Learning and Individual Differences 93 (2022) 102112

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Testing effects of promoting antecedents of mathematics achievement emotions: A change-change model

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ARTICLE INFO

Keywords:
Achievement emotions
Change-change model
Mathematics
Perceived control
Perceived value

ABSTRACT

Based on the control-value theory of achievement emotions, the present study investigates whether an intervention setting with the aim of inter alia promoting positive emotions could change control and value appraisals of low-achieving secondary school students in mathematics over two school years (Grades 7 and 8). Further, we examine the change-change assumption that positive intraindividual changes in perceived control and value longitudinally predict intraindividual changes in enjoyment, anger, anxiety, and boredom. Latent change models of 348 students revealed no significant effect of the intervention on changes in perceived control or value. Results confirmed the change-change hypothesis of the control-value theory for control and value and enjoyment, anger, anxiety, and boredom: Intraindividual changes in these emotions were longitudinally predicted by intraindividual changes in perceived control and value. Therefore, it can be assumed that the strategy of influencing students' control and value appraisals may be an effective measure to promote positive emotions while reducing negative ones.

1. Introduction

The day-to-day school life of students is characterized by different emotions. In recent years there has been a growing interest in these emotions, as they have been shown to affect future learning and performance (Pekrun, 2017). Emotions directly related to achievement activities (e.g., studying) or achievement outcomes (e.g., success or failure) are defined as *achievement emotions* (Pekrun & Perry, 2014). Achievement emotions are characterized according to their valence (positive vs. negative), level of activation (activating vs. deactivating), and object focus (activity vs. outcome-related; Pekrun & Perry, 2014). Empirical findings indicate that positive emotions (e.g., enjoyment) are connected with factors such as academic interest, motivation, engagement, and high achievement (e.g., Krapp, 2000; Pekrun, 2006, 2017). In contrast, negative emotions (e.g., boredom) reduce interest, attention, intrinsic motivation, and are associated with surface learning (Pekrun, 2017). Research has repeatedly shown that positive emotions decline during secondary education (e.g., Hagenauer & Hascher, 2010; Vierhaus et al., 2016), especially after the transitions from primary to secondary education. Regarding negative emotions such as boredom, with the exception of test anxiety, there is empirical evidence that they remain stable (e.g., Hill et al., 2016; Wigfield & Meece, 1988) or increase during secondary education (e.g., Niculescu et al., 2016; Vierhaus et al., 2016). A possible explanation for this unfavorable development is offered by the stage-environment fit theory (SEFT; Eccles et al., 1991). Because of the mismatch between students' needs and environmental opportunities provided by the school, positive emotions may decrease, and negative emotions increase or remain stable.

Because this unfavorable shift to a negative balance of achievement emotions may contribute to school alienation and eventually school dropout (Hascher & Hadjar, 2018), research that aims at understanding the antecedents of achievement emotions and their change is important in order to promote positive emotions and reduce negative emotions (Goetz et al., 2010). Frequently, the control-value theory of emotions (CVT; Pekrun, 2006) is used as the theoretical background to explain the development of emotions. In line with CVT, we investigated whether an intervention based on CVT could change *control* and *value* appraisals of low-achieving secondary school students over two school years. Further, we also tested CVT's assumption that changes in the antecedents' control and value are associated with changes in achievement *emotions* over time (the so-called change-change assumption). It is assumed that positive changes in antecedents lead to positive changes (increase) in positive emotions and that, conversely, a negative change in antecedents leads to a negative change (increase) in negative emotions. Existing

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https://doi.org/10.1016/j.lindif.2021.102112
Received 30 March 2021; Received in revised form 11 December 2021; Accepted 15 December 2021
Available online 4 January 2022

research has shown that achievement emotions as well as control and value appraisals are domain-specific and may differ across domains (e.g., Goetz et al., 2007; Goetz, Frenzel, et al., 2006; Goetz, Pekrun, et al., 2006). Thus, a student may have high control and value appraisals in English, leading to enjoyment of learning English, while having negative value and high control appraisals for mathematics, leading to anger related to learning mathematics. Based on this domain specificity, the present study focuses on the domain-specific emotions and appraisals in mathematics learning in early secondary education.

1.1. Antecedents of achievement emotions

Pekrun's (2006) control-value theory (CVT) of achievement emotions is an integrative framework to investigate the relations between motivation variables, learning behavior, performance and emotions in achievement settings. CVT focuses on the structure, antecedents, and outcome of emotions. A key element of this theory is the assumption that control and value appraisals are proximal antecedents of achievement emotions (Pekrun & Perry, 2014). Control and value represent different appraisal dimensions: *Perceived control* refers to the controllability of an action or a result that may be determined by either oneself or external factors. Therefore, perceived control covers constructs such as academic self-concepts (Shavelson et al., 1976), self-efficacy expectation (Bandura, 1977), and internal or external causal attribution (Weiner, 2010; cf. Pekrun & Perry, 2014). *Perceived value* is similar to the value concept in expectancy-value theory (EVT; Eccles, 1983) and comprises goal relevance (Pekrun & Perry, 2014). Accordingly, perceived value refers to constructs such as personal attainment value or utility (Eccles, 1983; Pekrun, 2006). Achievement emotions are defined as being elicited by the combination of control and value appraisal, whereby different combinations of control and value appraisals lead to different achievement emotions (Pekrun, 2006; Pekrun & Perry, 2014). For example, perceived control and positive value appraisals of a learning activity lead to positive emotions such as enjoyment, whereas negative value appraisals lead to negative emotions such as frustration (with low control value) or anger (with high control value; cf. Pekrun, 2006). Along with proximal antecedents, distal personal antecedents, such as achievement or gender, as well as situational factors of the environment such as feedback or teacher behavior that influence achievement emotions indirectly by affecting control and value appraisals (Frenzel et al., 2007a; Putwain et al., 2018), must be reconsidered.

1.2. The roles of enjoyment, anger, anxiety, and boredom

Four achievement emotions, namely enjoyment, anger, anxiety, and boredom, have been revealed to be of primary importance and to frequently occur in mathematics instruction (cf. Frenzel et al., 2007b). Together they cover a broad variety of different achievement emotions in everyday school life and are aligned with basic emotions (Izard, 2007). Enjoyment is characterized as a positive, activating and activity-related achievement emotion with favorable effects on learning, and is therefore worth cultivating and fostering (Hagenauer & Hascher, 2010; Pekrun, 2006). In contrast, anger, anxiety, and boredom are negative emotions with unfavorable effects on learning and achievement. Whereas anger is an activating, activity-related emotion, anxiety is an activating, outcome-related emotion. Boredom, as the third negative emotion, is defined as a deactivating, activity-related emotion that often occurs in everyday school life (Pekrun, 2006).

As outlined above, achievement emotions are expected to arise from different combinations of control and value appraisals. In terms of enjoyment, the CVT assumes that enjoyment arises when a high level of control and positive value are perceived (Pekrun, 2006). Existing research has confirmed that control and value are predictors of enjoyment (e.g., Buff et al., 2011; Putwain et al., 2018). According to CVT, anger is aroused if an activity is perceived as controllable, but negatively valued (e.g., Hall et al., 2006; Pekrun et al., 2011; Putwain et al., 2013; Shao et al., 2020). CVT assumes that anxiety is enhanced by the combination of negative outcome value and medium control (e.g., Hall et al., 2016; Lohbeck et al., 2016). Finally, no value and both high or low control appraisal (tasks are too easy or too hard) is assumed for boredom (e.g., Bieg et al., 2013; Shao et al., 2020).

Existing research has revealed group differences in appraisals and achievement emotions in mathematics. In terms of gender, it was found that girls report significantly less enjoyment than boys and more anxiety, hopelessness, and shame because of lower competence beliefs, combined with higher subjective values of mathematics achievement (Frenzel et al., 2007a, 2007b; Hill et al., 2016). As possible causes for these gender differences, a variety of psychological, biological, and social reasons are discussed (Frenzel et al., 2007a). Regarding achievement levels, it can be assumed that students with negative achievement experiences, such as low achieving students, report less positive and more negative emotions (Pekrun et al., 2017). In more detail, low achieving students report less enjoyment and pride, more anxiety, anger, and shame than typically performing students in mathematics (Holm et al., 2017). This difference highlights the importance of emotions in the learning process, as negative and positive emotions are bidirectionally and longitudinally related and can lead to a positive or negative emotion-achievement-cycle.

1.3. Change-change assumption

Overall, there is sound empirical evidence of medium to strong relationships between control and value appraisals and achievement emotions (e.g., Bieg et al., 2013; Pekrun et al., 2011; Putwain et al., 2018). These well-studied relationships are accompanied by a further assumption of the CVT that has been much less investigated: CVT assumes that changes in control and value appraisals lead to changes in perceived achievement emotions (cf. Buff, 2014). An increasing level of control and value appraisals raises the level of positive emotions (e.g., enjoyment), and lowers the level of negative emotions (e.g., anger). The hypothesis of this change-change process of the CVT was empirically investigated by Buff (2014), who showed that positive changes in perceived control and value led to a positive change in enjoyment in mathematics learning for primary students. Niculescu et al. (2016) extended this approach by testing Buff's (2014) hypothesis in terms of control appraisal for boredom, hopelessness, and anxiety with university students. Their results revealed that changes in perceived control are positively related to changes in enjoyment, and negatively related to changes in boredom, hopelessness and anxiety. However, regarding the change in value, no empirical evidence regarding the change-change hypothesis for negative emotions could be found. Significantly, as these change-change processes focus on intraindividual changes, their causes and consequences, they could provide implications on how learning environments should be designed (Buff, 2014, p. 22). Thus, this topic is particularly important for intervention research that seeks to increase both perceived control and perceived value, as such a program would be effective in promoting positive emotions (Buff, 2014; Goetz et al., 2010).

1.4. Control-value intervention research

Based on the change-change assumption, there is evidence that achievement emotions can be promoted by targeting control and value appraisals. The promotion of positive emotions through value and control appraisals aligns with social-psychological interventions that, rather than concerning academic content, address students' thoughts, feelings, and beliefs in and about school (Yeager & Walton, 2011). Prior research on interventions in the field of academic emotions demonstrated that students' academic emotions can be influenced by changing underlying appraisals. For example, one approach to change control-related appraisals is attributional retraining (Perry et al., 2005). Reattribution interventions showed small positive effects on positive and

negative achievement emotions (e.g., Hall et al., 2007; Hamm et al., 2014; Ruthig et al., 2004). Positive emotional experiences can also be promoted through interventions in value appraisals (e.g., Cohen et al., 2006; Gläser-Zikuda et al., 2005). Likewise based on Eccles (1983) expectancy-value theory (EVT), recent interventions successfully manipulated value in different settings (e.g., Gaspard et al., 2015; Hulleman et al., 2010). These results could also be adapted to CVT interventions to foster achievement emotions (Putwain et al., 2018).

Although some interventions targeting the promotion of achievement emotions exist, more intervention research is needed because the number of studies is relatively small (Schukajlow et al., 2017). Also, the heterogeneity of results calls for clarification as existing interventions tend to have no, or only weak effects on emotions (e.g., Chalk & Bizo, 2004; Gläser-Zikuda et al., 2005; Hamm et al., 2014). These weak effects might be explained in light of the key requirements of social-psychological interventions: Effective interventions address a specific psychological process based on a clear theoretical assumption, and thus must be tailored to a specific group of students and their thoughts, or feelings (Walton & Wilson, 2018). This implies a homogeneity in students with the same challenges regarding emotion development (i.e., low achieving students who are at risk for a negative emotion-achievement-cycle). Moreover, domain-specificity must be accounted for, as interventions regarding other subjects or emotional experiences in general might have no impact on emotions in mathematics.

To sum up, more intervention research is needed that explores how to promote adolescents' emotions by changing their control and value appraisals (Pekrun, 2017; Putwain et al., 2018). These interventions need to be well tailored (i.e., domain-specific), and target a specific process within a group of students with comparable or same challenges. Based on the CVT, the observed negative tendency of emotion development of low-achieving students in mathematics might be counteracted by a social-psychological intervention that aims to alter students' control and value appraisals for mathematics learning and thus might cause self-sustaining and long-lasting effects on emotions in mathematics (Walton & Wilson, 2018).

1.5. The present study: research questions and hypotheses

The present study is based on CVT as a frequently used and validated framework of the interplay between environment, appraisals, emotions, and learning achievement. The first aim of the present study is to investigate whether a multicomponent intervention with the aim of promoting positive emotions and learning motivation based on inter alia CVT could change control and value appraisals of low-achieving secondary school students in mathematics over two school years (Grades 7 and 8). Our second research goal is to investigate if changes in control and value appraisals are linked to changes in four achievement emotions of enjoyment, anger, anxiety, and boredom (change-change process).

Interventions based on CVT are scarce, and more research is needed to understand the interaction of antecedents and achievement emotions (Pekrun, 2017). In addition, prior interventions were predominantly designed for short periods of time (e.g., Gläser-Zikuda et al., 2005; Hall et al., 2007). However, the emotions of secondary school students' are habitualized through long-term experiences, so change needs to be addressed with long-term interventions (Gläser-Zikuda et al., 2005). Therefore, our first research goal addresses this lack of long-term intervention based on CVT, targeting both control and value appraisals. Based on the requirements for social-psychological interventions, our intervention is tailored to the domain-specific appraisals and emotions of low-achieving students in secondary education. Thus, we hypothesize that the intervention group will show an increase in control and value appraisals compared to the control group (Hypothesis 1).

Regarding the relationship between control and value appraisals and achievement emotions, there is empirical evidence of medium to strong relationships between control and value appraisals and achievement emotions. However, the hypothesis of the change-change process of CVT is less empirically investigated. Based on the results of Buff (2014) and Niculescu et al. (2016), we hypothesize that positive intraindividual changes in perceived control and value longitudinally predict positive intraindividual changes in enjoyment (Hypothesis 2a) and negative intraindividual changes in anger, anxiety, and boredom (Hypothesis b–d). These hypotheses are particularly important for intervention research because they can provide insight into the effect model of interventions aimed at changing control and value appraisals.

The aim of the present paper is to expand the existing knowledge in four ways: First, we apply a two-year longitudinal design with three measurement points to check whether this hypothesis is correct about long-term changes. Previous studies used two measurement points and checked for change hypothesis within a seven-week semester course (Niculescu et al., 2016) or within one year (Buff, 2014).

Second, we investigate change-change hypotheses with secondary-school students in the lowest ability tier in mathematics. This sample appears particularly interesting for several reasons: First-year students assigned to the lowest tier in secondary education (Grade 7) are vulnerable due to their negative selection experiences during the transition from primary to secondary education (cf. Eccles & Roeser, 2009). However, it can also be expected that the allocation of low-achievers in the heterogenous primary classroom into more homogeneous classes in secondary education may lead to (positive) changes in appraisals and achievement emotions (cf. big-fish-little-pond effect; Marsh, 1987). Additionally, existing research indicated that with low-achievers, the positive emotions are critical (e.g., Hagenauer & Hascher, 2010), and a high expression in boredom was recognized (e.g., Pekrun et al., 2010). Thus low-achieving students seem to be an at-risk group regarding their emotional development.

Third, we investigate the achievement emotions of enjoyment, anger, anxiety, and boredom. Buff (2014), in contrast, focused only on the positive emotion of enjoyment and Niculescu et al. (2016) investigated the negative emotions of anxiety, boredom and hopelessness, but only in combination with changes in perceived control. Thus, to the best of our knowledge, there is a scarcity of research that simultaneously investigated the development of learning enjoyment, anger, anxiety and boredom, and no research on change-change hypothesis between negative emotions and value; for anger, no evidence either in control or in value changes was found.

Fourth, we tested for differential effects of the intervention program on control and value appraisals and different emotions. This focus on emotional change is new, as in earlier publications, only the effects of the multicomponent intervention on motivational variables (intrinsic, identified, introjected, and extrinsic regulation, and self-concept) over one (Grade 7) or two intervention years (Grade 7 and 8) have been presented (Held & Hascher, submitted; Brandenberger et al., 2018; Sutter-Brandenberger et al., 2019). In addition, the relationships between motivational variables and basic need satisfaction (Held et al., in press) as well as between motivational variables and negative emotions (Sutter-Brandenberger et al., 2018) have been examined longitudinally. Therefore, the present paper investigates topical questions regarding sources of emotion change: Are there intraindividual changes in control or value appraisals due to an intervention, and can the underlying change-change assumption over two years (Grade 7 and 8) be confirmed? Thus, the study provides information about the assumed effect model and the effectiveness of the intervention on these variables.

2. Methods

2.1. Participants and procedure

The present study is part of the longitudinal intervention project “Maintaining and fostering students' positive learning emotions and learning motivation in math's instruction during adolescence” funded by the Swiss National Science Foundation. For the first recruitment step,

school representatives of "cooperation schools" (a school network participating in teacher education) were informed about the intervention project in a meeting at the University of Bern. These representatives invited mathematics teachers to participate in the study. Interested teachers were able to register their class for the study. The study is set within a quasi-experimental design with two experimental groups and one control group. Teachers who committed to participate could choose in which setting they wanted to participate. As none of these teachers (n = 16) signed up for the control group, math teachers at similar levels from the same school or a school in the same district were recruited (n = 6). The sample consists of 348 students, with a mean age of 12.75 (SD = 0.64) at the first measurement point, from 22 classes in the lowest ability tier of secondary education ("Realschule") in the German-speaking part of the canton of Bern in Switzerland. All students completed a questionnaire three times over the two school years: at the beginning of Grade 7, at the end of Grade 7, and at the end of Grade 8. Data collection took place during regular mathematics classes and was carried out by trained project staff. Participation was voluntary and since all students were underage at the beginning of the study, their parents or guardians had to sign a declaration of consent. All data provided by the students were anonymized. Of the total, 179 of the students are female (51.4%) and 169 are male (48.6%). There was an institutional review board at the University of Bern, but approval was not required by the institution because the Swiss National Science Foundation approved our study. Yet the ethical principles of the APA were followed.

134 students participated in a combined student–teacher intervention; 122 students participated in a student intervention, and 92 students were in the control group. The 256 students from the two intervention groups attended identical workshops during two regular consecutive mathematics lessons: twice in the autumn term and twice in the spring term in each school year. The workshops were delivered at the class level by three trained members of the project staff. Each workshop followed a structured implementation plan and was realized with the identical methods and training materials that had been pilot-tested to ensure that the implementation follows the intervention protocol (Brandenberger et al., 2018). The content of the workshops was primarily based on basic need satisfaction according to self-determination theory (SDT; Deci & Ryan, 2002) and the support of positive emotional experience on control-value theory (Pekrun, 2006). All student workshops attempted to target the three basic needs and reflection of control and value appraisals by including group work, reflection on one's own capabilities and learning (control appraisals), as well as reflection on the importance and value of mathematics (value appraisals). The student workshops consisted of a mix of theory (theoretical inputs, transfer activities, motivational self-regulation strategies), hands-on activities like applying learning strategies to authentic mathematic tasks, group collaboration and individual work (e.g., case studies), video examples, and reflection about their own learning and the importance and value of mathematic for academic learning for everyday life and for their future professional lives (for more detail about the multicomponent intervention content, see Table 1, Brandenberger et al., 2018, and Sutter-Brandenberger et al., 2019). Through these workshop contents, psychological processes should be triggered in the sense of social-psychological interventions (cf. Yeager & Walton, 2011), which may influence the trajectories of students' experiences.

For the student–teacher intervention, math teachers were first invited to attend a 90-minute introductory session where they were informed about the goals and structure of the project. Within the time range of two school years, teachers attended two 120-minute workshops. In these workshops, they were informed about the theoretical background of students' workshop contents (e.g., CVT or SDT) and encouraged to deepen their knowledge on student emotion and motivation. No measures on teacher interventions outcomes were conducted. Because the main aim of the study addressed student development and the effects of the intervention on students, the two groups (student–teacher intervention and student intervention group) were combined as students received the identical intervention.

Table 1
Overview of the workshop aims.

Grade 7	September–December	Workshop 1a	Students get an awareness of the multiple experiences in school, with a special focus on mathematics; Students learn more about scholastic learning and rethink their motivation and emotions concerning learning mathematics.
		Workshop 1b	Students reflect on subjective learning experiences in mathematics classes, determine positive attitudes toward mathematics, and rethink their learning goals in mathematics.
	March–May	Workshop 2a	Students enhance knowledge and improve their use of learning strategies in mathematics.
		Workshop 2b	Students learn to use emotional and motivational self-regulation strategies in mathematics.
Grade 8	September–December	Workshop 3a	Students improve their causal attributions to learning and their value- and control-cognition in mathematics.
		Workshop 3b	Students understand the relevance of mathematics learning and can link this relevance to their own lives.
	March–May	Workshop 4a	Repetition on learning strategies, emotional and motivational self-regulation strategies.
		Workshop 4b	Repetition on value cognitions in math, and the emotional and motivation self-regulation strategies.

2.2. Measures

According to theoretical assumptions about control appraisals and previous research (Buff, 2014; Pekrun et al., 2011), perceived control was measured using two scales (self-concept and self-efficacy) that served as manifest indicators. Students' self-concept and self-efficacy in mathematics were assessed in accordance with PISA 2012[1] (Schwantner et al., 2013) with four items for self-concept (e.g., "I have always believed that mathematics is one of my best subjects," $\alpha_{t0/t1/t2}$ = 0.83/0.85/0.85) and four items for self-efficacy (e.g., "In mathematics I am sure that I can understand even the most difficult material," $\alpha_{t0/t1/t2}$ = 0.79/0.80/0.82). The reliabilities for the composite construct of perceived control all three measurement points amount to $\alpha_{t0/t1/t2}$ = 0.88/0.89/0.89 and thus indicate a good to excellent internal consistency of the measurement (Tavakol & Dennick, 2011).

Perceived value was also measured using two scales (utility and attainment value) as manifest indicators. The use of this composite construct is in line with the theoretical assumption of value and existing research (e.g., Burić, 2015; Pekrun et al., 2011). Utility value was assessed with four items (e.g., "The learning contents in mathematics will help me in my life," a shortened version from Gaspard et al., 2014; $\alpha_{t0/t1/t2}$ = 0.77/0.82/0.84) and attainment value was assessed with four items (e.g., "It's important to me to be good at mathematics," a shortened version from Gaspard et al., 2014; $\alpha_{t0/t1/t2}$ = 0.84/0.79/0.81). The reliabilities for perceived value at all three measurement points amount to

[1] At the first and second measurement point, students were slightly younger (M_{t0} = 12.75; SD_{t0} = 0.64) than PISA's target group for which the original instruments were developed. All items were checked to ensure that they were adequate for younger students.

$\alpha_{t0/t1/t2} = 0.85/0.87/0.89$ and thus indicate a good internal consistency of the measurement (Tavakol & Dennick, 2011). Both control and value were rated on a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree).

Students' achievement emotions in mathematics were assessed using a shortened version of the Achievement Emotions Questionnaire – Mathematics (AEQ – M; Pekrun et al., 2005). All items were rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Enjoyment was assessed through four items (e.g., "I'm looking forward to the mathematics lesson," $\alpha_{t0/t1/t2} = 0.92/0.90/0.87$). Students' anger in mathematics was assessed with four items (e.g., "Because I'm angry, I get restless in mathematic class," $\alpha_{t0/t1/t2} = 0.82/0.83/0.82$). Anxiety was assessed by five items (e.g., "I feel nervous in mathematics class," $\alpha_{t0/t1/t2} = 0.85/0.81/0.82$) and boredom with three items (e.g., "Mathematics class bores me," $\alpha_{t0/t1/t2} = 0.76/0.83/0.82$).

For perceived control, value and emotions, confirmatory factor analyses were conducted at all three measurement points to test the assumed factor structure. Model fit was adequate-to-good for all latent constructs based on cut-off criteria: Comparative fit index (CFI) > 0.90, root mean square error of approximation (RMSEA) < 0.07, standardized root mean square residual (SRMR) < 0.08, and factor charges (λ) > 0.50 (Tabachnick & Fidell, 2012).

Gender, students' mathematics achievement, and intervention group membership were included as covariates. Gender (female = 0; male = 1) was included because existing research showed gender-specific differences in achievement, control and value beliefs, and perceived emotions (Frenzel et al., 2007a; OECD, 2014). Students' mathematic achievement was tested at the beginning of Grade 7 by means of a standardized achievement test of the HarmoS project, a national large-scale assessment. Average standard score was scaled to the mean of 500 points ($SD = 100$). The sample mean is 432 points ($SD = 60$) and corresponds to the expected range for students in this school type (Bauer et al., 2014). Since the intervention is based on CVT, and thus intends to change students' control and value appraisals, the intervention group membership was included. Because both intervention groups received the same intervention on student side, group membership was dummy coded (1 = intervention group; 2 = control group).

2.3. Data analyses

With the exception of the reliability and descriptive statistics calculation in R (R Core Team, 2019), all analyses were conducted in Mplus 8 (Version 1.6; Muthén & Muthén, 1998–2018).

2.3.1. Missing data

Based on teacher assessment of academic ability, at the end of primary education (Grade 6) students in Switzerland are assigned to different tiers (school types) of lower secondary education. Due to the permeability of the Swiss school system, however, students are still able to move between tiers after this transition. These changes typically occur during the first months of Grade 7. As this study exclusively addresses students in the lowest tier, called "Realschule", only those students who remained in this type of school throughout Grade 7 were included in our analyses. Of an initial cohort of 452 students, 348 remained in the "Realschule" and completed both surveys in Grade 7 (measurement points t0 and t1). At the end of Grade 8 (measurement t2) 23% of the dependent variables were missing (student absence due to moving to a different tier, illness, work experience, trial apprenticeship, or change of school). Based on these reasons for missingness and the specific sample population, missing data at the end of Grade 8 are potentially not missing completely at random (MCAR). Instead, missing values are assumed as missing at random (MAR), and were assessed with the full information maximum likelihood (FIML) estimation in Mplus (Muthén & Muthén, 1998–2018). Under MAR, FIML produce approximately unbiased results, particularly at smaller sample sizes, and perform well with a moderate amount of missing data (20%–25%; Buhi et al., 2008; Schlomer et al., 2010). For descriptive statistics and mean differences, missing data were assessed using multiple imputation by chained equation in R (package *mice* (van Buuren & Groothuis-Oudshoorn, 2011), version 3.9.0, number of imputed datasets (*m*) and iteration (*maxit*) = 20).

2.3.2. Measurement invariance

Measurement invariance across time was tested for all latent constructs to control whether the latent constructs were stable over time and whether they could be compared over the measurement times (Little, 2013). Therefore, a series of increasingly restrictive nested models were tested: First, configural model (configural invariance), which allowed parameters to be estimated freely across the three measurement points was used as baseline model. Second, weak invariance model (metric invariance), which constrained all factor loading to be equal across time. Third, strong invariance model (scalar invariance) whereby factor loadings, and intercepts were constrained to be equal. Fourth, a strict invariance model (invariance of unique variances) that also constrained the residual variances over time (Byrne, 2008; Sass, 2011). In order to investigate mean differences over time, at least scalar invariance must exist (Grimm et al., 2017; Sass, 2011). To test the different degrees of measurement invariances, any changes in fit indices, the comparative fit index (CFI), and the root-mean-square error of approximation (RMSEA) were compared between the nested models. Change in $\Delta CFI < 0.01$ and the change in $\Delta RMSEA < 0.01–0.015$ were set as limits (Chen, 2007). Within this range, it can be assumed that the more restrictive model does not present a significantly poorer fit than the less restrictive model (Little, 2013).

2.3.3. Latent change models

Given the nested structure of the data ($N = 22$ classrooms) and the non-independence of observations, the command "Type = Complex" was used for all analyses in Mplus (Muthén & Muthén, 1998–2018). In order to test our hypotheses, latent change models (Steyer et al., 2000) were conducted. These latent change models (or true change models or latent difference models) can provide the analysis of intraindividual changes and interindividual differences in intraindividual change, since intraindividual change between two measurement points is modeled as a latent variable (McArdle, 2009; Reuter et al., 2010; Steyer et al., 2000). The modeling of the present study is based on a neighbor change model (Geiser, 2010). Hence, the changes from the first to the second and from the second to the third measurement point were modeled as two latent variables.

Based on the limited sample size and the high model complexity, the latent change models were estimated separately for the two appraisals and different emotions. Model fit was assessed by examining the comparative fit index (CFI), and the root mean squared error of approximation (RMSEA). A satisfactory model fit is indicated by a CFI $>$ 0.90 (Tabachnick & Fidell, 2012) and a RMSEA < 0.07 (Steiger, 2007). First, latent change models were estimated for perceived control and value. Second, the latent change models for each emotion were estimated, including the baseline level of control and value appraisals and the latent change of control and value on the emotions at t0, and on the latent change of emotions (cf. Fig. 1). Based on existing research showing differences in mathematics emotions as a function of gender and mathematics achievement (cf. Frenzel et al., 2007a; Holm et al., 2017), gender and mathematics achievement were included as covariates in all models in addition to group membership.

3. Results

Descriptive statistics and correlations for all variables are presented in Table 2. As expected, perceived control and value are positively correlated with enjoyment and negatively with the negative emotions. Furthermore, perceived control and value correlate positively with gender and mathematics achievement at the first measurement point.

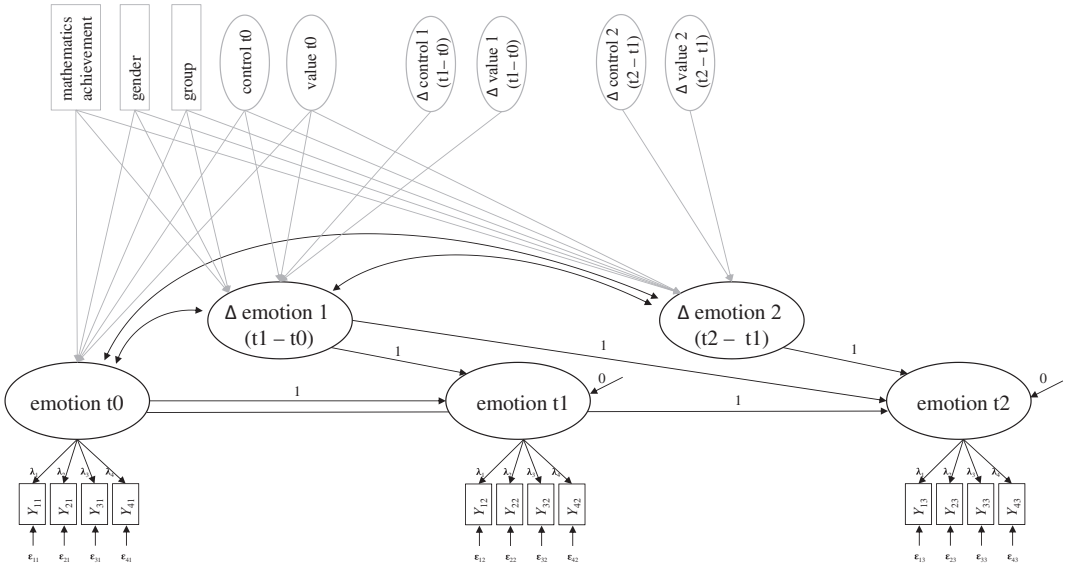

Fig. 1. Prototypic change-change model with covariates and extracted latent factor scores and latent difference of perceived control and value.

Separate measurement models were designed for each latent variable over the three measurement points to control whether the latent constructs were stable over time and whether they could be compared over the measurement points. Test of scalar invariance for each latent variable revealed the equality of factor loadings and intercepts across the three measurement points. Perceived control, enjoyment, anger, and boredom even revealed strict invariance, so that residual variances can be assumed to be equal over time as well (cf. Table 3).

3.1. Latent change models of control and value

To test the effectiveness of the intervention, latent change models were applied to investigate intraindividual changes in control and value. Two latent change variables reflecting the change between t0 and t1 (Δcontrol 1/Δvalue 1) and t1 and t2 (Δcontrol 2/Δvalue 2) were specified. The intervention setting was used as a predictor that explains the intraindividual change in perceived control and value across time relying on latent factors accounting for measurement errors (cf. Fig. 2). We assume that the intervention group will show an increase in control and value appraisals compared to the control group (Hypothesis 1).

The latent change model of perceived control (χ^2 (332) = 621.14, $p \leq .001$, CFI = 0.92, RMSEA = 0.05) and perceived value (χ^2 (312) = 599.53, $p \leq .001$, CFI = 0.91, RMSEA = 0.05) yield an adequate fit (Tabachnick & Fidell, 2012). With regard to our hypothesis, however, no significant intervention effect could be found: Neither perceived control nor perceived value increased significantly in the intervention group compared to the control group. Therefore, H1 must be rejected.

Additionally, perceived control at t0, as well as perceived value at t0, reveal a negative significant correlation with the change of the same construct ($r_{\Delta control1} = -0.453$, $p \leq .001$; $r_{\Delta control2} = -0.203$, $p \leq .001$; $r_{\Delta value1} = -0.428$, $p \leq .001$; $r_{\Delta value2} = -0.256$, $p \leq .001$). These negative relations indicate that the higher control and value at t0, the more negatively they develop, and vice versa. This result points to differences between students regarding their changes in control and value appraisals what can be described as interindividual differences in intraindividual change. For the model of perceived control and value, the included covariates show a significant effect of mathematics achievement at the beginning of the study and of gender on perceived control and perceived value at the first measurement point (t0). The higher the mathematics achievement at t0, the higher the perceived control (β = 0.210, $p \leq .001$) and perceived value (β = 0.110, $p = .032$) at t0. In addition, prior mathematics achievement has a significant effect on change in perceived control between t0 and t1 (Δcontrol 1). The better the mathematics achievement at t0, the more positive the change in perceived control between the first two measurement points (β = 0.142, $p = .023$). In terms of gender, results reveal that boys at t0 reported significantly more perceived control (β = 0.277, $p \leq .001$) and more perceived value (β = 0.116, $p = .049$) than girls. Furthermore, gender has a significant effect on the change of perceived value between the first two measurement points (Δvalue 1). Boys show a significant positive change in perceived value between t0 and t1 compared to girls (β = 0.111, $p = .036$).

Under control of the covariates, the latent factor scores (control and value at t0) and latent change scores of perceived control (Δcontrol 1/Δcontrol 2) and perceived value (Δvalue 1/Δvalue 2) were extracted, and in a next step they were included in the latent change models to investigate the separate change-change process for the four achievement emotions.

3.2. Change-change model of enjoyment

We assume that positive intraindividual changes in perceived control and value longitudinally predict positive intraindividual changes in enjoyment (Hypothesis 2a). The latent change model of enjoyment (χ^2 (148) = 176.86, $p = .05$, CFI = 0.99, RMSEA = 0.02) yields an adequate fit (Tabachnick & Fidell, 2012). As shown in Fig. 3, intraindividual change in enjoyment between the first and second measurement point is significantly predicted by intraindividual change in control (β = 0.470, $p \leq .001$) and change in value (β = 0.253, $p \leq .001$). The more positive perceived control and value develop between the first two measurement points, the more positive the change in enjoyment in the same time period. Between the second and third measurement point, change in enjoyment is only significantly predicted by change in control (β = 0.453, $p \leq .001$). Perceived value at t0 significantly and negatively predicts change in enjoyment between t1 and t2 (β = −0.111, $p = .03$), whereas the change in value between t1 and t2 does not significantly predict change in enjoyment between t1 and t2 (β = 0.117 $p = .19$). This result indicates that the higher the perceived value at t0, the more negative enjoyment develops between t1 and t2, while a change in perceived value could not predict a change in enjoyment between these two measurement points.

Additionally, change in enjoyment between t0 and t1 is negatively predicted by mathematics achievement at the beginning of the study (β = −0.105, $p = .036$). The higher the mathematics achievement at t0, the

Table 2
Descriptive statistics.

		M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Control t0	2.58	0.58		0.54***	0.39***	0.54***	0.38***	0.27***	0.65***	0.36***	0.25***	−0.25***	−0.17**	−0.08	−0.20***	−0.16**	−0.06	−0.28***	−0.23***	−0.18**	0.20***
2	Control t1	2.71	0.60			0.59***	0.37***	0.51***	0.29***	0.43***	0.64***	0.35***	−0.26***	−0.42***	−0.17**	−0.24***	−0.42***	−0.25***	−0.23***	−0.37***	−0.24***	0.31***
3	Control t2	2.78	0.58				0.22***	0.32***	0.51***	0.27***	0.36***	0.59***	−0.23***	−0.33***	−0.30***	−0.22***	−0.34***	−0.31***	−0.27***	−0.29***	−0.35***	0.28***
4	Value t0	3.23	0.53					0.56***	0.32***	0.50***	0.36***	0.19***	−0.22***	−0.19***	−0.12*	−0.12*	−0.09	−0.08	−0.36***	−0.24***	−0.18**	0.11*
5	Value t1	3.23	0.53						0.50***	0.35***	0.55***	0.33***	−0.22***	−0.41***	−0.20***	−0.17**	−0.25***	−0.14*	−0.26***	−0.41***	−0.28***	0.12*
6	Value t2	3.18	0.57							0.23***	0.28***	0.42***	−0.10	−0.25***	−0.41***	−0.11*	−0.20***	−0.32***	−0.13*	−0.20***	−0.40***	0.06
7	Enjoyment t0	3.04	1.06								0.53***	0.30***	−0.36***	−0.27***	−0.15**	−0.26***	−0.17**	−0.09	−0.48***	−0.31***	−0.21***	0.20***
8	Enjoyment t1	3.05	1.00									0.44***	−0.32***	−0.53***	−0.25***	−0.22***	−0.32***	−0.18**	−0.33***	−0.55***	−0.35***	0.16**
9	Enjoyment t2	3.04	0.91										−0.23***	−0.35***	−0.41***	−0.15**	−0.22***	−0.18**	−0.22***	−0.33***	−0.54***	0.16**
10	Anger t0	1.94	0.90											0.40***	0.29***	0.73***	0.35***	0.21***	0.64***	0.36***	0.21***	−0.18**
11	Anger t1	1.79	0.87												0.43***	0.32***	0.60***	0.30***	0.30***	0.76***	0.43***	−0.15**
12	Anger t2	1.95	0.87													0.20**	0.30***	0.58***	0.21***	0.34***	0.72***	−0.12*
13	Anxiety t0	1.99	0.93														0.40***	0.28***	0.52***	0.27***	0.15**	−0.19***
14	Anxiety t1	1.68	0.72															0.41***	0.26***	0.46***	0.21***	−0.23***
15	Anxiety t2	1.72	0.71																0.20***	0.20***	0.40***	−0.16**
16	Boredom t0	2.10	0.95																	0.37***	0.23***	−0.11*
17	Boredom t1	2.06	1.01																		0.48***	−0.09
18	Boredom t2	2.17	1.00																			−0.06
19	Mathematics achievement t0	432.64	60.61																			

* $p < .05$.
** $p < .01$.
*** $p \leq .001$.

more negative the change in enjoyment between the first two measurement points. Furthermore, enjoyment at t0 and change in enjoyment are negatively related ($r_{\Delta enjoyment1} = -0.560$, $p \leq .001$; $r_{\Delta enjoyment2} = -0.223$, $p \leq .001$). This negative relation indicates that the higher the enjoyment at t0, the more negatively it develops, and vice versa. This result points to differences between students regarding changes in enjoyment (i.e., interindividual differences in intraindividual change).

3.3. Change-change model of anger

We assume that positive intraindividual changes in perceived control and value longitudinally predict negative intraindividual changes in anger, anxiety, and boredom. The latent change model of anger (χ^2 (148) = 218.30, $p \leq .001$, CFI = 0.95, RMSEA = 0.04) also yields an adequate fit (Tabachnick & Fidell, 2012). Model results (cf. Fig. 4) reveal that changes in anger between the first and second, and the second and third measurement points are significantly negatively predicted by change in control ($\beta_{\Delta control1} = -0.237$, $p \leq .001$; $\beta_{\Delta control2} = -0.101$, $p = .048$) and change in value ($\beta_{\Delta value1} = -0.234$, $p \leq .001$; $\beta_{\Delta control2} = -0.325$, $p \leq .001$). The more positive perceived control and value develop, the more anger decreases.[2] These results confirm the change-change hypothesis of the CVT for perceived control and perceived value and anger (Hypothesis 2b).

With respect to the covariates, significant effects on anger at t0 could be found. Perceived control and perceived value at t0 have a negative effect, i.e., the higher the perceived control and value, the lower the anger at t0. Gender and group membership reveal a significant positive effect, i.e., boys and the students in the control group show more anger at t0. Furthermore, group membership has a significant negative effect on the change in anger between t1 and t2. Change in anger between these two measurement points develops more advantageously in the control group compared to the intervention group. In addition, anger at t0 and the change between the first two measurement point correlate. This negative correlation indicates that the higher the values of anger at t0, the more advantageously it develops, and vice versa ($r_{\Delta anger1} = -0.634$, $p \leq .001$) and thus points to differences between students regarding changes in anger.

3.4. Change-change model of anxiety

The latent change model of anxiety (χ^2 (203) = 327.93, $p \leq .001$, CFI = 0.94, RMSEA = 0.04) yields an adequate fit (Tabachnick & Fidell, 2012). As shown in Fig. 5, intraindividual change in anxiety between the first and second measurement point is significantly negatively predicted by change in control ($\beta = -0.232$, $p \leq .001$) and change in value ($\beta = -0.102$, $p = .040$). The more positive perceived control and value develop between the first two measurement points, the greater the decrease in anxiety that can be found at the same time period. Also, change in anxiety between the second and third measurement point is significantly predicted by the change in control between the same measurement points ($\beta = -0.203$, $p = .006$). These results partially confirm the change-change hypothesis of the CVT for perceived control and perceived value and anxiety (Hypothesis 2c).

Perceived value at t0 significantly predicts change in anxiety between t1 and t2 ($\beta = -0.138$, $p = .026$), but the change in perceived value is not a significant predictor ($\beta = -0.078$, $p = .114$). Thus, higher perceived value at t0 leads to a more desirable change in anxiety between t1 and t2. In terms of gender, boys report significantly more anxiety at t0 than girls, and the control group also shows significantly more anxiety at t0 than the intervention group. In addition, anxiety at t0 and the change between the first two measurement points correlate. This negative correlation indicates that the higher the values of anxiety at t0,

[2] Because anger, anxiety and boredom are negative emotions, lower values are more desirable, and therefore a negative change is more advantageous.

Table 3
Longitudinal measurement invariance.

Model	χ^2	df	χ^2/df	RMSEA	CFI	ΔRMSEA	ΔCFI
Perceived control							
1 Configural	439.03	225	1.95	0.052	0.937		
2 Metric	464.66	239	1.94	0.052	0.934	0.000	0.003
3 Scalar	487.06	253	1.93	0.052	0.931	0.000	0.003
4 Strict	509.22	269	1.89	0.051	0.930	0.001	0.001
Perceived value							
1 Configural	460.06	222	2.07	0.056	0.927		
2 Metric	481.49	236	2.04	0.055	0.925	0.001	0.002
3 Scalar	518.98	249	2.08	0.056	0.918	−0.001	0.007
4 Strict	606.68	265	2.29	0.061	0.896	−0.005	0.022
Enjoyment							
1 Configural	69.75	39	1.79	0.048	0.984		
2 Metric	74.30	45	1.65	0.043	0.985	0.005	−0.001
3 Scalar	80.96	51	1.59	0.041	0.985	0.002	0.000
4 Strict	78.57	59	1.33	0.031	0.99	0.01	−0.005
Anger							
1 Configural	56.16	39	1.44	0.036	0.984		
2 Metric	67.41	45	1.50	0.038	0.979	−0.002	0.005
3 Scalar	83.79	51	1.64	0.043	0.970	−0.005	0.009
4 Strict	90.12	59	1.53	0.039	0.971	0.004	−0.001
Anxiety							
1 Configural	88.52	72	1.23	0.026	0.989		
2 Metric	103.83	80	1.30	0.029	0.985	−0.003	0.004
3 Scalar	116.70	87	1.34	0.031	0.981	−0.002	0.004
4 Strict	202.92	97	2.09	0.056	0.932	−0.025	0.049
Boredom							
1 Configural	24.04	15	1.60	0.042	0.988		
2 Metric	24.63	19	1.30	0.029	0.993	0.013	0.003
3 Scalar	30.32	23	1.32	0.030	0.990	−0.001	0.003
4 Strict	38.21	29	1.32	0.030	0.988	0.000	0.002

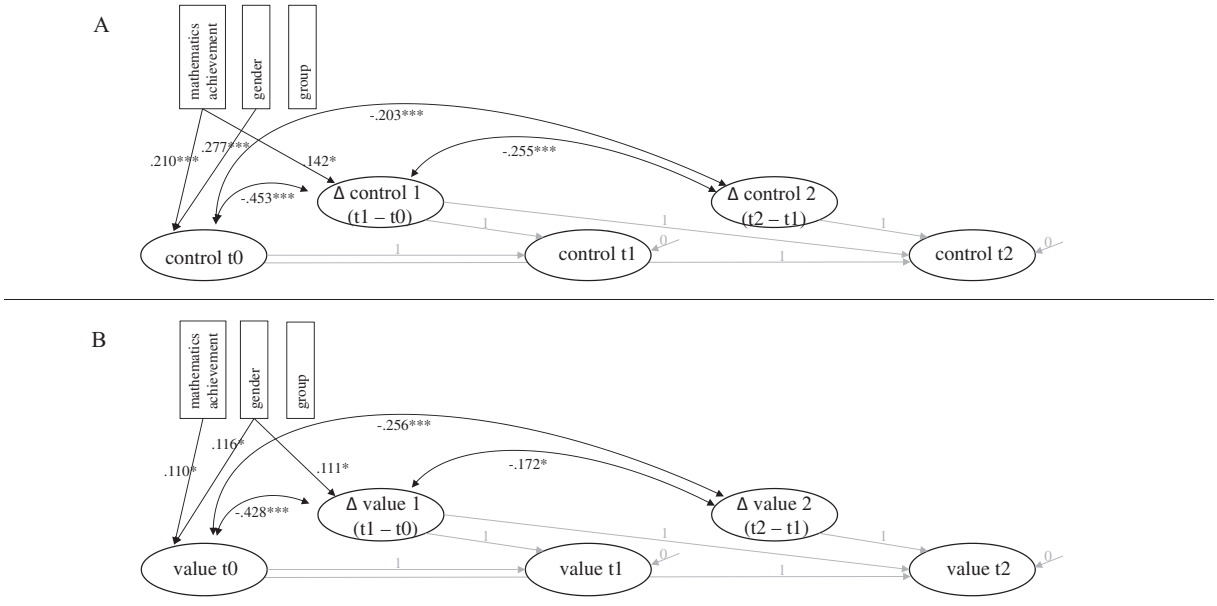

Fig. 2. Latent change models of perceived control (A) and perceived value (B). *p < .05; **p < .01; ***p ≤ .001. Non-significant paths are not displayed.

the more advantageously it develops, and vice versa ($r_{\Delta anxiety1} = -0.731, p \leq .001$). Similar to enjoyment and anger, differences between students regarding their changes in anxiety are found (i.e., interindividual differences in intraindividual change).

3.5. Change-change model of boredom

The latent change model of boredom (χ^2 (91) = 131.57, $p = .004$, CFI = 0.96, RMSEA = 0.04) yields an adequate fit (Tabachnick & Fidell, 2012). Intraindividual change in boredom between two adjacent measurement points are significantly negatively predicted by change in control ($\beta_{\Delta control1} = -0.208, p \leq .001$; $\beta_{\Delta control2} = -0.140, p = .016$) and change in value ($\beta_{\Delta value1} = -0.260, p \leq .001$; $\beta_{\Delta value2} = -0.265, p \leq .001$). The more positive perceived control and value develop between the measurement points, the more advantageous the change in boredom at the same time period. These results confirm the change-change

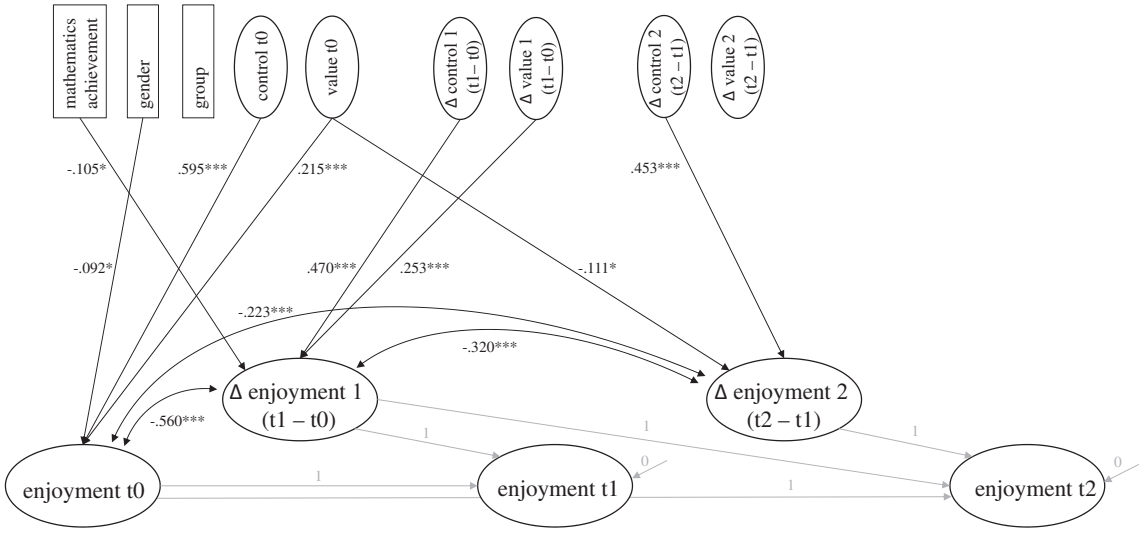

Fig. 3. Change-change model of enjoyment with covariates and extracted latent factor scores and latent difference of perceived control and value. *$p < .05$; **$p < .01$; ***$p \leq .001$. Non-significant paths are not displayed.

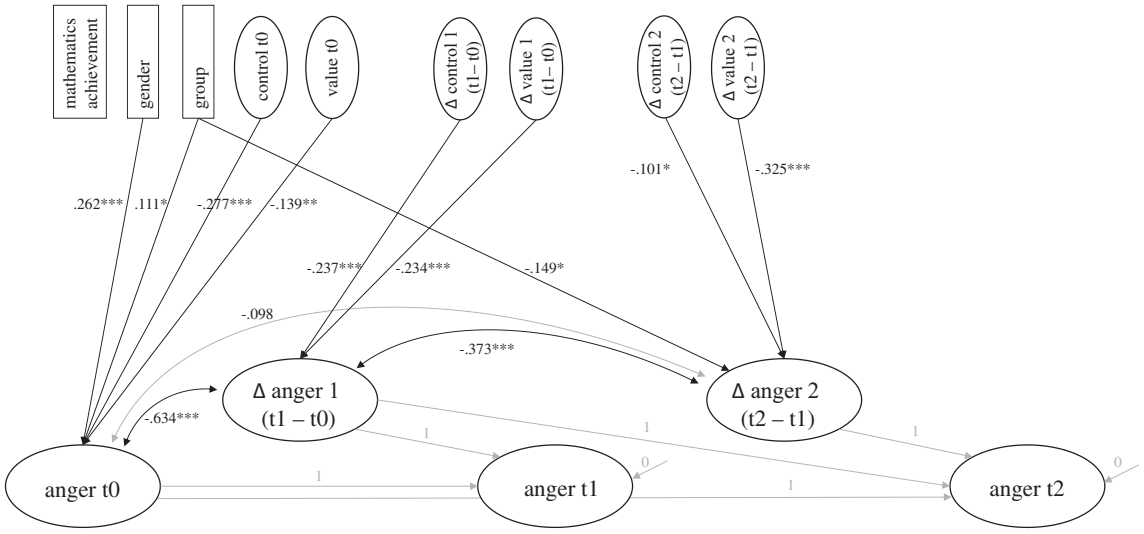

Fig. 4. Change-change model of anger with covariates and extracted latent factor scores and latent difference of perceived control and value. *p < .05; **p < .01; ***$p \leq .001$. Non-significant paths are not displayed.

hypothesis of the CVT for perceived control and perceived value and boredom (Hypothesis 2d).

In terms of gender, boys report significantly more boredom at t0 than girls, and the control group also shows significantly higher boredom at t0 than the intervention group. Furthermore, boredom at t0 and change in boredom are negatively related ($r_{\Delta boredom1} = -0.547$, $p \leq .001$; $r_{\Delta boredom2} = -0.181$, $p = .015$). This negative relation indicates that the higher the boredom at t0, the more advantageously it develops, and vice versa (cf. Fig. 6). Thus, interindividual differences in intraindividual change are also evident in boredom.

4. Discussion

4.1. Effectiveness of a multicomponent intervention

One of our research goals was to investigate whether a two-year intervention program related to CVT may change control and value appraisals of low-achieving secondary school students in mathematics. Although changes in control and value appraisals over two school years could be found, these changes could not be attributed to participation in the intervention program. Neither perceived control nor perceived value increased significantly in the intervention group compared to the control group (rejection of Hypothesis 1). Instead, the control group that expressed significantly more anger, anxiety, and boredom at the first measurement point reported a more pronounced decline in anger between the second and third measurement point. However, because no effects of the intervention were found on control and value appraisals, it must be assumed that classroom characteristics or context conditions that have converged over time are responsible for these effects on negative emotions. Moreover, because the effects of the control group only reach the 5% level of significance, they need to be carefully evaluated.

Whereas prior research has shown that control appraisal could be affected e.g., by attributional retraining through a writing assignment (e.g., Hamm et al., 2014), the result of our study did not show effects of a training program. Instead, intraindividual change in control appraisals in the first year of secondary education was predicted by mathematics achievement, and intraindividual change in value appraisal in the first

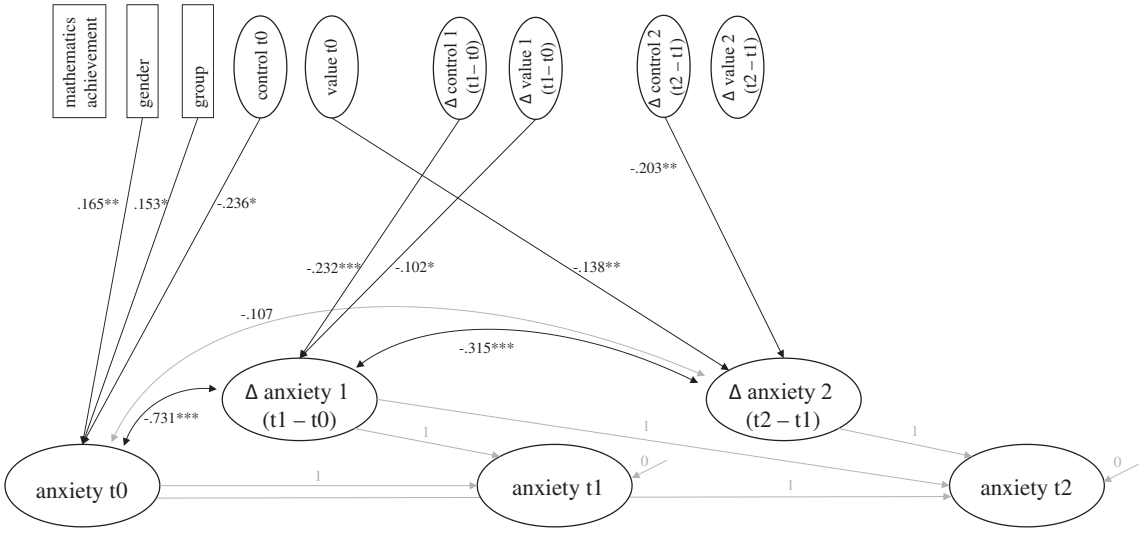

Fig. 5. Change-change model of anxiety with covariates and extracted latent factor scores and latent difference of perceived control and value. *p < .05; **p < .01; ***p ≤ .001. Non-significant paths are not displayed.

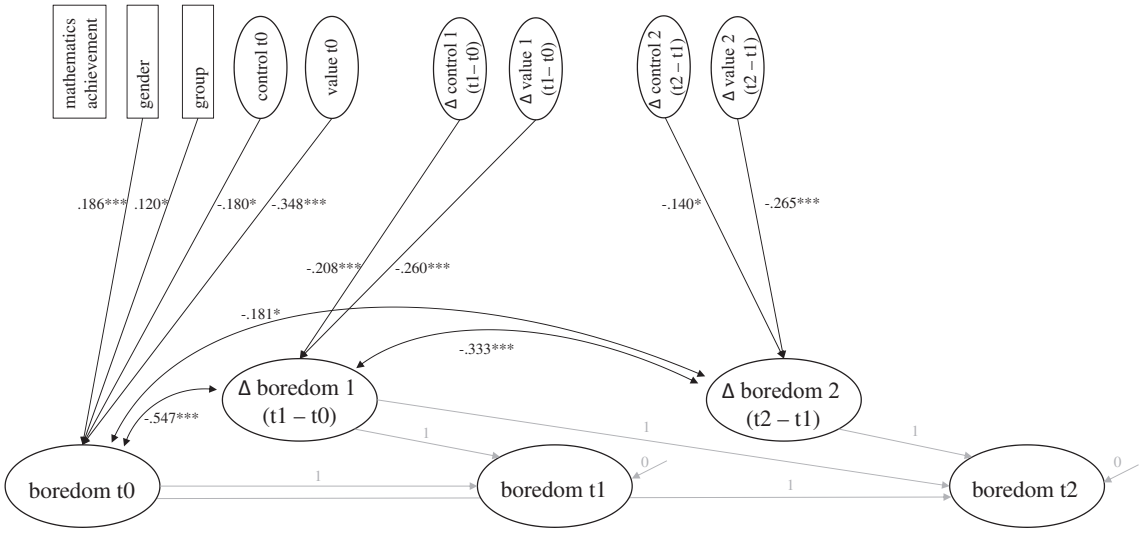

Fig. 6. Change-change model of boredom with covariates and extracted latent factor scores and latent difference of perceived control and value. *p < .05; **p < .01; ***p ≤ .001. Non-significant paths are not displayed.

year of secondary education was predicted by gender. One reason for the program's lack of impact may be related to the program's design. The broadness of the contents of the workshops, primarily based on basic need satisfaction according to SDT (Deci & Ryan, 2002) as well as the support of positive emotional experience in CVT (Pekrun, 2006), might not have been sufficiently tailored to influence student appraisals. Multicomponent interventions do less to address single variables but instead aim at a general opportunity to improve emotions, motivation and attitudes toward school. Thus, specific effects may be difficult to achieve. Taken the domain-specificity of emotions into account, the intervention contents regarding the change in control and value appraisals might have been not sufficiently related to the subject of mathematics. Future interventions could be improved by targeting the psychological process of appraisals closer to specific mathematical contents and less to mathematics in general (cf. Yeager & Walton, 2011). A denser combination of psychological process and mathematics contents (e.g., training that aims at improving specific mathematical problem-solving skills) might better align with the domain-specificity of emotions.

Another reason for the program's lack of impact may be related to the design of our intervention. It was found that interventions aiming to affect students' control appraisals through concrete video examples showing other students as role models had a positive effect on students' positive emotions (Kim & Hodges, 2012). However, in the present intervention, students in the intervention group did not receive a prepared set of strategies that help them recognizing how to get control over their attention, outcomes, or emotions. Instead, the students themselves had to translate these strategies from exercises (e.g., how to deal with mistakes) or self-reflection. This transfer might have been too challenging for the students—compared to an implementation of prompted strategies—and did fail to achieve the desired change.

Regarding the promotion of the value appraisal, short interventions based on EVT suggested that a psychoeducational presentation and relevance-inducing tasks (writing task or evaluation of interview quotations) had a positive effect on students' value (e.g., Gaspard et al., 2015). However, the effects of short interventions may differ from long-term interventions. Short-term effects may not have been detected in our study, which covered two school years. Further, a fatigue effect

(Hagenauer, 2010) may have set in, and students may have considered the workshops to be too long, or there may also have been a form of fade-out phenomenon (Bailey et al., 2020).

Overall, our results seem to align with the series of intervention studies on the promotion of emotions showing little or no effects (e.g., Chalk & Bizo, 2004; Gläser-Zikuda et al., 2005; Hamm et al., 2014) and demonstrates the challenge of such social-psychological interventions. It can be concluded that an efficient program needs to address a specific psychological process to achieve homogenous and long-lasting effects (Walton & Wilson, 2018). Also for example, Gläser-Zikuda et al. (2005, S. 492) stated that their "intervention may have had different effects on specific subgroups of students", and Hamm et al. (2014) found between-person differences in personal characteristics (i.e., performance orientation) leading to different effects. Thus, it is possible that the present sample of low-achieving students represents a less homogenous group than expected in terms of emotions and that the intervention had differential effects on different subgroups (i.e., aptitude-treatment interaction). In sum, the study supports the hypothesized model, but the intervention could not achieve corresponding effects on all students. Future research can thus refer to the hypothesized model and attempt to address control and value appraisals in specific subgroups and test subgroup-specific impacts.

4.2. Change-change assumption

Against the background of CVT, our second research goal focused on the antecedents of achievement emotions. We investigated the change-change hypothesis regarding the four achievement emotions of enjoyment, anger, anxiety, and boredom over two school years. We assumed that positive intraindividual changes in perceived control and value longitudinally predict positive intraindividual changes in enjoyment (Hypothesis 2a) and negative intraindividual changes in anger, anxiety, and boredom (Hypothesis 2b-d). Our results are in line with CVT and previous research (Buff, 2014; Niculescu et al., 2016). Intraindividual changes in the four achievement emotions are longitudinally predicted by changes in perceived control and value. The results show that for all four investigated achievement emotions, these longitudinal effects are more pronounced in the first year of secondary education and that one-year change-change effects are stronger than two-year change-change effects. After transition into secondary education, students seem to be differently responsive to changes in appraisals. These findings may support the idea to tailor interventions programs also regarding educational settings and trajectories.

Regarding the changes during the two school years (Grade 7 and 8), an additional difference could be found: Changes in value appraisals between the second (end of Grade 7) and third measurement point (end of Grade 8) significantly predicted changes in anger and boredom but not in enjoyment and anxiety. This result might indicate different roles of appraisals for emotional experiences. For enjoyment and anxiety, perceived control might be a stronger predictor than perceived value. This interpretation is underlined by the finding of a stronger prediction of change by control compared to value between the first and second measurement point for enjoyment and anxiety. For anger and boredom, perceived control and value are about equally strong predictors. From a theoretical perspective such as SDT (e.g., Deci & Ryan, 2002), enjoyment arises along with intrinsic motivation, that means, when something is valued for its own sake. External, instrumental value might lead to smaller effects on enjoyment. Analogous to EVT, different forms of value (e.g., utility value, intrinsic value) would need to be distinguished because they might have different effects (Putwain et al., 2018; Simonton & Garn, 2020). Alternatively, the significant association of enjoyment and anxiety between the first two measurement points might suggest that enjoyment and anxiety had become habitualized over time. Although perceived control and value might predict enjoyment and anxiety, a habitualization of enjoyment or anxiety might temper effects of appraisals. From a methodological perspective, it must be noted that perceived value at the first measurement point was predictive for the change in enjoyment as well as in anxiety between the second and third measurement point. This also points to the possibility of habitualization process that affected the level of enjoyment and anxiety.

Similar to Buff (2014), we found the "unexpected" negative effect of enjoyment at t0 in terms of its change. Complementarily, we note that the baseline measurement of enjoyment also negatively correlated with the change between the end of Grade 7 and the end of Grade 8 (Δenjoyment 2). This effect indicates that the higher enjoyment at the beginning of Grade 7, the more negatively enjoyment develops over two school years. Thus, students with initially high mathematics enjoyment are at risk of losing it during secondary education. For the negative emotions we found, corresponding to Niculescu et al. (2016), negative correlations between t0 and their changes between the first two measurement points for anger, anxiety, and boredom. In terms of boredom, this negative correlation can also be found regarding the change between the end of Grade 7 and Grade 8 (Δboredom 2). Therefore, high levels of negative emotions at the beginning of Grade 7 were associated with declines in negative emotions across time and vice versa. Overall, this indicates that there are between-person differences in intra-individual changes in different emotions. It is possible, however, that this result is based on a correction or approximation to the mean effect, where high initial values are corrected downwards and vice versa (Niculescu et al., 2016). It is also likely that the correction to the mean effect may result from a more differentiated perception of one's own emotions based on developmental processes during adolescence or adaptation processes after the transition from primary to secondary education.

4.3. Limitations

In spite of the advantages of the present study, such as the longitudinal approach over two school years, some limitations must be taken into account. First, in terms of our study design, the measurement took place at the beginning of Grade 7, right after the transition to secondary education. This transition is accompanied by big changes for students, such as new teachers, new classmates, and usually a new school environment as well. The effect of these changes on the baseline measurement cannot be excluded. Further, the second and third measurements took place at the end of Grade 7 and Grade 8, respectively. The long time span between measurement points may have been too great to identify treatment effects, and intervention effects may have faded. Further, the two intervention groups were grouped together in the present study due to their similarity in the students' workshops. As teachers of one student intervention group also have been introduced to basic need theory and CVT, changes in teaching behavior cannot be excluded to affect students' appraisals and emotions.

Second, our study focuses on secondary school students in the lowest ability tier and refers to the achievement emotions in mathematics. The specific characteristics of the sample might also explain why mathematics achievement was significant only for changes in the positive achievement emotion, namely enjoyment. Therefore, our results are limited regarding other age groups, other ability tiers, and other domains. Due to this fact, the results cannot be generalized.

Third, the change-change assumption assumes causality between control and value appraisals on emotions. However, this causality cannot be conclusively confirmed due to the potential influence of third variables such as teacher-student relationship. Further, it must be noted that control and value appraisals are not only antecedents of emotions, but also turn out to be consequences of emotions due to the postulated feedback loop in the relationship of appraisals and emotions (e.g., Goetz et al., 2010; Pekrun & Perry, 2014).

Fourth, a basic assumption of latent change models is that time lags between latent variables must be constant (Grimm et al., 2017). This requirement is only partially fulfilled since the time intervals are only approximately equal (10 months versus 12 months' time differences).

Future studies with more than two measurement points should therefore pay special attention to the equality of the measurement intervals or should use phantom variables to create this equality of time intervals (cf. McArdle, 2001). Based on the intervention setting, the estimation of phantom variables was not possible as the results would not have been reliable and interpretable. Thus, the results of the change between the second (end of Grade 7) and the third measurement point (end of Grade 8) can only be considered with caution and need additional validation from future studies.

4.4. Implications and future research

The confirmed change-change hypothesis over two school years provides important information for future research and practice. It can be assumed that the strategy of influencing students' perceived control and value appraisals may be an effective measure to promote positive emotions and reduce negative emotions. Future research must explore how this could be implemented into daily teaching practices and instructional design. Unfortunately, our multimethod approach did not lead to the intended outcomes in terms of an increase in control and value appraisals. Consequently, the development of effective treatment programs requires further attention. Future research should consider other factors influencing control and value appraisals in order to investigate a possible mediating role of control and value appraisals on emotions. Also, complementary research could apply a person-centered approach such as latent profile analysis to determine possible person-specific effects of an intervention. Regarding heterogeneity of society and student population, it must be taken into account that an intervention does not target all students equally. An intervention may have an effect on certain subgroups while having no effect on other subgroups. By examining individuals' prerequisites and their interactions with the intervention, differential effects may be identified (cf. aptitude-treatment interaction research).

4.5. Conclusion

Overall, the present paper indicates the relevance of control and value appraisals as antecedents of achievement emotions. By confirming the change-change hypothesis over two school years, it becomes evident that positive changes in control and value appraisals can lead to desirable changes in positive as well as in negative emotions, i.e., an increase in positive emotions and a decrease in negative emotions. Thus, this study contributes additional empirical evidence that achievement emotions can be changed by changes in their antecedents and that corresponding intervention approaches may be promising. This finding should be addressed in future research as well as in practice.

Funding

This research was supported by the Swiss National Science Foundation [grant number 156710].

Declaration of competing interest

None.

Acknowledgements

We thank all students and teachers who participated in the research project “Maintaining and fostering students' positive learning emotions and learning motivation in math's instruction during early adolescence (EMo-Math)”.

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