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Examining heterogeneity in student metacognition: A factor mixture analysis

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ABSTRACT

Based on data obtained from 873 Singapore Secondary 3 students, this study examined the possible existence of different factor structures of the Junior Metacognitive Awareness Inventory (Jr. MAI) that may represent distinct classes or subpopulations of students. Exploratory factor mixture modeling identified two distinct classes of students that differ in their manifestation of metacognition both quantitatively (i.e. different level of metacognition) and qualitatively (i.e. different factor structure of metacognition). Specifically, for students with lower levels of metacognition the Jr. MAI seemed to represent a unidimensional measure of metacognition, whilst for those with higher levels of metacognition the Jr. MAI appeared to reflect a two-dimensional measure of regulation and knowledge of cognition. Results also revealed that those with lower levels of metacognition reported significantly less utilization of deep learning strategies and had significantly lower levels of mathematics performance than their counterparts with higher levels of metacognition.

1. Introduction

The concept of metacognition is regarded as "one of the most important developments in the contemporary study of cognition" (Roberts & Erdos, 1993, p.259). The important role of metacognition for learning and academic success is well documented in the literature (e.g. Maqsud, 1997; Meloth, 1990; Swanson, 1990; Thiede, Anderson, & Therriault, 2003; Van der Stel & Veenman, 2008). Metacognition is defined as individuals' knowledge and regulation of their own thinking and learning strategies (Brown, 1978; Flavell, 1978). Knowledge of cognition refers to one's knowledge about their own cognition and cognition in general and it involves three knowledge processes, namely declarative knowledge about oneself as a learner and knowledge about strategies, procedural knowledge about how to use strategies, and conditional knowledge about when and why to use strategies (Schraw & Dennison, 1994). Regulation of cognition involves one's use of various self-regulatory strategy processes to control and monitor one's learning, including planning, information management, comprehension monitoring, debugging, and evaluation (Artzt & Armour-Thomas, 1992; Baker, 1989; Schraw & Dennison, 1994).

Schraw and Dennison's (1994) Metacognitive Awareness Inventory (MAI) is a self-report instrument developed to assess the three knowledge and the five strategy processes under the knowledge and regulation of cognition components of metacognition described above. Factor analyses conducted by Schraw and Dennison (1994) based on undergraduate students provided support for this two-factor structure of metacognition. Based on the MAI, Sperling, Howard, Miller, and Murphy (2002) developed the Junior Metacognitive Awareness Inventory (Jr. MAI) for use with younger student samples. Two versions were proposed as an assessment and diagnostic tool for grade school (Version A for grades 3 to 5) and middle school (Version B for grades 6 to 9) children. Version A includes 12 items measured with a 3-point Likert response scale (Never, Sometimes, Always), whilst Version B includes 6 additional items and utilizes a 5-point scale (Never, Seldom, Sometimes, Often, Always) to reflect "higher levels of regulation that would likely be evidenced in older, more experienced learners" (Sperling et al., 2002, p.56).

Despite that the questionnaire items were constructed based on the two components of metacognition, Sperling et al.'s (2002) initial validation using exploratory factor analysis revealed a five-factor model structure for both versions of the Jr. MAI based on 3rd to 9th grade student samples. Several items were found to load on more than one factor, and all five factors appeared to have moderate loadings from items that represent both knowledge and regulation of cognition. When an exploratory analysis that forced two factors was conducted, results also indicated that most of the regulation and knowledge items loaded onto the same factor. Sperling et al. (2002) thus suggested that the Jr. MAI might best be used as an overall measure of metacognition rather than separate factors measuring knowledge and regulation of cognition, given that these two constructs have consistently been shown to be highly correlated (even in the factor solution of the original MAI developed for adults). Other than this initial validation, we are only aware of one other study which has investigated the latent factor structure of the

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Jr. MAI. Schraw, Olafson, Weibel, and Sewing (2012) utilized the 12-item version of the Jr. MAI in their study of 4th and 5th grade students' metacognition and science learning. Contrary to Sperling et al. (2002), two distinct factors (which explained 35% of the total variation) that clearly distinguished between the regulation and knowledge items emerged from Schraw et al.'s (2012) exploratory principal component analysis with varimax rotation. The knowledge and regulation factors were also only found to be moderately correlated (4th grade: $r = 0.38$; 5th grade: $r = 0.39$).

One probable explanation for these inconsistent findings is that the different factor structures of the Jr. MAI may actually represent distinct types of students who differ in their manifestation of metacognition, although this conjecture has not been empirically investigated to date. Given that past research has identified subpopulations or classes of students that differ in terms of level of metacognitive awareness (Ling, Leppiman, & Venesaar, 2011), it is not unreasonable to hypothesize that there may even exists heterogeneous subpopulations of students that differ in their patterns of engagement of metacognitive processes. Factor mixture modeling is an analytic approach that combines latent class analysis with factor analysis (Lubke & Muthén, 2005). Unlike basic factor analysis which presumes homogenous population and factor structure, exploratory factor mixture modeling (EFMM) allows for the detection of possible unobserved latent classes inherent in the data, together with the simultaneous exploration of the factor structure underlying the observed variables, which are treated as separate for each latent class (i.e. the model parameters are free to vary across latent classes). EFMM (see Lubke & Neale, 2006, 2008 for a detailed description of this method) involves the fitting of a series of different mixture models with an increasing number of classes, and within each class exploratory factor models (whereby all the observed variables are specified to load on all factors) are estimated with an increasing number of factors. Models are then compared with respect to some model fit criteria. As such, EFMM allows for the determination of the potential existence of different factor structures among different subpopulations. Based on data obtained from a sample of Singapore secondary students, the main objective of this study was to apply EFMM to investigate the latent factor structure of metacognition as measured by the Jr. MAI. EFMM was conducted to examine if the factor structure of the Jr. MAI is consistent across all students, or if there exist different factor structures that represent distinct subpopulations or classes of students.

If the existence of latent subpopulations of students was evident from EFMM, the second objective of this study was to examine latent class differences with respect to demographics (gender, ethnicity, educational tracks) and various learning outcome measures, including mathematics achievement and deep and surface learning strategies. The concept of deep and surface approaches to learning was first introduced by Marton and Saljo (1976a, 1976b). Deep learning involves the use of strategies such as elaboration, organization, critical thinking, relating ideas as well as integrating new information with existing knowledge to help achieve meaningful learning and understanding. Surface learning, on the other hand, involves the use of strategies such as memorization, rehearsal, minimizing scope of study and reproduction of material which are characteristics of rote learning (Pintrich & Garcia, 1991). Previous research (Sperling, Howard, Staley, & DuBois, 2004; Vrugt & Oort, 2008) have demonstrated that metacognitive knowledge and regulation play important roles in influencing students' selection and implementation of learning strategies. Findings from Sperling et al. (2004), for example, have shown that college students' engagement of metacognitive processes (as measured by the MAI) was significantly and positively related to their use of a large variety of learning strategies, including organization, elaboration, information processing, critical thinking, time and study environment management, and effort regulation. Their results also revealed that the regulation of cognition component had slightly higher correlations with learning strategies than the knowledge of cognition component. Vrugt and Oort (2008) have also found that university students' metacognition was positively predictive of their reported use of deep strategies (elaboration, organization, critical thinking), resource management strategies, and even the surface strategy of rehearsal.

2. Method

2.1. Participants

The sample comprised 873 Secondary 3 students (432 boys and 441 girls) from 10 Singapore schools, with an average age of 15.36 years ($SD = 0.32$). Approximately 79.1% of the students were Chinese, 12.8% were Malay, 5% were Indian, and 3.1% were of other ethnicities. In Singapore, students are placed in different educational tracks in secondary school based on their results in the Primary School Leaving Examination (PSLE) taken in Primary 6: the most elite Integrated Programme (IP) track, the more mainstream and academically demanding Express track, and then the Normal (Academic) and the vocational Normal (Technical) tracks. Among this sample, 4.9% were in the Integrated Programme track, 74.8% were in the Express track, 18% were in the Normal Academic track, and 2.3% were in the Normal Technical track. Students were briefed on the nature of the questionnaire and confidentiality was confirmed. Parental consent and student assent were obtained from all participants. The measure was administered during regular class sessions coordinated with help from teachers.

2.2. Measures

2.2.1. Metacognition

The 18-item Jr. MAI (Version B; Sperling et al., 2002) was used to assess students' metacognitive processes. Knowledge of cognition (KOC) and regulation of cognition (ROC) were each measured by 9 items (the same items as in Version A plus 3 additional items for each of KOC and ROC), with the following sample items for KOC ("I use my learning strengths to make up for my weaknesses") and ROC ("I occasionally check to make sure I'll get my work done on time"). Students were asked to give a response to each item on a 5-category response scale: 1 = never, 2 = seldom, 3 = sometimes, 4 = often, 5 = always.

2.2.2. Deep and surface learning strategies

Students' deep and surface learning strategies were measured via items from the Revised Learning Process Questionnaire (R-LPQ-2F; Biggs, Kember, & Leung, 2001). Deep strategies include relating ideas (2 items; e.g., "I try to relate what I have learned in one subject to what I learn in other subjects") and understanding (2 items; e.g., "When I read a textbook, I try to understand what the author means"). Surface strategies include minimizing scope of study (4 items; e.g., "I see no point in learning material which is not likely to be in the examination") and memorization (2 items; e.g., "I learn some things by rote, going over and over them until I know them by heart"). Students were asked to give a response to each item on a 5-point rating scale ranging from 1 (strongly disagree) to 5 (strongly agree).

2.2.3. Mathematics achievement

Students' performance in a 15-item standardized test in mathematics was included as an objective outcome measure of achievement. Previously developed by a panel of experienced educators and researchers with reference to the Secondary 3 curriculum standards, the multiple-choice test items assess students' mathematical knowledge, reasoning, and problem solving. Rasch scores were computed for use in the analyses in this study.

2.3. Data analysis

To explore the potential latent classes and latent factor structures of the Jr. MAI, MPlus 7.3 (Muthén & Muthén, 2014) was used to fit the