

## A comparison of self-reports and electrodermal activity as indicators of mathematics state anxiety. An application of the control-value theory

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### Abstract

*In the present study with 86 undergraduate students, we related trait Mathematics Anxiety (MA) with two indicators of state anxiety: self-reported state anxiety and electrodermal activity (EDA). Extending existing research, we included appraisals of control and perceived value in hierarchical multiple regression analyses in accordance with the control-value theory of achievement emotions (Pekrun, 2006). Results showed that trait MA predicted self-reported state anxiety, while no additional variance was explained by including control and value. In contrast, we found no significant relation between trait MA and physiological state anxiety, but a significant, negative three-way interaction effect with control and value. Regression coefficients indicated that trait MA predicted physiological state anxiety, but only in the presence of negative perceived control and positive perceived value. Thus, our results support the control-value theory for physiological state anxiety, but not for self-reports. They emphasize the need to distinguish between trait and state MA, the advantages of adopting the control-value theory, and the benefits of using EDA recording as a supplemental assessment method for state anxiety.*

**Keywords:** mathematics anxiety, electrodermal activity, galvanic skin response, control-value theory, state anxiety.



## 1. Introduction

Mathematics Anxiety (MA) has a substantial impact on many students' academic and personal lives. It influences achievement in mathematics tests and classes (Hembree, 1990; Ma, 1999; Namkung, Peng, & Lin, 2019). Moreover, students with high MA avoid mathematics in everyday life as well as in career and academic choices (Dowker, Sarkar, & Looi, 2016; Ma, 1999). MA is common across countries, cultures, and ages (Dowker et al., 2016; Lee, 2009). In the 2012 study of the *Programme for International Student Assessment (PISA)*, 30% of students reported that they felt helpless when doing a mathematic problem (OECD, 2013b). At the same time, MA is a problem of increasing relevance. On average across OECD countries, MA increased significantly from PISA 2003 to PISA 2012 (OECD, 2013b). Thus, for educational research, it is important to understand how MA affects students when doing mathematics. Research has elaborated the distinction between (momentary) *state* anxiety ( $MA_{state}$ ) and (habitual) *trait* Mathematics Anxiety ( $MA_{trait}$ ), assessed through separate self-reports, but the findings left their relationship ambiguous (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). Hence, merely assessing  $MA_{trait}$  cannot exhaustively explain how MA affects mathematical activities momentarily. Then again, directly assessing  $MA_{state}$  provides a challenge, because self-reports of state emotions might be unreliable (Pekrun & Bühner, 2014). Among other physiological measures, *electrodermal activity* (EDA; also referred to as *galvanic skin response*; GSR) had sporadically been used as an indicator for  $MA_{state}$  in the 1980s, but its relationship with self-reports of  $MA_{state}$  or to  $MA_{trait}$  remained unclear. In this paper, we addressed this research gap by combining two novel approaches. First, we included and compared both self-reports and EDA as measures of  $MA_{state}$ . Second, we used the *control-value theory* of achievement emotions (Pekrun, 2006) as a framework to test their relation to  $MA_{trait}$ . Accordingly, we included appraisals of control and perceived value as moderators of the relation between  $MA_{trait}$  and  $MA_{state}$ .

### 1.2 Mathematics Anxiety

MA “involves feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p. 551). MA has an adverse effect on cognitive resources, independent of actual abilities (Ashcraft, 2007; Ashcraft & Kirk, 2001; Maloney et al., 2013). Ashcraft and Kirk (2001) found that in a mental addition task, undergraduates with high MA showed a smaller working memory capacity that led to an increase in reaction time and errors. This first finding started an intensive line of research, largely confirming direct effects of MA on performance (for overviews, see Dowker et al., 2016; Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). This influence is not limited to working memory capacity. For example, Maloney, Ansari, and Fugelsang (2011) found that high MA students suffer from low-level numerical deficits, like a less precise representation of numerical magnitude. Although most studies refer to MA as a unidimensional construct, a number of studies reported evidence that it consists of more than one factor, most prominently a cognitive component (“worry”) and an affective component (“emotionality”); e.g., Ho et al., 2000; Lukowski et al., 2016; Wigfield & Meece, 1988). These studies typically analyzed the factorial structure of questionnaires and related the dimensions to cognitive outcomes like mathematical achievement (e.g., Ashcraft & Ridley, 2005; Lukowski et al., 2016).

### 1.3 Trait and state Mathematics Anxiety

While there are a large number of studies on MA, very few of them differentiate between  $MA_{state}$  and  $MA_{trait}$  (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013; Goldin, 2014). However, this distinction arguably is important when focusing on the effects of MA during mathematical activities. Self-reports of  $MA_{trait}$  refer to multiple, generalized mathematical situations (Bieg, Goetz, Wolter, & Hall, 2015). In contrast,  $MA_{state}$  refers to the specific, current situation. Therefore, reports of  $MA_{trait}$  might be a good predictor for long-term effects of MA on learning or career and course choices (Dowker et al., 2016) but do not necessarily accurately predict  $MA_{state}$  during specific mathematical activities like tests or classes. When investigating the effects of MA during such activities, directly addressing  $MA_{state}$  seems to be more appropriate.



Studies investigating the role of emotions in mathematics and of MA in particular predominantly focus on trait emotions rather than state emotions (Goetz et al., 2013; Goldin, 2014). Accordingly, an extensive number of findings have been gathered on effects, individual differences, and precursors of  $MA_{\text{trait}}$  (Dowker et al., 2016). In contrast, there are fewer studies on  $MA_{\text{state}}$ , often using qualitative analyses (Goldin, 2014). Yet, specific mechanisms explaining the impact of  $MA_{\text{state}}$  have rarely been reported for mathematics (Dowker, 2016).

The relationship between  $MA_{\text{state}}$  and  $MA_{\text{trait}}$  is ambiguous. On the one hand, a number of studies indicate a strong positive relation. For high  $MA_{\text{trait}}$  students,  $MA_{\text{state}}$  is considered a key explanation for a lower working memory capacity (Ashcraft & Moore, 2009; Beilock, 2008). In his meta-analysis, Hembree (1990) reports a mean correlation of  $r = .42$  between  $MA_{\text{trait}}$  and state anxiety. However, state anxiety was not necessarily assessed during specific mathematical activities in the four reported studies (e.g. Plake & Parker, 1982). On the other hand, some studies indicate that there is a notable discrepancy between  $MA_{\text{trait}}$  and  $MA_{\text{state}}$ . Goetz et al. (2013) found that girls systematically report higher levels of  $MA_{\text{trait}}$ , but that this difference is not present in reports of  $MA_{\text{state}}$  during mathematics tests or classes. This difference between reports of  $MA_{\text{trait}}$  and  $MA_{\text{state}}$  is largely explained by individual beliefs and perceptions of competence (Bieg et al., 2015; Goetz et al., 2013). Another reason for differences between  $MA_{\text{trait}}$  and  $MA_{\text{state}}$  might be that MA negatively affects achievement in mathematics through long-term avoidance behavior, but not during mathematical activities per se (Dowker et al., 2016): To avoid aversive consequences,  $MA_{\text{state}}$  can even enhance motivation momentarily and lead to an increase in effort and strategy use during mathematics tests (Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007). This indicates that  $MA_{\text{trait}}$  does not necessarily induce  $MA_{\text{state}}$ .

In general, state anxiety can have various cognitive and motivational-affective effects on learning and performance. Zeidner (2014) lists 15 specific deficits in information processing during learning caused by anxiety, which are likely to be transferable to  $MA_{\text{state}}$ . This includes cognitive deficits in areas like information encoding, information storage and processing, and information retrieval and production. Moreover, state anxiety is associated with physiological reactions. However, this has not been described for  $MA_{\text{state}}$  in particular, but only for state anxiety in general. Per definition, state anxiety is a “transitory emotional state consisting of feelings of apprehension, nervousness, and physiological sequelae such as an increased heart rate or respiration” (Wiedemann, 2015, p. 808). Among other aspects, state anxiety is thus characterized by increased arousal and activation of the autonomic nervous system (Steimer, 2002; Wiedemann, 2015). Accordingly, state anxiety does not only cause cognitive deficits, but also a physiological reaction.

In sum, existing studies mostly focus on  $MA_{\text{trait}}$ , while its relation to  $MA_{\text{state}}$  is left ambiguous. Thus, to better understand how MA affects learning not only over a longer period of time but also momentarily, additional research is needed. This refers both to the question of the relation between  $MA_{\text{trait}}$  and  $MA_{\text{state}}$ , as well as to the mechanisms and precursors of  $MA_{\text{state}}$  in particular. In the following, we propose a theoretical framework for investigating these questions.

#### 1.4 The control-value theory

The *control-value theory of achievement emotions* (Pekrun, 2006) characterizes predictors of achievement emotions, including state anxiety. It states that appraisals of control and the perceived subjective value of an achievement situation are the most proximal predictors of achievement emotions. A low appraisal of control and a simultaneous high perceived value of the task are key determinants of state anxiety. In contrast, trait emotions, environmental factors, or former achievement are considered distal factors and are assumed to have a mostly indirect effect on state emotions. According to the control-value theory,  $MA_{\text{trait}}$  should therefore predict  $MA_{\text{state}}$  mostly indirectly, in association with low appraisals of control and a high subjective value. Several empirical studies support aspects of the control-value theory in mathematics (e.g., Niculescu, Tempelaar, Dailey-Hebert, Segers, & Gijsselaers, 2015). Frenzel, Pekrun, and Goetz (2007) found that  $MA_{\text{trait}}$  is associated with a pattern of low competence beliefs paired with high achievement values in mathematics. Extending the scope, research about attitudes and beliefs about competence in mathematics offers plenty of evidence supporting the control-value theory for other mathematical achievement emotions (for an overview, see Goldin et al., 2016). However, to our knowledge, no study implemented both  $MA_{\text{trait}}$  and  $MA_{\text{state}}$  as well as appraisals of control and perceived value in one model.



## 1.5 Assessing mathematics state anxiety

To assess  $MA_{state}$ , research has mostly focused on qualitative research (see Goldin, 2014, for an overview). These approaches included retrospective interviews and videotaping, but the reliability of these methods has been questioned (Goldin, 2014). Using a more quantitative approach, Goetz et al. (2013) proposed short self-reports that could be used both for measuring anxiety during tests as well as during classes. The advantage of self-reports is that they can be used conveniently for experience-sampling and might be more reliable than observations. However, self-reports about achievement emotions might disrupt the current activity (Goldin, 2014). Moreover, it is questionable if self-reports can reflect an accurate evaluation of current emotions. In general, self-reports can only cover aspects of emotions that a person is aware of, depend on the use of language, and are subject to systematic biases, e.g. social desirability (Pekrun & Bühner, 2014).

Consequently, other researchers have attempted to use physiological measures to directly investigate MA in performance situations (Dowker et al., 2016; Hannula, 2016), predominantly using neuropsychological methods (e.g., Lyons & Beilock, 2012; Pletzer, Kronbichler, Nuerk, & Kerschbaum, 2015). These studies revealed that MA activates brain areas linked to fear processing, disgust and pain processing, but they did not distinguish between  $MA_{trait}$  and  $MA_{state}$  (Artemenko, Daroczy, Nuerk, 2015; Suárez-Pellicioni et al., 2016).

State anxiety in general is associated with arousal and stress and with physiological reactions due to the activation of the autonomic nervous system. This leads to an increased heart rate and respiration, among other physiological reactions (Steimer, 2002; Wiedemann, 2015). This also holds for state anxiety in the context of education (Zeidner, 2014). Therefore, these specific physiological reactions can be assumed to be an indicator for  $MA_{state}$ . Some studies have assessed heart rate or cortisol secretion to monitor stress levels during mathematical tests (Dew, Galassi, & Galassi, 1984; Faust 1992, as cited in Ashcraft, 2002; Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011; Pletzer, Wood, Moeller, Nuerk, & Kerschbaum, 2010; Sarkar, Dowker, & Cohen Kadosh, 2014). These studies produced mixed results. Mattarella-Micke et al. (2011) showed that cortisol secretion can be associated with high performance (for low MA students) or with low performance (for high MA students), probably associated with a working memory overload. In contrast, Pletzer et al. (2010) did not find a correlation between cortisol secretion and reports of MA, but used self-reports of  $MA_{trait}$ , not  $MA_{state}$ . A relation between heart rate and state anxiety has been shown in various fields (e.g. Kantor, Endler, Heslegrave, & Kocovski, 2001), but has rarely been used in mathematics. Faust (as cited in Ashcraft, 2002) reported changes in heart rate when a highly math-anxious group performed mathematics tests of increasing difficulty. In contrast, Dew, Galassi, and Galassi (1984) found no substantial relation between heart rate and  $MA_{trait}$  or  $MA_{state}$ .

In addition to heart rate, Dew, Galassi, and Galassi (1984) observed physiological arousal during a timed mathematics test assessing participants' EDA. EDA are fluctuations in skin conductance due to an increase in sweat gland activity. Since sweat gland activity is associated with the autonomic nervous system activity, EDA is an established method to assess physiological reactions to arousal, concerns, or stress (Boucsein, 2012; Naveteur & Freixa i Baqué, 1987; Nikula, 1991). In his overview of the method, Boucsein (2012) extensively reviewed applications and correlates of various measures of EDA. He concludes that EDA "can be regarded as a valid indicator for the strength of – mostly negative – emotions, for observing the course of psychological stress, and for objectively determining coping efficacy" (p. 521). Therefore, EDA can indicate state anxiety by detecting associated physiological reactions (Boucsein, 2012).

EDA has recently been used to observe emotions during educational processes like self-regulated and multimedia learning (Dindar et al., 2019; Mudrick, Taub, Azevedo, Price, & Lester, 2017) and reading (Meer, Breznitz, & Katzir, 2016). Dew et al. (1984) used various measures of EDA and different scales to assess  $MA_{trait}$  and  $MA_{state}$ , but found no relation between EDA and  $MA_{state}$ , and only a small relation between EDA and  $MA_{state}$  for one of their measures of EDA. As a possible explanation, they acknowledge that the challenge of comparing cognitively experienced anxiety and physiologically experienced anxiety might need a larger sample than their 31 students. Moreover, their study design did not include a baseline measure, which is generally advisable for data quality (Boucsein, 2012) and could indicate if EDA is indeed influenced by a mathematical test context. Thus, while their theoretical assumptions seem well-founded, the authors argue that their data was not sufficient for a meaningful interpretation (Dew et al., 1984).

In conclusion,  $MA_{state}$  has been assessed through qualitative methods, self-reports, and physiological measures. Physiological reactions are a vital aspect of anxiety in general and arguably of  $MA_{state}$  in particular,





but previous research has not provided clear results concerning the relation between self-reports and physiological measures of  $MA_{state}$ , or the relation between  $MA_{state}$  and  $MA_{trait}$  in general.

## 1.6 The present research

So far, we have discussed that the relation between  $MA_{state}$  and  $MA_{trait}$  is not yet fully understood. In performance situations,  $MA_{state}$  might be stronger related to processes influencing mathematical thinking, like a reduction of working memory capacity. Therefore, taking into account  $MA_{state}$  seems important when analyzing effects of MA, but it can be assessed in different ways. While self-reports of  $MA_{state}$  are easy to obtain, they might suffer from systematic biases. As an alternative, some studies used physiological measures of stress and arousal instead of self-reports to assess  $MA_{state}$  in mathematical performance situations. Yet, these studies did either not address both  $MA_{state}$  and  $MA_{trait}$  or, in the case of Dew et al. (1984), did not show clear results. Moreover, no study did yet include appraisals of control or value to describe the relation between  $MA_{state}$  and  $MA_{trait}$  in accordance with the control-value theory. We consider this a considerable gap in research on MA. We assume that the approach by Dew and colleagues (1984) to use EDA as an indicator for  $MA_{state}$  is more promising today, because the possibilities to record and analyze EDA have greatly improved. Particularly, the innovations in EDA recording offer better possibilities in observing the association between EDA and  $MA_{trait}$ , since they allow to assess  $MA_{state}$  more reliable and in an authentic environment. At the same time, using the control-value theory offers a better theoretical framework for the correlation between  $MA_{state}$  and individual antecedents. It has been supported by a number of studies using self-reports and other methods to assess state anxiety, but to our knowledge, the control-value theory has not yet been utilized to analyze precursors of EDA.

## 1.7 Hypotheses

In the present study, we investigated the relation of  $MA_{trait}$  with two indicators for  $MA_{state}$ , the physiological measure EDA and self-reported state anxiety. We assessed  $MA_{state}$  both in a baseline context (a relaxation exercise) and a mathematics test. First, we assumed that the mathematics test would lead to an increase in both measures (hypothesis 1) and thus indicate that anxiety is successfully induced by the mathematics test. Second, we assumed that there is a relation between self-reported  $MA_{state}$  and EDA (hypothesis 2). Moreover, we anticipated that our findings would replicate the direct association between self-reported  $MA_{state}$  and  $MA_{trait}$  (Goetz et al., 2013; hypothesis 3a). We expected to find a similar relation between EDA and  $MA_{trait}$ , since EDA should reveal physiological arousal, which in turn is an indicator of  $MA_{state}$  (hypothesis 3b). According to the control-value theory, appraisals of control and subjective value were included as predictors. We expected that this would confirm the relation between these appraisals and both measures of  $MA_{state}$  (hypotheses 4a and 4b). Finally, the relation between  $MA_{state}$  and  $MA_{trait}$  should be higher when students report low control and high perceived value. Thus, we expected a negative three-way interaction between  $MA_{trait}$ , appraisals of control, and perceived value, on both measures of  $MA_{state}$ , respectively (hypotheses 5a and b).

## 2. Method

### 2.1 Sample and procedure

95 undergraduate students participated in the study. They gave written informed consent before participation. The study was conducted according to the *Ethical Principles of Psychologists and Code of Conduct* of the *American Psychological Association* from 2017. An ethics approval was not required by institutional guidelines or national regulations, in line with the guidelines of the *German Research Foundation*. Due to technical difficulties, 5 participants had to be excluded from the sample. Additionally, we excluded 4 students because of deviations of more than 3 *SD* in one of the assessed measures. The remaining participants were 86 undergraduate students (53 female) from programs other than mathematics, ranging from engineering



to nutritional science. Mathematics students were not recruited as participants to avoid a bias in their beliefs and attitudes towards mathematics, as well as in their mathematical skills. The mean age was 23.2 years ( $SD = 4.07$ ). Participants were recruited on campus and were paid 15 EUR for participation. During recruitment and before the experiment any indication of a mathematical content of the study was avoided. The study was described as a study investigating EDA during various tasks.

The individual sessions of the experiment took place in an office at the university containing only two tables, two chairs, and a closed closet. At the beginning of the experiment, the experimenter made participants familiar with the wristband assessing EDA. She then put the device on the wrist of the participant's non-dominant hand and fitted it comfortably. After recording had started, participants were presented a 5-minute relaxation exercise via headphones. The exercise facilitated relaxation through breathing exercises, accompanied by an audio track that included sounds from nature to help promote a relaxing environment for the participant.

When the participant removed the headphones after the exercise, the experimenter immediately presented the first questionnaire assessing state-anxiety. After the participant finished the questionnaire, a first mathematical test was presented. The participant was asked to read the instruction carefully and then wait for the signal to start. All participants had 10 minutes to solve the test and received a short notice after 8 minutes. After the test, the participant answered the second state-questionnaire. The procedure was repeated for a second mathematics test. At the end of the experiment, trait and demographic data were assessed.

## 2.2 Mathematics tests

Both mathematics tests consisted of six items. Eleven items were taken from a pool of released items from the PISA-Study (OECD, 2013a); one item was adopted from the *Trends in International Mathematics and Science Study* (TIMSS, International Association for the Evaluation of Educational Achievement [IEA], 2013). Since research suggests that anxiety might have a larger influence for cognitively demanding tasks (Ching, 2017; Faust, Ashcraft, & Fleck, 1996), we composed both tests to be fairly difficult. The overall solution rate of 42% ( $SD = 21\%$ ) suggests that the tests were appropriately demanding.

The items covered a broad range of mathematical problems, ranging from geometry to statistics. They were based on the concept of mathematical literacy and therefore covered mathematical competencies beyond mere factual knowledge. The tasks required knowledge that all students should have achieved by the end of their compulsory education. For an overall achievement score, we coded each item according to the coding instructions from PISA and TIMSS (0 = incorrect, 0.5 = partially correct, 1 = correct; OECD, 2013a; IEA, 2013) and calculated a sum score for all 12 items.

## 2.3 Study measures

We assessed  $MA_{\text{trait}}$  using the ANXMAT-Scale developed for the PISA-studies (five items, e.g. "I feel helpless when doing a mathematics problem",  $\alpha = .87$ ; OECD, 2005). Participants answered on a 4-point Likert scale from 1, *strongly disagree* to 4, *strongly agree*. We assessed self-reported  $MA_{\text{state}}$  twice during the experiment according to Goetz et al., 2013, asking if participants felt anxious in the previous situation (1, *definitely not* to 4, *definitely*). Appraisals of control and perceived values were assessed after both tests and were task-specific. For appraisals of control, we used two items accounting for the *controllability* and *probability* of outcomes (e.g. "I think my competence in this area is ...",  $\alpha = .78$ ) on a 7-point Likert-scale (1, *low* to 9, *high*; Engeser & Rheinberg, 2008; Pekrun & Perry, 2014). Appraisals of perceived value were assessed with the four-item *cognitive preferences*-scale by Kehr, Von Rosenstiel, and Bles (1997) on a 7-point Likert-scale (e.g. "It is important to me to solve the exercises"; 1, *not at all* to 9, *very much*;  $\alpha = .85$ ).

For EDA data collection during the relaxation exercise and the tests, we used an *Empatica E4 wristband*. The wristband is worn like a watch and measures skin conductance with two stainless steel electrodes at the inner wrist. The exosomatic non-invasive sensor applies a very small, non-perceptible alternating current with a peak value of 100  $\mu\text{A}$  at 1V with an 8Hz frequency. The 4 Hz signal is recorded on an integrated flash memory.



## 2.4 EDA data analyses

EDA signals consist of two components. The *tonic* signal is influenced by medium-term factors like room temperature or physiological characteristics of the individual. It provides a level of skin conductance that is rather stable within some seconds. Even though the tonic signal can be an indicator for stress or anxiety, the *phasic* component of the signal is suited better to compare EDA between individuals and is commonly used as an indicator for state anxiety (Boucsein, 2012). Phasic components of the EDA signal are usually called *responses*, since they reflect a short peak in the signal. Responses can be *specific* responses to a stimulation, for example a bursting balloon. However, there are phasic responses that are not associated to any specific external stimulation, hence *nonspecific*. The frequency of these nonspecific responses in skin conductance is associated with stress and anxiety and is one of the most common measures for EDA (Boucsein, 2012). The phasic and the tonic components of an EDA signal overlap and need to be decomposed for analyses.

Data processing was carried out using MATLAB (V9.2.0) and the MATLAB-based software Ledalab (V3.4.9). The software applies *Continuous Decomposition Analysis* to extract the phasic signal (Benedek & Kaernbach, 2010). After the extraction, any peak in the phasic signal bigger than  $.01 \mu\text{S}$  is counted as a response (Boucsein, 2012). For both phases of the experiment (relaxation and test), the number of events is then summed up and divided by the duration of the phase in minutes. The result is the frequency of nonspecific skin conductance responses per minute (SCR.freq). SCR.freq served as the measure for physiological  $\text{MA}_{\text{state}}$ .

## 2.5 Analyses

For hypothesis 1, we conducted a repeated measures ANOVA to test for differences in state anxiety during the relaxation and the test. To assess the relation between the two measures of  $\text{MA}_{\text{state}}$  and their relation to  $\text{MA}_{\text{trait}}$  (hypothesis 2 and 3), we calculated the correlations controlling for gender, achievement, and the respective baseline measures (see Sect. 3.1). For hypotheses 4 and 5, we adopted a 5-step hierarchical multiple regression model for both measures of  $\text{MA}_{\text{state}}$  as outcome variables (self-reported and physiological  $\text{MA}_{\text{state}}$ ). All predictors except gender were z-standardized before the analyses. In step 1, we included the control variables as predictors. In step 2, we additionally included  $\text{MA}_{\text{trait}}$ . In accordance with the control-value theory, step 3 included appraisals of control and subjective value. In step 4, we included the interaction term between control and subjective value. Finally, step 5 included the interaction terms between  $\text{MA}_{\text{trait}}$  and appraisals of control and subjective value, respectively. Additionally, we included the three-way interaction between  $\text{MA}_{\text{trait}}$ , control, and subjective value.

## 3. Results

### 3.1 Control variables

Gender differences exist between self-reports of MA (Dowker et al., 2016). Moreover, because of physiological differences in the sweat gland density and activity, women tend to display a weaker EDA reactivity than men (Boucsein, 2012). Accordingly, our results revealed significant gender differences, with females showing weaker EDA,  $t(84) = 2.93, p = .004$ , reporting higher  $\text{MA}_{\text{trait}}$ ,  $t(84) = -2.38, p = .020$ , and lower control,  $t(84) = 2.37, p = .020$ . No significant gender differences were found regarding self-reports of  $\text{MA}_{\text{state}}$ ,  $t(84) = -0.49, p = .626$ , and perceived value  $t(84) = 0.02, p = .984$ . Because of this general influence of gender, we included gender as a control variable in all following analyses.

In addition, achievement is associated both with trait anxiety (Ma, 1999) and with physiological reaction (Mattarella-Micke et al., 2011). In our data, we similarly found a significant relation between the test score and reports of  $\text{MA}_{\text{trait}}$ ,  $r(86) = -.28, p = .008$ , self-reports of  $\text{MA}_{\text{state}}$ ,  $r(86) = -.31, p = .004$ , and control,



$r(86) = .51, p = .000$ , respectively, but no significant relation between the test score and EDA,  $r(86) = .15, p = .177$ , and perceived value,  $r(86) = .07, p = .518$ , respectively. Since our analyses focused on the interplay of  $MA_{\text{trait}}$  and  $MA_{\text{state}}$ , irrespective of achievement, we also controlled for the test score in the following analyses. For both measures of  $MA_{\text{state}}$  (self-reports and EDA), we used the data from the relaxation exercise as respective baseline measures.

### 3.2 Main analyses

#### 3.2.1 Descriptive results

Table 1 provides the means and standard deviations for  $MA_{\text{trait}}$  and appraisals of control and perceived value. Additionally, mean scores and standard deviations for both measures of  $MA_{\text{state}}$  during the relaxation exercise and the test are included. For both measures,  $MA_{\text{state}}$  was significantly higher during the test compared to the relaxation exercise, confirming hypothesis 1. While physiological  $MA_{\text{state}}$  increased from 15.43 events per minute to 20.04 events per minute ( $F(85) = 10.53, p = .002, \eta^2 = .10$ ), self-reported anxiety increased from 1.37 to 1.62 ( $F(85) = 17.23, p < .001, \eta^2 = .17$ ).

Table 1

*Descriptive statistics and differences between  $MA_{\text{state}}$  in relaxation exercise and tests*

Measure	<i>M</i>	<i>SD</i>	<i>F</i>	<i>part. <math>\eta^2</math></i>
<b>Predictors</b>				
$MA_{\text{trait}}$	2.23	0.80		
Control	5.08	1.57		
Value	5.21	1.05		
<b>Self-reported <math>MA_{\text{state}}</math></b>				
Relaxation	1.37	0.57	$F(85) = 10.53^{**}$	.10
Test	1.62	0.69		
<b>Physiological <math>MA_{\text{state}}</math></b>				
Relaxation	15.43	12.70	$F(85) = 17.23^{***}$	.17
Test	20.04	15.65		

*Note.* The unit for physiological state Mathematics Anxiety is SCR.freq [1/min].

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

#### 3.2.2 Correlations

Table 2 provides correlations between all measures. All correlations were controlled for gender and test score and for the respective  $MA_{\text{state}}$  baseline during the relaxation exercise. Contrary to hypothesis 2, no significant correlation was observed between the two measures of  $MA_{\text{state}}$  ( $r = .06, p = .63$ ).  $MA_{\text{trait}}$  showed a moderate and significant correlation with self-reported  $MA_{\text{state}}$  ( $r = .34, p = .002$ ), but not with physiological  $MA_{\text{state}}$  ( $r = .08, p = .48$ ), which supports hypothesis 3a, but not 3b.

Including appraisals of control and perceived values,  $MA_{\text{trait}}$  correlated moderately and significantly with control and value ( $r = -.38, p < .001; r = .24, p = .029$ ). A significant, moderate correlation emerged between appraisals of control and self-reported  $MA_{\text{state}}$  ( $r = -.29, p = .008$ ), but not physiological  $MA_{\text{state}}$  ( $r = -.05, p = .65$ ). In contrast, appraisals of the perceived value were significantly related to physiological  $MA_{\text{state}}$  ( $r = .29, p = .007$ ), but not to self-reported  $MA_{\text{state}}$  ( $r = .16, p = .15$ ). Appraisals of control and perceived value showed no significant relation ( $r = -.01, p = .95$ ).





Table 2

*Correlations between measures of anxiety and appraisals of control and perceived value*

Measure	1.	2.	3.	4.	5.
1. Self-reported MA <sub>state</sub>					
2. Physiological MA <sub>state</sub>	.06				
3. MA <sub>trait</sub>	.34**	.08			
4. Control	-.29**	-.05	-.38***		
5. Value	.16	.29**	.24*	-.01	

*Note.* Correlations of the two measures of state Mathematics Anxiety are controlled for their respective baseline. All correlations are controlled for gender and test score.  $n = 86$ .

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

### 3.2.3 Hierarchical multiple regression

Results of the hierarchical multiple regressions are reported in Table 3. It displays only the predictors added in each step. For the full hierarchical models, see Appendix A.1. For the two regressions, we used the two measures of MA<sub>state</sub> as outcome measures respectively. Inclusion of the control variables explained 58% of the variance in physiological MA<sub>state</sub> during the test ( $p < .001$ ), and 24% of the variance in self-reported MA<sub>state</sub> ( $p < .001$ ).

For self-reported MA<sub>state</sub>, step 2 revealed a significant relation between MA<sub>trait</sub> and self-reported MA<sub>state</sub> ( $\beta = 0.32$ ,  $p = .002$ ) that explained additional 9% of the variance in self-reported MA<sub>state</sub> ( $p = .002$ ). Step 3 did not confirm a relation between appraisals of control or perceived value and self-reported MA<sub>state</sub> ( $\beta = -0.20$ ,  $p = .090$ ;  $\beta = 0.09$ ,  $p = .37$ ). Step 4 did not reveal an interaction effect of control  $\times$  value ( $\beta = -0.00$ ,  $p = .98$ ), and step 5 revealed no three-way interaction effect of MA<sub>trait</sub>  $\times$  control  $\times$  value ( $\beta = -0.15$ ,  $p = .20$ ). Similarly, the interaction effects MA<sub>trait</sub>  $\times$  control and MA  $\times$  value were not significant ( $\beta = -0.06$ ,  $p = .59$ ;  $\beta = -0.23$ ,  $p = .053$ ). These findings do not support hypothesis 4a or 5a. Overall, the predictors explained 39% of the variance in self-reported MA<sub>state</sub> ( $p < .001$ ).

We conducted the same hierarchical multiple regression for physiological MA<sub>state</sub>. Contrary to self-reported MA<sub>state</sub>, step 2 did not reveal a significant relation with MA<sub>trait</sub> ( $\beta = 0.06$ ,  $p = .48$ ). In step 3, adding appraisals of control and perceived value increased the  $R^2$  significantly by 4% ( $p = .033$ ). In this step, perceived value had a significant positive relation with physiological MA<sub>state</sub> ( $\beta = 0.19$ ,  $p = .009$ ), while no relation was found for control ( $\beta = -0.04$ ,  $p = .65$ ). Again, step 4 did not reveal an interaction of the control and value on MA<sub>state</sub> ( $\beta = 0.04$ ,  $p = .65$ ). Contrary to self-reported MA<sub>state</sub>, step 5 revealed a negative three-way interaction effect of MA<sub>trait</sub>  $\times$  control  $\times$  value ( $\beta = -0.23$ ,  $p = .008$ ), while the interaction effects MA<sub>trait</sub>  $\times$  control and MA<sub>trait</sub>  $\times$  value were not significant ( $\beta = -0.06$ ,  $p = .44$ ;  $\beta = -0.01$ ,  $p = .96$ ). These effects explained an additional 4% of the variance in physiological MA<sub>state</sub> ( $p = .041$ ). The three-way interaction effect is displayed in Figure 1 (right). For comparison, Figure 1 (left) displays the non-significant interaction for self-reported MA<sub>state</sub>. Because there was no significant direct relation between MA<sub>trait</sub> and physiological MA<sub>state</sub>, the slopes are less steep in Figure 1 (right) than for self-reported MA<sub>state</sub>. However, it illustrates that the slope of MA<sub>trait</sub> on physiological MA<sub>state</sub> increases for students appraising low control and high perceived value at the same time. These results support hypothesis 5b, but not hypothesis 4b. Overall, the predictors explained 66% of the variance in physiological MA<sub>state</sub> ( $p < .001$ ).



Table 3

*Hierarchical multiple regression analyses for physiological MA<sub>state</sub> and self-reported MA<sub>state</sub>*

Added Predictor	MA <sub>state</sub> measure			
	Self-reported MA <sub>state</sub>		Physiological MA <sub>state</sub>	
	$\Delta R^2$	$\beta$	$\Delta R^2$	$\beta$
Step 1	.24***		.58***	
Control variables <sup>a</sup>				
Step 2	.09**		.00	
MA <sub>trait</sub>		0.32**		0.06
Step 3	.03		.04*	
Control		-0.20		-0.04
Value		0.09		0.19**
Step 4	.00		.00	
Control × Value		-0.00		0.04
Step 5	.04		.04*	
MA <sub>trait</sub> × Control		-0.06		-0.06
MA <sub>trait</sub> × Value		-0.23		-0.01
MA <sub>trait</sub> × (Control × Value)		-0.15		-0.23**
Total R <sup>2</sup>	.39***		.66***	
n	86		86	

<sup>a</sup>Control variables included respective baseline state Mathematics Anxiety, gender, and test score.

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

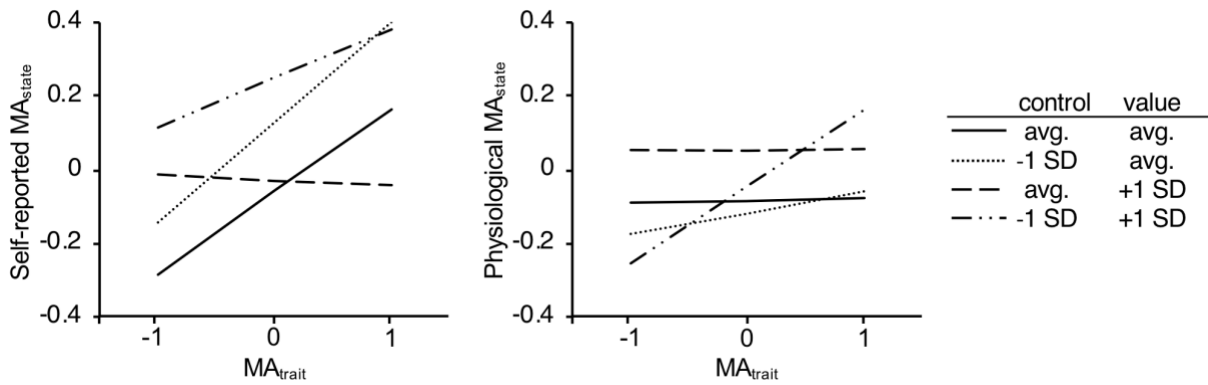


Figure 1. Relation between MA<sub>trait</sub> and MA<sub>state</sub> in dependence of control and perceived value.

## 4. Discussion

### 4.1 Measures of state anxiety in mathematics tests

In line with hypothesis 1, we found significant differences between the relaxation exercise and the test for both measures of MA<sub>state</sub>. This implies that the mathematics test induced anxiety compared to the relaxation exercise. However, descriptive analyses showed that self-reports of MA<sub>state</sub> were relatively low in our study.



This might be due to the fact that the experiment was a low-stakes test for the participants. We would assume that our result might emerge even stronger in a high-stakes test situation.

In contrast to our hypothesis, students' self-reports about  $MA_{state}$  and their physiological  $MA_{state}$  were not significantly related. Our assumption had been that even though self-reports and physiological measures might differ to some extent, they should still refer to a similar  $MA_{state}$  and hence be related. Judging from our results, the two measures might refer to conceptually different aspects of  $MA_{state}$ . Some researchers suggest that  $MA_{trait}$  is a multidimensional construct, usually differentiating between a cognitive and an affective dimension (Lukowski et al., 2016; Wigfield & Meece, 1988). Similarly, physiological  $MA_{state}$  and self-reported  $MA_{state}$  as assessed in this study might refer to different facets of  $MA_{state}$ . Consequently, they might not necessarily be related. For example, EDA might be more associated with arousal and an affective, emotional dimension of  $MA_{state}$ . In contrast, self-reports might be more related to a cognitive dimension of  $MA_{state}$  that is associated with worries and cognitive resources (Ashcraft & Moore, 2009; Beilock, 2008; Liebert & Morris, 1967). Future research could include a multi-dimensional assessment of MA to address this possibility. Additionally, the measures might differ because of their differing mode of assessment (Pekrun & Böhner, 2014). Self-reports might not be able to paint an adequate picture of achievement emotions, especially for a highly physiological emotion like anxiety (Pekrun & Böhner, 2014). Furthermore, self-reports of  $MA_{state}$  might be subject to biases like social desirability (Pekrun & Böhner, 2014) or stereotypes (Goetz et al., 2013).

#### 4.2 The relation between $MA_{state}$ and $MA_{trait}$

In line with Goetz et al. (2013), we found a significant relation between  $MA_{trait}$  and self-reported  $MA_{state}$  which was within the range of previous findings reported by Hembree (1990). Students with higher  $MA_{trait}$  also reported higher  $MA_{state}$  during a mathematical test. However, we did not find a relation between  $MA_{trait}$  and physiological  $MA_{state}$ . This finding is contrary to hypothesis 3b but is in line with previous findings by Dew et al. (1984). Dew et al. (1984) proposed two explanations. First, the results might be viewed as questioning the construct validity of  $MA_{trait}$  scales. Since these scales have been further validated since then and worked as expected with regard to self-reported  $MA_{state}$ , this explanation seems unlikely. Alternatively, since students reporting  $MA_{state}$  need to evaluate their perceived anxiety cognitively, it is assumed that they might in part refer to generalized beliefs about mathematics. This might include the same resources as their evaluation of  $MA_{trait}$  (Bieg, Goetz, & Lipnevich, 2014; Goetz et al., 2013), or students might even refer directly to their  $MA_{trait}$  when trying to evaluate  $MA_{state}$ . This would increase the relation between self-reported  $MA_{state}$  and  $MA_{trait}$ , but not between physiological  $MA_{state}$  and  $MA_{trait}$ .

#### 4.3 The control-value theory

According to the control-value theory (Pekrun, 2006),  $MA_{state}$  should primarily be determined by appraisals of control and perceived value. These appraisals should also moderate the relation between  $MA_{trait}$  and  $MA_{state}$ . For the two measures of  $MA_{state}$ , the application of the control-value theory in the present study produced diverging results.

Both  $MA_{trait}$  and self-reported  $MA_{state}$  were related to appraisals of control. Nevertheless, the hierarchical multiple regression did not produce signs that appraisals of control or value play an important role for the relation between  $MA_{trait}$  and self-reported  $MA_{state}$ . Rather, this relation seemed to be direct. Hence, we did not find support for the control-value theory for self-reported  $MA_{state}$ . As was proposed above, the relation between  $MA_{trait}$  and self-reported  $MA_{state}$  might be increased by the similar mode of assessment. The resulting direct relation could overweight a possible indirect effect of appraisals of control and perceived value.

In contrast, physiological  $MA_{state}$  showed a different pattern. In opposition to self-reported  $MA_{state}$ , we did not find a direct correlation with  $MA_{trait}$ . However, we found strong support for the control-value theory in this second multiple regression analysis. First, perceived value was related to  $MA_{state}$ , independent of  $MA_{trait}$ . Second, including appraisals of control and perceived value explained additional 8% of variance of physiological  $MA_{state}$ , which indicates a substantial contribution to its emergence. Third, the interplay between  $MA_{trait}$ , control, and value also was observed as expected. As illustrated in Figure 1 (right), high  $MA_{trait}$  was related to high  $MA_{state}$ , but only when students appraised their control low and their perceived value high. This effect is in line with the control-value theory, since  $MA_{trait}$  is considered a distal antecedent, whereas appraisals



of control and perceived value are considered proximal causes of  $MA_{state}$ . These results further support the notion that the causal relation between  $MA_{trait}$  and the two measures of  $MA_{state}$  might be conceptually different.

#### 4.4 Limitations

Using EDA comes with some immanent limitations, and only some of them can be overcome. For example, EDA is subject to physiological gender differences. This inhibits its practicality for inquiring the gender gap in MA. Even when controlling for a baseline value, differences in reactivity exist. In general, a large variance between students' EDA makes comparisons more difficult. In our study, we assessed the baseline value during a relatively short period of time. A more reliable value could be obtained through several hours or days of baseline recordings (Boucsein, 2012). Of course, such a study requires much more time. Lastly, even though MA is common in students of all ages, our specific sample cannot be overgeneralized. It needs to be verified if EDA recording can be useful in schools and for specific groups of students, for example high-anxiety students or younger students.

More generally, our test did not seem to induce a very strong emotional reaction. In order to generalize our findings to high-stakes testing which might cause more  $MA_{state}$ , additional studies are needed. Moreover, we followed Goetz et al. (2013) in using a single-item scale to assess self-reported  $MA_{state}$ . This keeps the disruption of the participants at a minimum but might result in some inaccuracies. Our results indicate that the scale was working properly, but future studies might try to assess  $MA_{state}$  at more occasions or check if the one-item scale is appropriately precise. Similarly, a number of different questionnaires exist to assess MA and general test anxiety. Comparing these questionnaires regarding their relation to EDA, particularly regarding cognitive and affective dimensions of these scales, could help to explain the absent relation between self-reported and physiological  $MA_{state}$ .

The relation between EDA and physiological arousal has been well established by previous research (Boucsein, 2012). However, other factors than  $MA_{state}$  might additionally influence EDA during mathematics tests. Future research could incorporate additional state measures that assess cognitive load or situational motivation to further narrow down the processes associated with EDA reactivity, and might support these findings through qualitative data like interviews or think-aloud-protocols. Until the validity of EDA as a measure of physiological  $MA_{state}$  is fully understood, results will always require a cautious discussion of limitations and different explanations.

The control-value theory is generalizable to various achievement emotions, including both trait and state emotions (Pekrun, 2006). In the current cross-sectional study, we focused on  $MA_{state}$  as an outcome, and task-specific appraisals of control and perceived value as moderators. Consequently, we considered  $MA_{trait}$  as a distal predictor. However, future studies could also consider  $MA_{trait}$  as an outcome itself. For analyzing effects of general appraisals of control and perceived value towards mathematics as predictors of  $MA_{trait}$ , longitudinal designs would be more advantageous.

#### 4.5 Conclusion

Our study combined several innovative approaches that have emerged in research on MA within the last years. With the distinction between  $MA_{trait}$  and  $MA_{state}$ , we differentiated between two different facets of MA. Further, through the adoption of the control-value theory, we compared EDA recordings and common self-reports as a tool for observing  $MA_{state}$  and investigated their unique relations to  $MA_{trait}$ . Overall, we found that EDA was related to  $MA_{trait}$ , but that this relation only got visible when taking appraisals of control and perceived value into account. Students reporting high  $MA_{trait}$  were not necessarily more physiologically anxious during mathematical activities. Rather, a pattern of appraisals of low control and high perceived value accompanied that relation. Hence, with regard to EDA, our results were in line with the control-value theory, which on the other hand was not supported by self-reported measures of  $MA_{state}$ . In sum, our findings match the plea by Goetz et al. (2013) to consequently distinguish between  $MA_{trait}$  and  $MA_{state}$  in research on MA, as well as to additionally include physiological data in assessing emotions in learning.






Furthermore, our results indicate that self-reports and physiological measures might refer to different aspects of  $MA_{state}$ . Thus, our results support theoretical considerations and empirical findings that self-reports of  $MA_{state}$  should be interpreted cautiously. Ultimately, we cannot decide if self-reports or EDA captured actual  $MA_{state}$ . Rather, the two measures both seem to be related to  $MA_{trait}$ , but in different ways. Therefore, we cannot conclude that EDA can make self-reports obsolete, but we propose that the assessment of EDA can provide additional information about underlying affective aspects of  $MA_{state}$ . Because of recent technical advances in recording and analyses of EDA, the method seems to offer a convenient addition to the common practice of self-reports. Furthermore, the advances in EDA-recording offer the possibility to conduct studies in the classroom during regular classes with hardly any disruption. We believe that our study can be a first step into this promising direction of *in vivo* research on MA.

As a next step, the relation to mathematical achievement should be investigated. In the recent study, we used a mathematics test, the goal of which was to trigger MA, but that was not designed to diagnose mathematical achievement in detail. Our preliminary results indicate that achievement might be differently associated with self-reported and physiological  $MA_{state}$ , but a study that assesses mathematical performance in more detail is needed to shed light on this question. Additionally, achievement under conditions of  $MA_{state}$  and no  $MA_{state}$  should be compared in a within-subject design, since EDA shows a notable variance between subjects. Similarly, using tests that are not mathematical could help to distinguish how specific  $MA_{state}$  is linked to mathematics. At the same time, using EDA for other domains or test anxiety in general, possibly using the control-value theory, might be an interesting and fruitful perspective for future research. Lastly, the relation to working memory capacity, which has proven to be a key factor in the effects of MA, should be taken into account. Ultimately, this knowledge could be used to design longitudinal and intervention studies that use EDA to observe the role of  $MA_{state}$  for learning processes or create ways to decrease  $MA_{state}$  in mathematics tests, possibly without necessarily tackling  $MA_{trait}$ .

With a number of questions remaining unanswered, our study is merely a first step in including EDA as an indicator for  $MA_{state}$ . Nevertheless, the results illustrate that self-reports only comprise one perspective on the multi-faceted phenomenon of Mathematics Anxiety, and that including EDA can be uniquely insightful.

## Keypoints

-  We did not find a correlation between EDA and measures of state anxiety or trait Mathematics Anxiety, respectively.
-  Self-reported state anxiety correlated significantly with trait anxiety independent of appraisals of control and perceived value, which is in contrast to the control-value theory.
-  In line with the control-value theory, trait Mathematics Anxiety predicted physiological state anxiety when high perceived value and low control of the achievement situation were reported.

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**Table A.1**  
*Full hierarchical multiple regression analyses for physiological MA<sub>state</sub> and self-reported MA<sub>state</sub>*

Predictor	MA <sub>state</sub> measure									
	Self-reported MA <sub>state</sub>					Physiological MA <sub>state</sub>				
	$\Delta R^2$	<i>B</i>	<i>SE</i>	$\beta$	<i>Sig.</i>	$\Delta R^2$	<i>B</i>	<i>SE</i>	$\beta$	<i>Sig.</i>
Step 1	.24				<b>.000</b>	.58				<b>.000</b>
Intercept		1.58	0.09		<b>.000</b>		19.08	1.46		<b>.000</b>
Baseline		0.26	0.07	0.38	<b>.000</b>		11.43	1.19	0.73	<b>.000</b>
Gender		0.10	0.14	0.07	.417		2.50	2.44	0.08	.309
Test Score		-0.22	0.07	-0.32	<b>.002</b>		0.10	1.15	0.01	.934
Step 2	.09				<b>.002</b>	.00				.480
Intercept		1.55	0.08		<b>.000</b>		18.90	1.49		<b>.000</b>
Baseline		0.26	0.06	0.37	<b>.000</b>		11.23	1.23	0.72	<b>.000</b>
Gender		0.19	0.14	0.14	.161		2.99	2.54	0.09	.244
Test Score		-0.16	0.07	-0.24	<b>.016</b>		0.38	1.21	0.02	.780
MA <sub>trait</sub>		0.22	0.07	0.32	<b>.002</b>		0.88	1.24	0.06	.480
Step 3	.03				.178	.04				<b>.033</b>
Intercept		1.54	0.08		<b>.000</b>		18.92	1.45		<b>.000</b>
Baseline		0.26	0.06	0.37	<b>.000</b>		11.14	1.19	0.71	<b>.000</b>
Gender		0.21	0.14	0.15	.119		2.91	2.48	0.09	.245
Test Score		-0.12	0.07	-0.17	.113		0.20	1.29	0.01	.881
MA <sub>trait</sub>		0.16	0.07	0.23	<b>.036</b>		-0.09	1.33	-0.01	.946
Control		-0.14	0.08	-0.20	.090		-0.64	1.40	-0.04	.648
Value		0.06	0.07	0.09	.365		3.02	1.14	0.19	<b>.009</b>
Step 4	.00				.975	.00				.649
Intercept		1.54	0.08		<b>.000</b>		18.86	1.46		<b>.000</b>
Baseline		0.26	0.07	0.37	<b>.000</b>		11.11	1.20	0.71	<b>.000</b>
Gender		0.21	0.14	0.12	.125		3.04	2.51	0.10	.230
Test Score		-0.12	0.07	-0.17	.122		0.11	1.32	0.01	.937
MA <sub>trait</sub>		0.16	0.08	0.23	<b>.038</b>		-0.11	1.34	-0.01	.934
Control		-0.14	0.08	-0.20	.096		-0.53	1.43	-0.03	.712
Value		0.06	0.07	0.09	.403		3.20	1.21	0.20	<b>.010</b>
Control × Value		-0.00	0.06	-0.00	.975		0.49	1.06	0.04	.649
Step 5	.04				.241	.04				<b>.041</b>
Intercept		1.58	0.09		<b>.000</b>		18.73	1.49		<b>.000</b>
Baseline		0.24	0.07	0.35	<b>.000</b>		11.21	1.18	0.72	<b>.000</b>
Gender		0.18	0.14	0.12	.210		2.76	2.46	0.09	.266
Test Score		-0.10	0.08	-0.14	.203		-0.41	1.30	-0.03	.756
MA <sub>trait</sub>		0.16	0.08	0.23	<b>.046</b>		0.10	1.33	0.01	.942
Control		-0.13	0.08	-0.19	.123		0.52	1.43	0.03	.087
Value		0.02	0.08	0.03	.762		2.16	1.25	0.14	.716
Control × Value		-0.06	0.07	-0.10	.413		1.05	1.21	0.08	.385
MA <sub>trait</sub> × Control		-0.03	0.06	-0.06	.586		-0.81	1.04	-0.06	.437
MA <sub>trait</sub> × Value		-0.17	0.08	-0.23	.053		-0.08	1.44	-0.01	.958
MA <sub>trait</sub> × (Control × Value)		-0.07	0.05	-0.15	.203		-2.44	0.90	-0.23	<b>.008</b>
Total R <sup>2</sup>	.39				<b>.000</b>		.66			<b>.000</b>
<i>n</i>	86						86			

*Note.* Variables *Baseline* and *Test Score* were z-standardized before the regression. *Gender* is coded 0 = female, 1 = male.