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Achievement Emotions Questionnaire-Mathematics (AEQ-M) in Adolescents: Factorial structure, measurement invariance and convergent validity with personality

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Abstract

The Achievement Emotions Questionnaire-Mathematics (AEQ-M) is a self-report measure of emotions experienced in class, when self-studying, and during tests for the domain of mathematics. Our aim was to present a Portuguese version of this instrument for use with adolescents and to test its reliability, factorial structure, measurement invariance, and construct validity with personality dimensions. Our sample comprised 1,387 Portuguese students from the 7th, 8th and 9th grades (mean age = 13.2 years). Student responses to the AEQ-M were found to be reliable. Confirmatory factor analysis validated a seven-emotion × three-setting factorial structure. This model demonstrated measurement invariance across gender and grade. As a demonstration of construct validity, the emotions measured by the AEQ-M showed a pattern of associations with psychobiological personality dimensions that were in line with theoretical predictions. These results validate the AEQ-M as a suitable instrument for assessing adolescents' mathematics-related achievement emotions and their associations with personality.

Keywords: achievement emotions; adolescents; mathematics; measurement invariance; validity; personality

Introduction

The emotions that the students experience related to achievement activities or achievement outcomes (*achievement emotions* according to control-value theory; Pekrun, 2006) are an important influence on academic experience. Such emotions directly influence the psychological processes involved with self-regulated learning and motivation, which in turn effect academic performance (Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017) and other long-term outcomes such as psychological health (Pekrun, 2017).

According to control-value theory, emotions are multifaceted psychological processes with affective, cognitive, motivational, and physiological components (Pekrun, 2006). These discrete multidimensional emotions can be classified within a three-dimensional taxonomy according to valence (positive vs. negative), degree of activation (activating vs. deactivating) and object focus (activity, outcome prospective, and outcome retrospective) (Pekrun & Stephens, 2010). Achievement emotions are typically domain-specific because they result from students' appraisals, which in turn are dependent on domain-specific expectancies, attributions, self-concepts, values and goals (Goetz, Frenzel, Pekrun, Hall, & Lüdtke, 2007).

Researchers have highlighted the importance of domain-specificity when assessing achievement emotions (Butz, Stupnisky, Pekrun, Jensen, & Harsell, 2016). One example is the Achievement Emotions Questionnaire-Mathematics (AEQ-M; Pekrun, Goetz, & Frenzel, 2005). This self-report instrument assesses seven mathematics-related achievement emotions (enjoyment, pride, anger, anxiety, shame, hopelessness, and boredom) that can occur in three different achievement settings (when attending class, self-studying, or taking tests). It is critical to consider these different settings because they differ in function and social structure and might, therefore, be

related to different achievement emotions (Pekrun et al., 2002). Domain-specific achievement emotions, which are typically experienced over the duration of a semester, lie on a continuum of temporal generality between emotional traits (habitual emotional experience) and emotional states (temporary emotional experience) (Pekrun et al., 2002). The AEQ-M subscales have good internal consistency (α = .75 - .93) and confirmatory methods have demonstrated that "the relationships between different achievement emotions can be best explained by taking into account both the differences between discrete emotions and the differences between emotions that occur in different achievement settings" (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011, p. 44.).

To facilitate cross-cultural research it is necessary to develop valid and culturally sensitive translated versions of instruments. This is particularly relevant for achievement emotions for which there are theoretical and empirical reasons to expect differences in the mean levels and specific content of emotions across cultures (Pekrun, 2006). The AEQ-M has been shown to be reliable for use with English-speaking university undergraduates (Pekrun et al., 2011; Pekrun et al., 2005) and German and Chinese 8th graders (Frenzel, Thrash, Pekrun, & Goetz, 2007; Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009; Frenzel, Pekrun, & Goetz, 2007). A Portuguese version of the AEQ-M already exists (Peixoto, Mata, Monteior, Sanches, & Pekrun, 2015), but we argue it would not allow for meaningful cross-cultural comparisons with the English, German or Chinese versions because it was designed to assess a specific population (pre-adolescents; 5th to 7th grades) using a reduced selection of items. More crucially, this scale omits emotions related to self-study, thus neglecting a critical component of the adolescent student experience.

Study Aims

We aimed to create a Portuguese translation of the 60-item AEQ-M (Pekrun, Goetz, & Perry, 2005) and to validate it in Portuguese adolescents. Overall, we hoped to demonstrate the Portuguese AEQ-M is a reliable measure of mathematics-related achievement emotions via the calculation of Cronbach's alpha (α) and omega total (ω_t). We also aimed to validate the factorial structure of this instrument by performing confirmatory factor analyses (CFA), and to contribute to AEQ-M psychometric research by testing for measurement invariance across gender using a multi-group CFA approach. Finally, we assessed the convergent validity of AEQ-M. An instrument has convergent validity when it shows theoretically consistent associations to a related construct. As part of his psychobiological model of personality, Cloninger defined temperament as "differences between individuals in their automatic responses to emotional stimuli" (1987, p. 2.). No study has tested the link between achievement emotions and Cloninger's temperament dimensions, although prior studies suggest a link between temperament and emotionality (Moreira, Cloninger, Rocha, Oliveira, Ferreira et al., 2017; Rothbart, 2007). Garcia (2011) showed that high harm avoidance (fearfulness, shyness) predicted low levels of positive affect while high persistence (determinedness, eagerness) predicted high levels of positive affect. High novelty seeking (impulsiveness, irritableness) and reward dependence (sentimentality, warmth) were not predictive of affect, and similar results have been found elsewhere (Nima, Archer, & Garcia, 2012). Soric, Penezic and Buric (2013) have also shown that the Big Five neuroticism dimension, which corresponds to high harm avoidance (De Fruyt, Van De Wiele, & Van Heeringen, 2000), predicted anger and anxiety achievement emotions. Harm avoidance itself has been directly linked to anxiety (Hofmann & Bitran, 2007; Miettunen & Raevuori, 2012). High novelty seeking has been associated with

aggression and is a characteristic of antisocial, passive-aggressive and explosive personality disorders (Cloninger, 1987).

Given this empirical evidence, we formed specific research hypotheses with which to test convergent validity. We anticipated that; (a) harm avoidance would be positively correlated with negative emotions, particularly anxiety, and negatively correlated with positive emotions, (b) persistence would be associated with positive emotions, and (c) high novelty seeking would be associated with anger. Because of the lack of clear evidence of association between emotionality and reward dependence, we did not form specific hypotheses, but continued to explore its associations.

Method

Participants

The sample comprised 1,387 adolescents (50.4% female) attending the 7th (n = 612, M_{age} = 12.5 years), 8th (n = 427, M_{age} = 13.4 years) and 9th (n = 348, M_{age} = 14.3 years) grades in 10 schools from the north of Portugal.

Measures

Participants individually completed two written self-report questionnaires, during class, while being supervised by a school staff member. The study had a cross-sectional design.

Achievement Emotions Questionnaire – Mathematics. The original AEQ-M comprises 60 items that measure 7 achievement emotions (enjoyment, pride, anxiety, anger, shame, boredom, and hopelessness) related to mathematics in 3 settings (class, self-studying, and test). Items were anchored before (e.g. “I look forward to my math class”), during (e.g. “I am annoyed during my math class”), or after (e.g. “After taking a test in mathematics, I feel ashamed”) the setting. Temporal generality appropriate for domain-specific emotions is set by the questionnaire instructions e.g., “*Please indicate*

how you feel, typically, before/during/after math class". Items are scored on a 5-point Likert scale.

To translate the AEQ-M into Portuguese we followed the procedures proposed by Mallinckrodt and Wang (2004): translation, back-translation, analysis of equivalence of translated items by experts, and "think aloud" (See Supplementary Table 1 for Portuguese items).

Junior Temperament and Character Inventory. The 127-item Portuguese JTCI (Moreira et al., 2012) measures the seven major dimensions of the psychobiological model of temperament and character. Because of the implied relation between temperament and emotion, we considered only the temperament dimensions: novelty seeking (NS; 23 items), harm avoidance (HA; 19 items), reward dependence (RD; 15 items), and persistence (PS; 18 items). All items are rated on a 5-point Likert scale. Values for α ranged between .55 (RD) and .78 (NS).

Statistical Analysis

The percentage of missing data per variable was between 0 and 0.2%. We subsequently used a listwise deletion method for all analyses (Graham, 2009).

We assessed the reliability of the Portuguese AEQ-M via Cronbach's alpha (α), omega total (ω_t), and item-total correlations. For α and ω_t values > .70 indicate acceptable reliability (Kline, 2013). We then conducted a series of CFAs. Because prior studies have shown the relations between achievement emotions are best explained with a multidimensional structure, we were primarily interested in testing a seven-Emotion × three-Setting model using a correlated uniqueness approach (Pekrun et al., 2011). Thus, the seven emotions were modelled as correlated latent factors, and the influence of setting (in class, when studying, and during tests) was considered via correlated item residuals. We used a robust Maximum Likelihood estimator and assessed fit using CFI,

SRMR, and RMSEA. The reference values considered as indicators of acceptable model fit were: CFI ≥ .95, SRMR < .05, and RMSEA < .08 (Cangur & Ercan, 2015).

To assess measurement invariance across grade and gender we used a multi-group CFA approach that tests nested models differing in the number of applied restrictions. Increasing restrictions allows the testing of configural, weak, and strong invariance (Meredith & Teresi, 2006). Invariance was determined based on the change in CFI and RMSEA between models (ΔCFI ≤ -.010 and ΔRMSEA ≥ .015 indicative of non-invariance: Chen, 2007).

We assessed latent factor correlations between temperament and achievement emotions via structural equation modelling (SEM). We assessed the seven-Emotion × three-Setting model with four additional orthogonal temperament latent factors, each of which was correlated with all seven emotion latent factors. Because of the associated disadvantages of testing models with large numbers of items (Little & Cunningham, 2009), we parcelled JTCI items into summed aggregates based on the dimension subscales defined by Cloninger, Dragan, Svrakic, and Przybeck (1993).

Results

Scale Reliability

All of the seven emotion scales had acceptable reliability based on ω_t (> .75; see Supplementary Table 2). The pride and shame emotion scales had values of α < .70, suggesting questionable reliability. Item-total correlations indicated items in each subscale were generally measuring the same construct, although two items had values < .20, indicating low fidelity (Everitt, 2002), and were dropped from further analyses. Supplementary Table 3 presents subscale statistics across settings. Manifest correlations between subscales indicated that the emotion constructs were correlated, particularly

neighbouring emotions such as anger and boredom ($r < .67$), but also clearly separable (Table 1).

##Table 1 about here##

Factorial Structure and Measurement Invariance

The Emotion × Setting model had acceptable fit (CFI = .950, RMSEA = .033, SRMR = .056) and was superior to one-factor, seven-emotion factor, and three-setting factor models (Supplementary Table 4). High latent correlations, particularly between anger and boredom (see Figure 1) indicated there might be an issue with discriminant validity in the Emotion × Setting model.

##Figure 1 about here##

Based on ΔCFI and ΔRMSEA (see Table 2) it was evident that the Emotion × Setting model had strong invariance across grade and gender.

##Table 2 about here##

Convergent Validity

In accordance with our expectations, the structural model indicated HA was correlated with anxiety ($r = .14$), shame ($r = .22$), and hopelessness ($r = .11$), although there was no observed correlation between HA and anger, and no negative correlations with positive emotions (see Table 3). Also consistent with our expectations, PS was the only dimension positively correlated with positive emotions: enjoyment ($r = .22$) and pride ($r = .27$). PS was also negatively correlated with the negative emotions anger ($r = -.19$), shame (r = -.16), boredom (r = -.19) and hopelessness ($r = -.20$). Finally, results were consistent with our expectation that NS would be positively associated with anger ($r = .23$). NS was also positively associated with anxiety ($r = .19$) and boredom ($r = .24$) and negatively related to enjoyment ($r = -.17$). RD was not correlated with achievement emotions.

##Table 3 about here##

Discussion

The aim of this study was to present a Portuguese translation of the AEQ-M for use with adolescents and to assess its psychometric properties. Overall, the results indicated the psychometric properties were good and supported modelling this measure via a seven-Emotion × three-Setting model. The observed relationships between novelty seeking, harm avoidance and persistence with achievement emotions were an indication the Portuguese AEQ-M has convergent validity.

Although confirmatory methods championed the Emotion × Setting model, strong correlations between latent constructs, notably boredom and anger, suggested an issue with discriminant validity. There are, however, theoretical reasons to expect these strong associations. Boredom proneness has been shown to be a strong predictor of anger, even after accounting for personality (Dahlen, Martin, Ragan, & Kuhlman, 2004), and some authors have argued that boredom corresponds to anger directed at oneself (McHolland, 1988). Furthermore, strong inter-emotion associations have been demonstrated consistently in prior studies. Peixoto et al. (2015), for example, presented latent correlations of > .90 for hope and pride, hope and enjoyment, and anxiety and shame. For the AEQ (Pekrun et al., 2011) a latent correlation of .90 was found for anxiety and shame. Our findings thus appear to add to the growing body of evidence that high covariation between achievement emotions may be an “empirical reality” (Pekrun et al., 2004, p. 311). It is important to note that manifest correlations between emotions indicated the emotion constructs were related, yet separable, and that latent coefficients, which are corrected, represent high estimates for these relationships (Pekrun et al., 2011). Nonetheless, researchers may wish to consider changing items that demonstrate multi-emotionality to improve discriminant validity in future research,

or to exclude one emotion from each pair of highly correlated emotions (e.g. boredom) as a means to shortening the AEQ-M without substantial loss of information.

A novel aspect of this study was our approach to testing the construct validity of the Portuguese AEQ-M by assessing the relations between achievement emotions and temperament. Because of the close theoretical link between temperament and emotionality (Cloninger et al., 1993), and available empirical evidence (Garcia, 2011; Soric et al., 2013), we were able to make specific predictions about these associations. Our results were broadly consistent with these expectations. Students with high HA temperament were more likely to experience anxiety, shame and hopelessness, which is consistent with evidence that this trait is linked to anxiety disorders (Miettunen & Raevuori, 2012). Students with high PS were more likely to experience the positive emotions, which is also consistent with past results (Garcia, 2011). NS was associated with the negative achievement emotions anger, anxiety and boredom, and negatively related to enjoyment. Although this finding is consistent with the link between NS and aggression (Cloninger, 1987) it contrasts with past results that have found no association between NS and negative affect and thus highlights the importance of examining separate emotion constructs as opposed to collapsing them into more general positive and negative categories.

The present study had several limitations. The sample was cross-sectional, meaning we were unable to determine whether this instrument has adequate test-retest reliability. Moreover, as we did not collect data from students outside of Portugal we were unable to test for cultural invariance. Finally, the reliability of the reward dependence JTCI subscale was unsatisfactory, meaning it is difficult to interpret its lack of significant associations with achievement emotions.

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Table 1.

Manifest AEQ-M scale correlations

		Enjoyment (1)	Pride (2)	Anxiety (3)	Anger (4)	Shame (5)	Boredom (6)	Hopelessness (7)
Correlations within settings								
	Class	.44						
(2)	Test	.36						
	Learning	.40						
	Class	-.32	-.26					
(3)	Test	-.10	-.10					
	Learning	-.20	-.21					
	Class	-.49	-.37	.41				
(4)	Test	-.28	-.23	.55				
	Learning	-.38	-.28	.34				
	Class	-.04	-.17	.38	.34			
(5)	Test	-.08	-.16	.56	.35			
	Learning	-.07	-.18	.35	.39			
	Class	-.51	-.34	.34	.67	.29		
(6)	Test	-	-	-	-	-		
	Learning	-.45	-.32	.32	.64	.34		
	Class	-	-	-	-	-	-	
(7)	Test	-.21	-.29	.66	.43	.57	.25	
	Learning	-	-	-	-	-	-	

Correlations across settings							
Class vs. learning	.21	.24	.26	.37	.23	.33	-
Class vs. test	.20	.20	.17	.31	.22	-	-
Learning vs. test	.21	.17	.16	.29	.26	-	-

Table 2.

Tests of measurement invariance across school year and gender for the seven Emotion × three Setting model.

		CFI (ΔCFI)	RMSEA (ΔRMSEA)	χ^2	df (Δdf)
School Year					
	Configural	.927	.041	5752.8	3282
	Weak	.926 (.001)	.040 (.000)	5875.6	3384 (102)
	Strong	.923 (.003)	.040 (.000)	6079.0	3486 (102)
Gender					
	Configural	.947	.034	3927.1	2188
	Weak	.946 (.001)	.034 (.000)	3998.4	2239 (51)
	Strong	.939 (.007)	.036 (.007)	4277.3	2290 (51)

Table 3.

Latent correlations between achievement emotions and temperament obtained via SEM.

	Enjoyment	Pride	Anxiety	Anger	Shame	Boredom	Hopelessness
NS	**-.17*****	.00	**.19*****	**.23*****	.08*	**.24*****	.09*
HA	.09	.06	**.14****	.01	**.22*****	-.00	**.11***
RD	-.04	.01	.03	.02	-.03	.02	-.04
PS	**.22*****	**.27*****	-.09*	**-.19*****	**-.16*****	**-.19*****	**-.20*****

Note. NS = Novelty Seeking; HA = Harm Avoidance; RD = Reward Dependence; PS = Persistence; Correlations > .10 (small effect) shown in boldface; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. CFI = .90, RMSEA = .036, SRMR = .062.

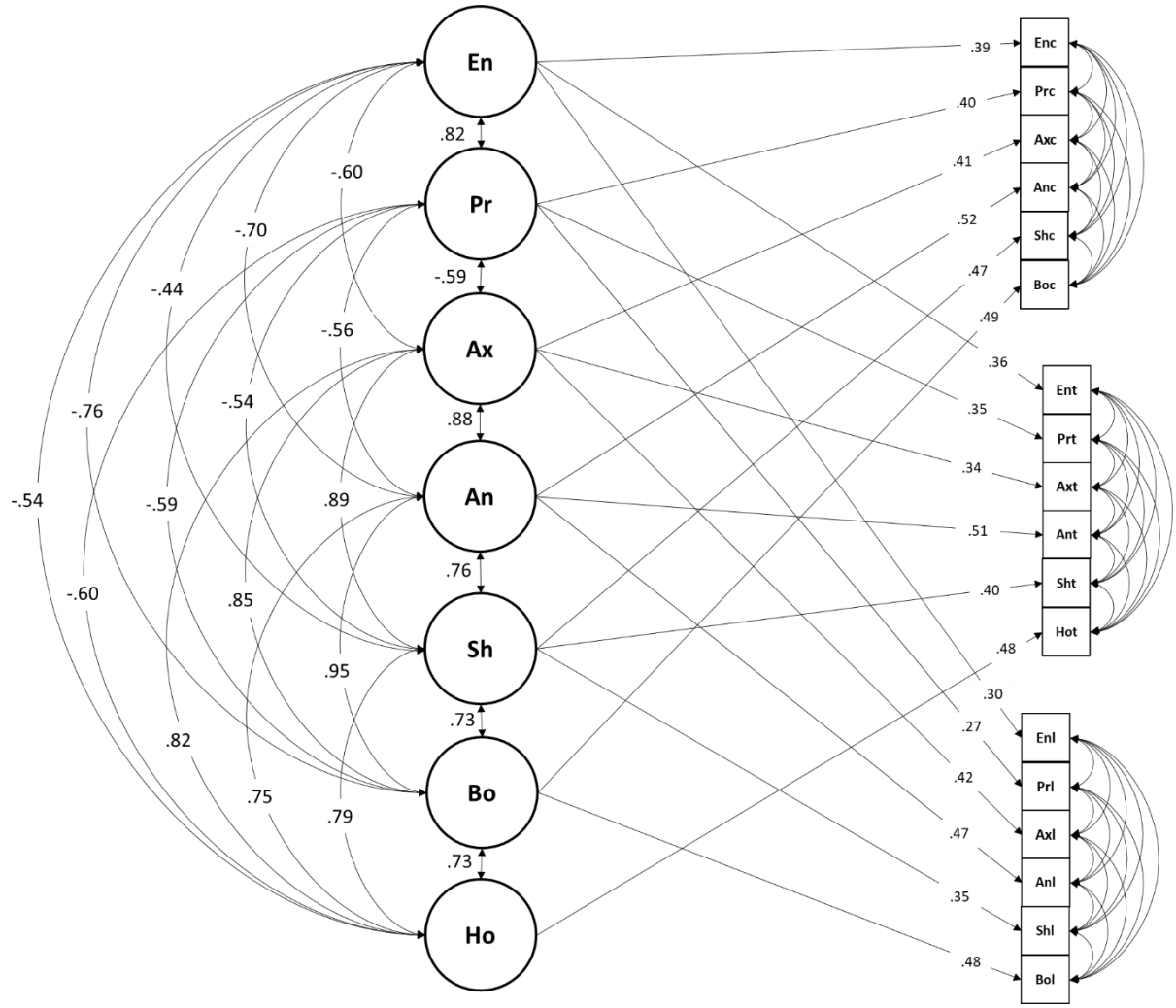

Figure 1. Emotion × Setting model for class-, test-, and learning-emotions with latent factor correlation and mean standardized factor loadings; En = Enjoyment; Pr = Pride; Ax = Anxiety; An = Anger; Sh = Shame; Bo = Boredom; H = Hopelessness; Enc = Items pertaining to class-related Enjoyment; Ent = Items pertaining to test-related Enjoyment; Enl = Items pertaining to learning-related Enjoyment. Correlated error terms between emotions within each setting are not presented.