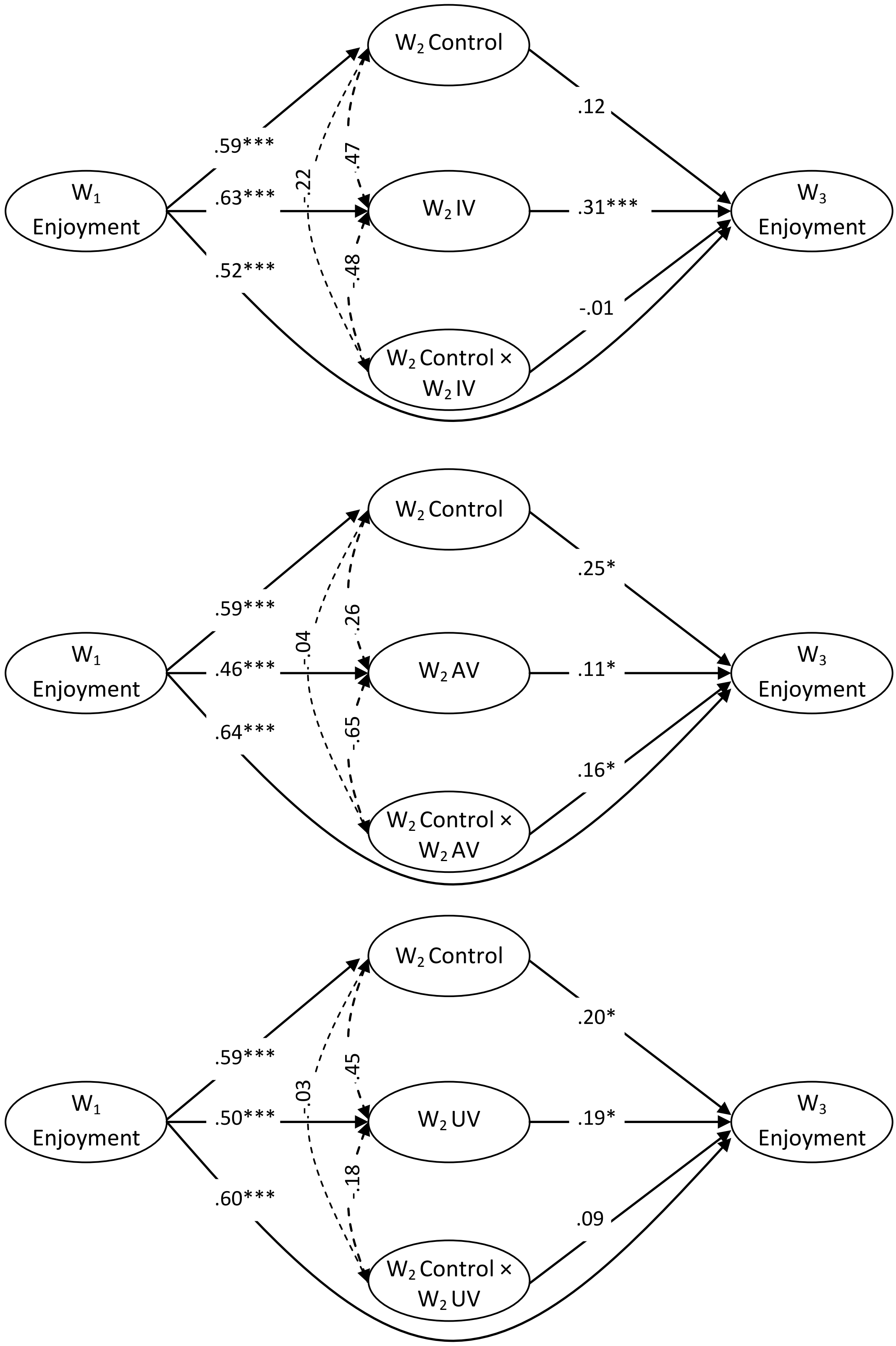


Figure 2. LI-SEMs for perceived control, intrinsic value (IV), achievement value (AV), utility value (UV), and enjoyment. Solid lines represent structural paths (βs) and dashed lines represent correlations (*r*s). *$p < .05$. **$p < .01$. ***$p < .001$.

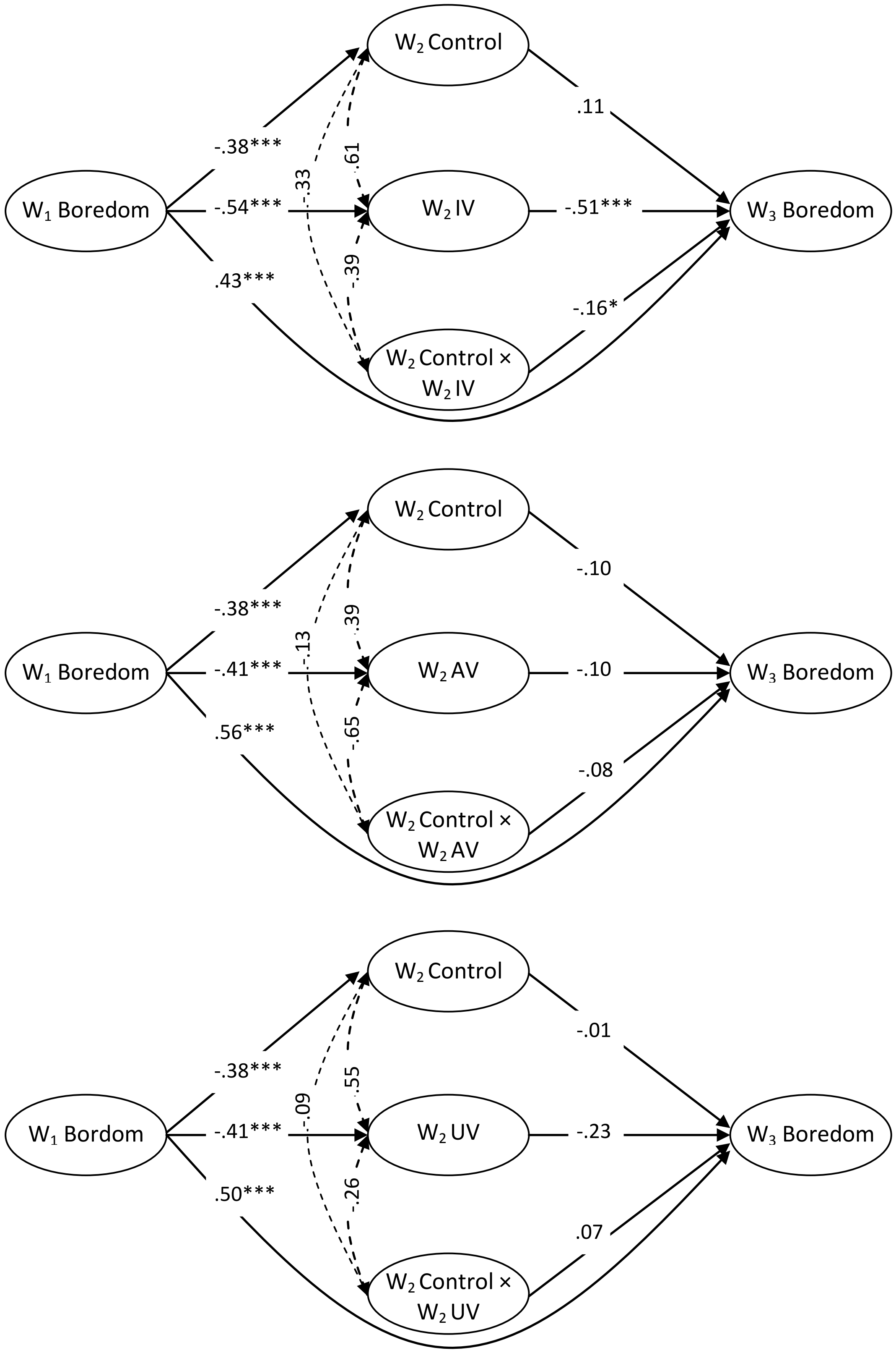
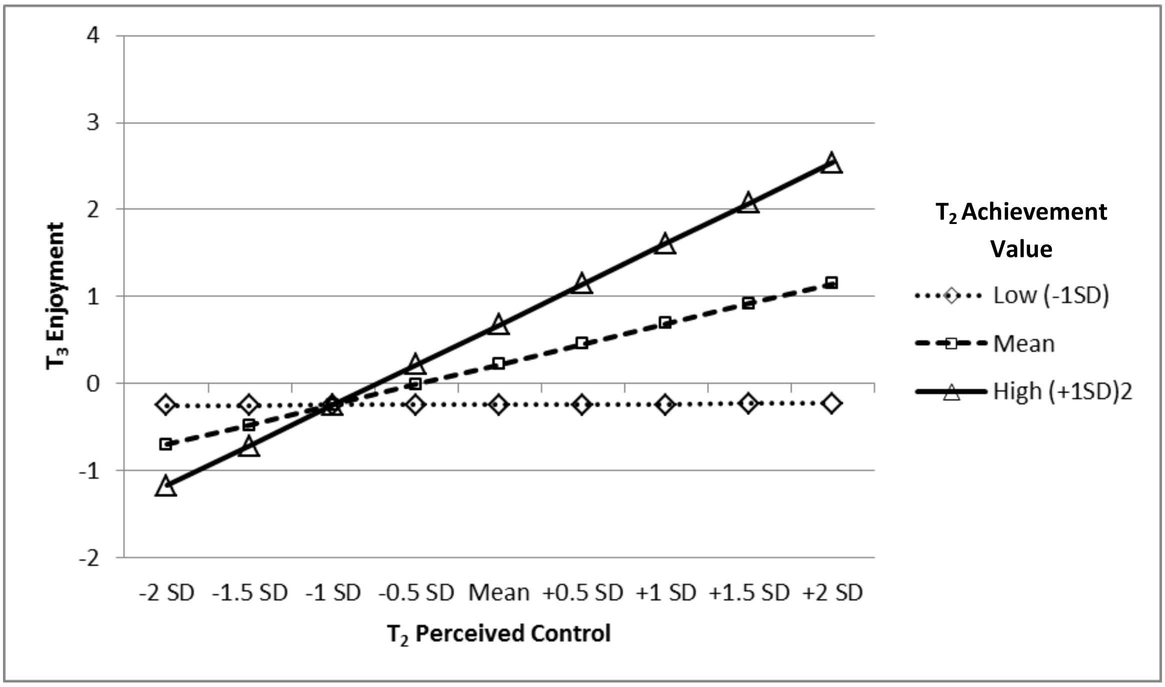


Figure 3. LI-SEMs for perceived control, intrinsic value (IV), achievement value (AV), utility value (UV), and boredom. Solid lines represent structural paths (βs) and dashed lines represent correlations (*r*s). **p* < .05. ***p* < .01. ****p* < .001.



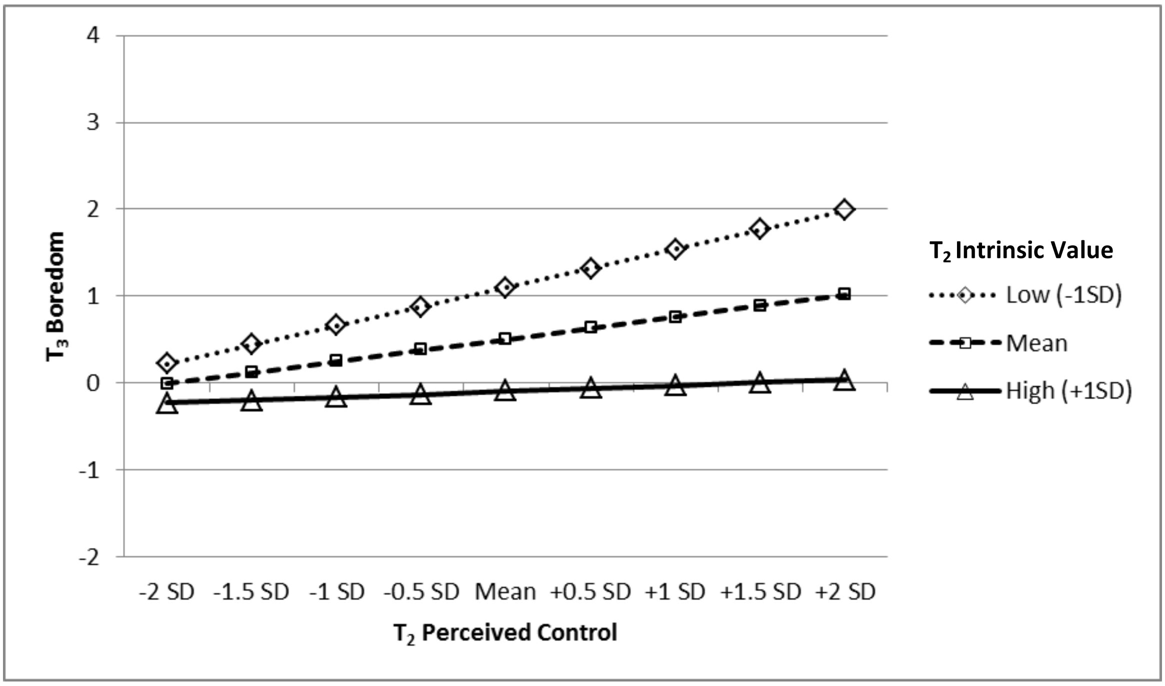


Figure 4. The model-implied interaction effect of perceived control and achievement value on enjoyment (upper panel) and perceived control and intrinsic value on boredom (lower panel).