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Extending expectancy-value theory predictions of achievement and aspirations in science: Dimensional comparison processes and expectancy-by-value interactions

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ABSTRACT

Based on TIMSS data (18,047 Grade 8 students from the four OECD countries that collected data for multiple science domains), this study integrated dimensional comparison theory and expectancy-value theory and tested predictions about how self-concept and value are related to achievement and coursework aspirations across four science domains (physics, chemistry, earth science, and biology). First, strong support for social comparisons suggested that high achievement in a particular domain enhance students' motivation in the same domain, which in turn predicted domain-specific aspirations. Particularly, self-concept significantly interacted with value to predict aspirations. Second, in the processes underlying the formation of self-concept and intrinsic value, students tended to engage in negative dimensional comparisons between contrasting domains (physics vs. biology) but positive dimensional comparisons between assimilating domains (physics vs. chemistry). Similar dimensional comparison processes were evident for the effects of self-concept and intrinsic value on aspirations. The results generalized well across all countries.

The issue of talented and capable students opting out of the STEM (i.e., science, technology, engineering, and mathematics) pipeline has been a topic of enduring interest in the science education community. Given that dropping out of science coursework at high school makes it very difficult to undertake STEM college majors and careers, growing attention in research on science motivation has focused on disentangling the relationship between students' motivational beliefs and achievement in science on one hand, and high-school science course taking, aspirations, and persistence on the other (e.g., Guo, Parker, Marsh, & Morin, 2015; Nagy et al., 2008; Parker et al., 2012).

These studies have demonstrated that motivation beliefs (e.g., academic self-concept and value beliefs) represent important determinants of achievement-related decisions in STEM subjects, net of individual's actual ability and achievement (Wang & Degol, 2013). However, much of this research has focused on motivational beliefs in general science, whereas science choices and aspirations are often measured in specific science domains. Indeed, the process of subject selection is inherently comparative. For example, let us consider the decision to major in physics at college. Students will be most likely to select this major only if they hold high confidence in their ability to do well in the course required by this major and place high value on majoring in physics by comparing the physics major to other majors including other science domains (see Eccles, 2009). Such intraindividual dimensional comparisons have been found to be useful for predicting academic choices. Nevertheless, existing research has focused almost exclusively on the dimensional comparison processes between math and verbal domains (e.g., Parker et al., 2012).

The aim of this study was to overcome the shortcomings of prior research, by testing the relations between academic achievement, motivational beliefs, and coursework aspirations taking into account several different science disciplines. In pursuing this overarching aim, we integrated and extended two major theoretical

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models of academic motivation (i.e., dimensional comparison theory [DCT], Möller & Marsh, 2013; expectancy-value theory [EVT], Eccles, 2009) in relation to four major science domains (physics, chemistry, biology, and earth science). First, contrasting achievement and motivation, we tested how students' subject-specific self-concept and intrinsic and utility values in science were shaped by dimensional comparisons. Second, extending theoretical developments based on DCT, we explored how such dimensional comparison processes predicted coursework aspirations across different science domains. Third, extending recent developments based on EVT, we tested how academic self-concept interacted with value beliefs in predicting aspirations.

The present study drew on eight-grade students from the Trends in International Mathematics and Science Study (TIMSS 2007). TIMSS has been a major basis of international comparisons of countries in terms of educational motivation and achievement in the four major science domains. Thus, it presents an unprecedented opportunity for researchers to investigate students' motivational pathways to different STEM-related fields. This study was among the first to take advantage of the TIMSS data to address this substantive issue. In order to test the cross-national generalizability of our results, we rely on a convenience sample of all OECD countries who chose to conduct separate motivation assessments in physics, chemistry, biology and earth science, including the Czech Republic, Hungary, Slovenia, and Sweden (Olson, Martin, & Mullis, 2008). We note that the current approach, aiming to identify pan-human generalizations rather than country-specific idiosyncratic effects, is well-aligned with the approach typically taken in the study of similar educational phenomenon (e.g., the Internal-External frames of reference [I/E] model, the Big-Fish Little-Pond effect) using large international data sets (Marsh et al., 2014, Marsh, Lüdtke, Nagengast, Trautwein, & Abduljabbar, 2015).

Focusing on motivational beliefs in general science or a single subject domain would result in a very limited perspective in explaining achievement-related behavior choices in STEM and may even be counterproductive in understanding coursework selection and aspirations in particular science disciplines (Eccles, 2009). By evaluating the influence of the intraindividual dimensional comparisons in relation to self-concept and value within science domains, this investigation may shed some light on how achievement and motivational beliefs might affect the decision students make to remain in or leave from the pathway toward different STEM-related fields.

1. Dimensional comparison processes

Academic self-concept, the self-evaluation of a student's ability in a given domain, has been assumed to be a multifaceted, hierarchical construct including a number of self-perceptions in different academic domains (Marsh, 2007). In order to evaluate their strengths and weaknesses, students compare and contrast their own performances across different school disciplines (Möller & Marsh, 2013). The I/E model were originally developed to explain the apparently paradoxical relations among domain-specific self-concepts and achievement: near zero-correlations between math and verbal self-concepts despite math and verbal achievement being moderately to strongly correlated (Marsh, 2007). The I/E model posits that students form their verbal and math self-concepts as a function of two underlying processes: social and dimensional comparison. Using an external frame of reference, students conduct social comparisons by comparing their self-perceived performance in a subject domain with that of their peers in the same school or classroom. For instance, if students have higher math achievement than do their classmates, their math self-concept is also likely to be higher. Thus, the social comparison processes lead to a positive prediction from achievement and self-concept within a subject domain. Employing a dimensional frame of reference, students conduct dimensional comparisons by comparing their performances in one particular subject domain against their performance in other subject domains. However, the dimensional comparison processes are ipsative, so that high levels of math ability should lead to lower verbal self-concept once the positive effect of verbal ability is controlled for.

Recently, the I/E model has been extended into DCT (Möller & Marsh, 2013) by incorporating a wider variety of subject domains. DCT postulates that academic self-concepts are formed by different dimensional comparisons. On the one hand, contrasting dimensional comparison processes predict that good performance in one domain leads to lower self-concept in other domains (i.e., contrast effects). On the other hand, assimilating dimensional comparison processes are characterized by good performance in one domain leading to higher self-concept in other domains (i.e., assimilation effects). Whether students engage in contrasting or assimilating dimensional comparisons is related to their beliefs as to whether two abilities are negatively or positively correlated (Möller, Helm, Müller-Kalthoff, Nagy, & Marsh, 2015). One of the critical assumptions of DCT is that perceived subject similarity corresponds to the verbal-mathematical continuum of core academic self-concept domains (Möller & Marsh, 2013). This assumption has been well supported in both empirical and experimental studies. For example, Haag and Götz (2012) demonstrated that subjects (far from each other on the continuum, e.g., math vs. German) with low self-concept correlations were perceived as rather dissimilar and that subjects (close to each other, e.g., math vs. physics) with high self-concept correlations are perceived as more similar. A recent empirical study (Helm, Mueller-Kalthoff, Nagy, & Moller, 2016) also confirmed this assumption and addressed that contrast effects were stronger when students focus on differences between two subject domains than when they focused on similarities. Thus, according to the verbal-mathematical continuum of academic self-concept, assimilation effects are assumed to occur between "near" domains, whereas contrast effects are assumed to occur between "far" domains.

In relation to science domains, physics and chemistry are assumed to be located closer to the math domain, whereas biology is assumed to be located in the middle of the continuum. More recently, Jansen, Schroeders, and Lüdtke (2014) contrasted achievement and self-concept in physics, chemistry, and biology and found that associations of self-concept with achievement and grades were substantial in the same domains. For cross-subject relations, they revealed slightly negative contrast effects between biology and physics but assimilation effects between chemistry and physics (for similar results, also see Jansen, Schroeders, Lüdtke, & Marsh, 2015). However, these two previous studies focus on German high school students, and the findings have yet to be replicated with other populations across different science curricula. Moreover, these studies have not included earth science and thus miss out on the opportunity to gain insight into dimensional comparison processes between four major science disciplines.

More recently, based on DCT, the Generalized I/E (GI/E) Model (Möller et al., 2015) has been developed by connecting dimensional comparison processes to broader cognitive, affective, and motivational consequences. Dimensional comparisons are assumed to serve as a critical source of information as to students' strength and weakness across different domains. These self-evaluations would help students to distinguish domains in which they can specialize, and for which they could develop particular interests, emotions, and preferences. Thus, dimensional comparisons are underlying mechanisms for the process of self-differentiation to serve motivational needs (Möller et al., 2015). In this regard, the GI/E model