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Motivated Strategies for Learning Questionnaire (MSLQ): Adaptation, validation, and development of a short form in the Chinese context for mathematics

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Abstract

The Motivated Strategies for Learning Questionnaire (MSLQ) is one of the most widely used instruments to measure students' motivation and self-regulated learning. However, the MSLQ was developed and has been predominantly used in the Western context, is a domain-general measure, and is quite lengthy. Hence, adapting the MSLQ to the Chinese educational context, validating its application in specific subjects, and developing a short form would be an optimal way to improve its accessibility. This study aimed to investigate the psychometric properties of the Chinese version of the MSLQ in mathematics learning (i.e., MSLQ-C) and develop a short form (i.e., MSLQ-CS) using set exploratory structural equation modeling. The sample consisted of 563 senior secondary students in China. Results demonstrated that both MSLQ-C and MSLQ-CS showed acceptable construct validity, reliability, and concurrent validity. Furthermore, structural relationships and interrelationships among the subscales and their relationships with mathematics achievement were highly similar for MSLQ-C and MSLQ-CS. Theoretical and practical implications are discussed.

KEYWORDS

Chinese version, mathematics learning, Motivated Strategies for Learning Questionnaire (MSLQ), set exploratory structural equation modeling (Set-ESEM), short form

1 | INTRODUCTION

In the 21st century, knowledge and mastery of mathematics are becoming increasingly critical (Gravemeijer et al., 2017). In the coming decade, occupations related to science, technology, engineering, and math (STEM) will see a rapid increase and grow at twice the rate compared to non-STEM occupations (Zilberman & Ice, 2021). However, mathematics is often perceived as a difficult subject, with many students experiencing motivational problems and using suboptimal learning strategies. For example, international studies have shown that 41% of eighth-grade students do not like learning mathematics, and 44% of students are not confident in learning mathematics (Mullis et al., 2020).

Existing research has consistently highlighted the critical role of self-regulated learning in facilitating mathematics achievement (e.g., Perels et al., 2009; Robson et al., 2020). Measuring students' learning motivation and strategies with a psychometrically sound tool should be an important leverage point for improving mathematics achievement. The Motivated Strategies for Learning Questionnaire (MSLQ), developed by Pintrich et al. (1991), might be useful in this regard. The MSLQ has been extensively used to understand students' self-regulated learning, such as exploring individual differences in motivation and evaluating the effectiveness of interventions targeting learning strategies (Duncan & McKeachie, 2005).

However, there are two gaps in terms of the questionnaire itself. First, the psychometric properties of the MSLQ (e.g., factor structure, reliability, and construct validity) vary across countries, subjects, and grade levels, demonstrating the necessity of adapting and validating the MSLQ with diverse populations (Pintrich et al., 2000). In a meta-analytic study, Credé and Phillips (2011) reviewed 59 studies that adapted the MSLQ in several countries (e.g., the United States and Canada) across a wide variety of subjects (e.g., mathematics and English). They found that the MSLQ is a reliable instrument; however, the psychometric properties of items and variables need further modification to obtain better criterion validity and factor structure. To our knowledge, little research has been conducted to explore the psychometric properties of the MSLQ in the Chinese context, especially for mathematics learning. Such research is of great significance in terms of the critical role of mathematics in the 21st century. Meanwhile, Chinese secondary school students face fierce competition in the Chinese National Higher Education Entrance Examination, where mathematics is a major subject and occupies a relatively large portion of the total score. As Kennedy and Lee (2007) argued, examination systems in China follow the traditional culture of "assessment for selection". The test score would determine the ranking of the university that students can enter and subsquently influence their career development. Hence, it is important to establish a valid and reliable instrument to measure students' motivation and learning strategies in mathematics. Second, the MSLQ was designed based on Pintrich's integrated self-regulated learning framework and aimed to measure various motivational, cognitive, and behavioral strategies (Pintrich et al., 1993). However, the broad scope entails the use of a large number of items in the MSLQ (i.e., 81 items), which may result in survey fatigue and weakened quality and effectiveness of measurement. More importantly, the large space accounted for by the lengthy MSLQ items makes it unrealistic to simultaneously measure self-regulated variables and other constructs, preventing researchers from exploring complex research questions that might interest them (Ziegler et al., 2014).

Given the above gaps, the current study has two purposes. The first is to adapt and validate the Chinese version of the MSLQ for the mathematics domain (i.e., MSLQ-C). The second is to develop and validate a short form of the MSLQ (i.e., MSLQ-CS). Furthermore, considering that the MSLQ includes multiple related variables of the same domain, set exploratory structural equation modeling (Set-ESEM) is carried out to explore the factor structure of the MSLQ-C and the MSLQ-CS (Marsh et al., 2020).

1.1 | Self-regulated learning and mathematics learning

Self-regulated learning is an umbrella concept that involves a set of conscious and effortful awareness, achievable task-specific targets and cognitive goals, coordination of various cognitive strategies, and regulation of behaviors and contextual factors (Cleary & Zimmerman, 2004; Duncan & McKeachie, 2005). Pintrich (2000, p. 453) described self-regulated learning as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate and control their cognition, intentions, and behavior, guided and constrained by their goals and the contextual features of the environment." Pintrich's self-regulated learning model posits that students' ability to regulate cognition, motivation/affect, behavior, and context can be learned, controlled, and regulated (Pintrich & Zusho, 2002; Pintrich, 2004; Schunk, 2005). Accordingly, self-regulated learners are the ones who can successfully activate and maintain their motivational beliefs, adopt adaptive learning cognitive and metacognitive strategies, and control overt behaviors (Pintrich, 2004).

In the domain of mathematics, the critical role of self-regulated learning strategies in mathematics learning has been well-documented. For example, Cleary et al. (2021) classified students into five profiles based on their self-regulated learning variables (e.g., students' perceived use of regulatory strategies and self-efficacy beliefs to engage in self-regulated learning) and found that students in the adaptive self-regulated learning profile tended to have a higher level of classroom engagement and mathematics achievement than their peers. In another study, DiGiacomo and Chen (2016) indicated that the self-regulated learning intervention incorporating monitoring and self-regulation strategies into the math curriculum could facilitate mathematics achievement.

1.2 | MSLQ

The MSLQ is a self-reported questionnaire developed by Pintrich et al. (1991, 1993) to measure students' self-regulation, which comprises 81 Likert-scale items with five sets. The first three sets were designed to measure motivational beliefs, including *expectancy*, *value*, and *affect*. Expectancy refers to students' beliefs in accomplishing the given tasks, represented by self-efficacy (i.e., students' judgment on their ability to perform a task) and control beliefs for learning (i.e., students' beliefs about whether their effort can result in positive outcomes). Value focuses on why students engage in academic tasks, including intrinsic goal orientation (i.e., doing tasks for reasons of learning and mastery), extrinsic goal orientation (i.e., doing tasks for reasons of rewards, grades, and competition with others), and task value beliefs (i.e., beliefs about the interest, importance, and utility of tasks). Affect is operationalized as test anxiety (i.e., students' feelings of panic and fear regarding the test) and measured by students' worry about taking the exam.

The fourth set was used to measure students' cognitive and metacognitive strategies. Cognitive strategies include a series of basic to complex strategies that students use to process information in learning, including rehearsal (e.g., reciting or naming items from a list to be learned), elaboration (e.g., paraphrasing and summarizing), organization (e.g., selecting appropriate information), and critical thinking (e.g., applying previous knowledge to new situations). Metacognitive strategies are operationalized as students' use of strategies that help them control and regulate their cognition.

The last set was resource management, which refers to students' regulatory strategies for controlling other resources besides their cognition, including managing time and study environment (e.g., managing study time), effort regulation (e.g., persisting in the face of difficulties), peer learning (e.g., learning in a group with peers), and help-seeking (e.g., seeking help from peers when needed).

The MSLQ is one of the most promising tools to measure students' self-regulated learning for several reasons. First, the MSLQ is developed based on Pintrich's self-regulated learning framework and is an integrative instrument that measures various facets of self-regulated learning, including cognitive, motivational, and behavioral–contextual elements (Panadero, 2017). Second, the MSLQ can be flexibly applied to various research questions on self-regulated learning, given that all variables can be used either jointly or separately (Duncan & McKeachie, 2005). Third, many studies have indicated that MSLQ is an efficient, practical, and ecologically valid measure of students' self-regulated learning across cultures, countries, samples, and subjects (e.g., Meijs et al., 2019; Rao & Sachs, 1999; Wong et al., 2013). Fourth, the MSLQ is designed at the course level with appropriate grain size, avoiding either too much generality (e.g., all learning situations) or too much specificity (e.g., specific situations within one course) (Duncan & McKeachie, 2005).

1.3 | Psychometric properties of MSLQ

Pintrich and Zusho (2002) demonstrated that self-regulated learning was context-specific and influenced by the interaction of person, behavior, and environment. A large body of research indicates that students' self-regulation is subject to different cultures (King & McInerney, 2014, 2016; McInerney & King, 2018), domains (Wolters & Pintrich, 1998), and grade levels (Dent & Koenka, 2016).

Considering the influence of contexts, researchers have validated the psychometric properties of the MSLQ in many countries (e.g., Australia, Germany, and Korea), subjects (e.g., mathematics, language, and science), and samples at different grade levels (e.g., middle school students, high school students, and graduate students) (see Bonanomi et al., 2018; Duncan & McKeachie, 2005 for reviews). It was reported that the psychometric properties of the MSLQ varied in different contexts (e.g., Hilpert et al., 2013; Jackson, 2018; Pintrich & de Groot, 1990; Pintrich et al., 1991). For example, Hilpert et al. (2013) administered the MSLQ to postsecondary students enrolled in introductory geoscience courses. They retained six MSLQ variables (i.e., self-efficacy, control of learning, intrinsic goals, task value, metacognitive regulation, and effort regulation) and fit a three-factor structure model (i.e., expectancy, value, and self-regulation). Meijs et al. (2019) investigated the underlying structure of the learning strategy section for university students who majored in distance education. A five-factor structure was found, including management of time and effort, complex cognitive strategy use, simple cognitive strategy use, contacts with others, and academic thinking.

However, relatively fewer studies have investigated the psychometric properties of the MSLQ in the Chinese context (e.g., Lee et al., 2010; Sachs et al., 2001; Tong et al., 2019; Wang et al., 2021; Xu, 2020). The targeted samples of these studies were limited to junior secondary school students (e.g., Lee et al., 2010; Xu, 2020), a mixture of primary and junior secondary school students (e.g., Sachs et al., 2001), or college students (e.g., Tong et al., 2019). Furthermore, these studies focused on the application of the MSLQ in the general domain (e.g., Tong et al., 2019; Zhou & Wang, 2021). Although the study conducted by Xu (2020) is rooted in mathematics, only three cognitive variables (e.g., organization, elaboration, and critical thinking) were adapted and validated. To conclude, studies that specifically explored the psychometric properties of the MSLQ for Chinese senior secondary school students and focused on mathematics are relatively limited.

1.4 | The need for a short form of MSLQ

There are at least three advantages to applying the short form in research. First, a short questionnaire allows researchers to simultaneously measure more constructs (Ziegler et al., 2014). Second, a short questionnaire is easier to administer given that it saves response time, maximizes the utility of questionnaire space, and has fewer logistical issues. Third, a short questionnaire may mitigate the problems caused by participants' feelings of fatigue and boredom, reducing missing data produced by careless answers (Credé et al., 2012).

Researchers have attempted to develop a short form of MSLQ by removing some of the variables (e.g., Pintrich & de Groot, 1990; Rao & Sachs, 1999). For example, Pintrich and de Groot (1990) developed a short form for junior high school students by keeping five variables (i.e., self-regulation, cognitive strategy use, self-efficacy, intrinsic value, and test anxiety). However, these studies created a short form by removing some variables from the original MSLQ rather than selecting a subset of items within each variable, making it difficult to compare whether the short form is better than its long form. Second, the short form with selected variables cannot measure the whole complexity of motivation and learning strategies proposed in Pintrich's self-regulation framework. Hence, this study aims to develop a short form of the MSLQ by reducing items within each variable and keeping the full range number of variables included in the original MSLQ.

1.5 | Set-exploratory structural equation modeling (Set-ESEM)

In the existing studies, exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and ESEM have been widely used in examining the factor structure of the MSLQ (e.g., Hilpert et al., 2013; Thomas & Cassady, 2019; Tong et al., 2020; Xu, 2020). However, these studies might be beset by some limitations. EFA is utterly data-driven and is not aimed at fitting any pre-designed models. For CFA, the independent clusters model assumption is too restrictive for multidimensional constructs, which is often not available in practice with the poor model fit (Morin et al., 2013). Meanwhile, ESEM lacks parsimony (especially applied in complex models with many constructs based on small-to-moderate sample sizes, such as MSLQ) and might confound constructs that need to be separated theoretically (Marsh et al., 2020).

Set-ESEM might be able to address these problems. In Set-ESEM, items are first divided into different sets, with different factors within a set. Then, item loadings across different sets are restricted to be zero, while item loadings across different factors within the same set are constrained to be close to zero. Finally, item loadings within the same factor are freely estimated (Dicke et al., 2018). Hence, set-ESEM is a compromise between CFA and ESEM regarding goodness-of-fit, parsimony (regarding the number of estimated parameters), rigor (based on model constraints), and factor structure (i.e., the empirical mapping of items to factors that corresponds to the a priori theoretical model) (Marsh et al., 2020). To date, Set-ESEM has been popular in many research fields. For example, Dicke et al. (2018) applied Set-ESEM to validate the Copenhagen Psychosocial Questionnaire. Yukhymenko-Lescroart and Gilbert (2021) adopted Set-ESEM to develop and validate the Coaching Athlete Purpose Scale.

Set-ESEM is especially appropriate for investigating the factor structure of MSLQ. The whole MSLQ questionnaire can be grouped into five sets for measuring different facets of self-regulated learning, including value, expectancy, affect, cognitive and metacognitive strategies, and resource management strategies. Identifying these five sets in exploring the factor structure of the MSLQ is vital. The five sets of factors are different from each other. Hence, item loadings across sets are restricted to be zero. Meanwhile, item loadings across different factors within a set are allowed to be non-zero but small, given that variables within each subset are closely related.

1.6 | The Chinese context

The present study focused on Chinese senior secondary students, who are influenced by Confucian culture and experience tremendous pressure in preparing for the Chinese National Higher Education Entrance Examination. Generally, Chinese students tend to study in a teacher-directed, exam-oriented, and utilitarian learning environment (Hwang, 2015; Zhang et al., 2004). It has been reported that Chinese students are quiet, receptive, and disinclined to challenge authority (Pratt et al., 1999). Teachers get accustomed to adopting strategies that teach to the exam rather than fostering deep learning, which could thwart students' self-regulated learning (Zhao, 2020). For example, Chinese mathematics teachers tend to implement the traditional didactic approach as the primary teaching strategy and view the repeated practice as a key to consolidating knowledge (Wang & Cai, 2007). Hence, Chinese students tend to use more surface learning strategies (e.g., rehearsal) than their counterparts in western countries (Leung, 2001).

Meanwhile, motivational factors could interact with cognitive, behavioral, and environmental factors to influence self-regulated learning (King, 2022; Schunk, 2005). For example, existing studies have documented that students' intrinsic and extrinsic goal orientation are closely associated with self-regulated learning strategies (Cai et al., 2022; Haw & King, 2022; Wolters et al., 1996). Evidence from Western cultures indicated that intrinsic goal orientation generally facilitates the use of sophisticated strategies, while extrinsic goal orientation makes students feel controlled and hinders self-regulated learning (e.g., Pintrich & de Groot, 1990; Walker et al., 2006). However, the influence of motivational factors on Chinese students' self-regulated learning might differ. For example, Chinese students tend to have high attainment and utility value for learning due to the importance of education in social mobility (Li, 2003). Hence, researchers indicated that extrinsic goal orientation plays a more critical role than intrinsic goal orientation for Chinese students (Hau & Ho, 2010; Wang et al., 2019). These findings suggest the need to explore self-regulated learning (i.e., motivational beliefs and learning strategies) among Chinese senior secondary students.

1.7 | The present study

Two research goals directed this study. The first goal is to adapt MSLQ in the Chinese context for mathematics (i.e., MSLQ-C) and scrutinize its psychometric properties, including construct validity, reliability, and concurrent validity. The second goal is to develop the short form (i.e., MSLQ-CS) based on the adapted Chinese version of MSLQ and assess its psychometric properties by conducting systematic comparisons with the MSLQ-C.

2 | METHODS

2.1 | Participants

The sample was selected using a convenience sampling method from Guangdong province, an economically advanced province in China. First, Soper's (2022) online SEM calculator, developed based on Cohen (1988) and Westland (2010), was used to determine the minimum sample size in the present study. The result indicated that a sample size of 498 was adequate to detect a small to moderate effect size (0.3), assuming a 95% power and a 5% level of statistical significance. Second, several invitation letters were sent to the principals. Third, within each school whose principal accepted, we randomly invited two classes of Grade 11 students to participate in our research. Consent forms were collected before data collection, and all participants were informed of the research purposes and procedures. Finally, we obtained 563 senior secondary school students from four schools. The average age of the participants was 17.12, with a standard deviation of 0.48. There were 259 females (46.6%).

2.2 | Procedures for translating MSLQ

Following the International Test Commission (2018) guidelines for test adaptation, items were translated into Chinese and adapted to the subject of mathematics using a committee approach. The team consisted of an educational measurement expert, a mathematics educationalist, and a PhD candidate majoring in educational assessment in mathematics education. The committee members are equipped with the combined knowledge of (1) the languages involved (i.e., English and Chinese), (2) the Chinese cultures, (3) the Chinese mathematics education, and (4) the knowledge of educational measurement and assessment.

According to the recommendation of the Organization for Economic Co-operation and Development (OECD, 2020), a double-translation and reconciliation procedure was applied. First, the educational measurement expert and PhD candidate conducted the forward translation independently to translate the questionnaire from English to Chinese. Second, the discrepancies were recorded and reconciled by the mathematics educationalist. Third, the modification was conducted after the discussion with a consensus on each item.

2.3 | Measures

2.3.1 | MSLQ

The five sets with full 81-item MSLQ were measured in the present study. First, the expectancy set comprises control of learning beliefs (e.g., “It is my own fault if I don't learn the material in the math course.”) and self-efficacy for mathematics learning and performance (e.g., “I believe I will receive an excellent grade in the math class.”). Second, the value set includes intrinsic goal orientation (e.g., “In the math class, I prefer course material that really challenges me so I can learn new things.”), extrinsic goal orientation (e.g., “Getting a good grade in the math class is the most satisfying thing for me right now.”), and task value (e.g., “I think I will be able to use what I learn in the math course in other courses.”). Third, the affect set is composed of test anxiety (e.g., “When I take math tests I think if the consequences of failing.”). Fourth, the set of cognitive and metacognitive strategies includes rehearsal (e.g., “I make lists of important terms for the math course and memorize the lists.”), elaboration (e.g., “I try to apply ideas from the math course readings in other class activities such as lecture and discussion.”), organization (e.g., “I make simple charts, diagrams, or tables to help me organize math course material.”), critical thinking (e.g., “I treat the math course material as a starting point and try to develop my own ideas about it.”), and metacognitive self-regulation (e.g., “If I get confused taking notes in math class, I make sure I sort it out afterwards.”). Fifth, the set of resource management strategies comprises time and study environment management (e.g., “I make good use of my study time for the math course.”), effort regulation (e.g., “I work hard to do well in the math class even if I don't like what we are doing.”), peer learning (e.g., “When studying for the math course, I often try to explain the material to a classmate or a friend.”), and help seeking (e.g., “I try to identify students in the math class whom I can ask for help if necessary.”).

The original MSLQ was designed to measure undergraduates' learning motivation and strategies on a “Learning to Learn” course at the University of Michigan. In the original MSLQ, all items were rated on a 7-point Likert scale, from 1 (*Not at all true of me*) to 7 (*Very true of me*). The reliability of the variables ranged from 0.52 to 0.93. The confirmatory analyses showed that MSLQ showed sound structure and good factor loadings. However, the goodness-of-fit was not stellar in the original MSLQ as the sample was from various courses and subject domains (Pintrich et al., 1991).

In this study, items were adapted and answered on an 11-point Likert scale from 0 (*Not at all true of me*) to 10 (*Very true of me*), given that 11-point scale is closer to the interval level of scaling and normality (Leung, 2011). Previous studies that adapted and validated the MSLQ for Chinese students have found that it has acceptable reliability and validity in the Chinese context (e.g., Lee et al., 2010; Sachs et al., 2001; Tong et al., 2019; Zhou & Wang, 2021). For example, Tong et al. (2019) adapted the MSLQ for Chinese undergraduate students and found the overall reliability coefficient for motivation and learning strategies was 0.80 and 0.85, respectively. The fit indices of factor structure were also acceptable. Meanwhile, these studies suggested that the psychometric properties of MSLQ differed in diverse contexts regarding the subjects and students' grade levels.

2.3.2 | Mathematics achievement

We developed a practice test based on the Chinese National Higher Education Entrance Examination test to measure students' basic mathematics knowledge and skills based on the curriculum standard. Two steps were conducted to ensure the content validity of the test. First, we examined the test specifications to scrutinize the nature of the examination, cognitive framework, topics to be covered, and the cognitive requirement for each topic. The cognitive frameworks have three levels of knowing, understanding, and mastering, and the skills to be evaluated, including spatial imaginary skills, abstract thinking skills, reasoning/deductive skills, computational skills, data handling skills, and creative and application skills. Second, we determined the content areas through an evaluation of each item in the test. Finally, we developed 12 multiple-choice items, four short-answer questions, and four open-response items (see Table S1 for the contents covered in the test). The scores were converted to a scale of 0–100. This test demonstrated good internal consistency with Cronbach's α coefficients of .93.

2.4 | Data analyses

The percentage of missing data was low, ranging from 0% to 1.4%. Full Information Maximum Likelihood estimation was used to handle missing data. This method led to unbiased parameter estimates and is superior to other methods such as listwise deletion, pairwise deletion, and mean substitution (Enders, 2010).

2.4.1 | Phase 1: Adapting and validating the long form: MSLQ-C

2.4.1.1 | *Initial examination of item performance*

The mean, standard deviation (SD), skewness, kurtosis, and item-total correlations were computed to examine the item performance. Univariate normality was assessed by Kline's (2005) criteria, following the recommended values that skewness and kurtosis should be under |3| and |10|, respectively.

2.4.1.2 | *Construct validity*

Set-ESEM with target rotation was used to investigate the construct validity of the MSLQ-C with Mplus 8.0 (Muthén & Muthén, 2017). Based on the factor structure proposed by Pintrich et al. (1991), Set-ESEM analyses with five-set factors were conducted. Figure 1 shows the conceptual model.

The classical goodness-of-fit indices were used to assess the model fit. The value of the comparative fit index (CFI) and Tucker–Lewis index (TLI) greater than 0.90 and root mean square error of approximation (RMSEA) less than 0.08 were interpreted as acceptable fit (Marsh et al., 2004).

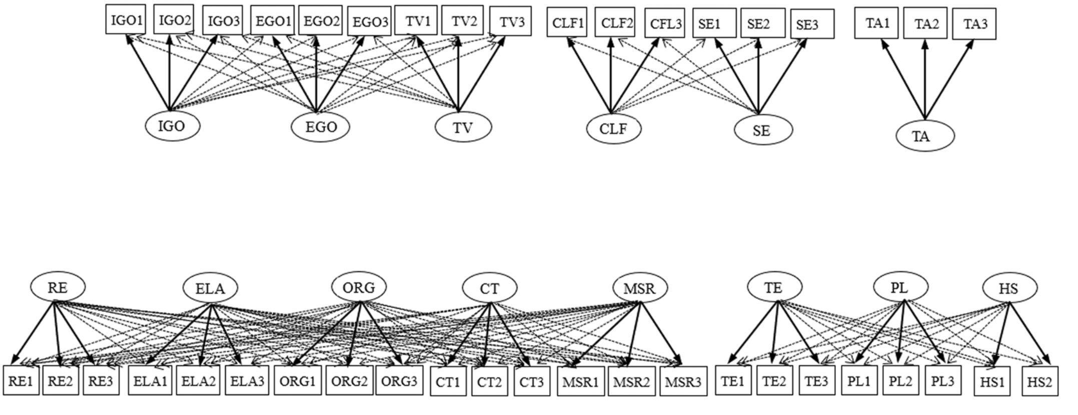

FIGURE 1 Factor structure of MSLQ based on Set-ESEM method. *Note*: The correlations between latent variables were not shown in the figure for parsimony. The solid lines indicate that the items are mainly loaded on the factor, while the dotted lines indicate the items cross-loaded on factors. CLF, control of learning beliefs; CT, critical thinking; EGO, extrinsic goal orientation; ELA, elaboration; HS, help seeking; IGO, intrinsic goal orientation; MSR, metacognitive self-regulation; ORG, organization; PL, peer learning; RE, rehearsal; SE, self-efficacy for learning and performance; TA, test anxiety; TE, time and study environment management; TV, task value.

2.4.1.3 | *Reliability*

We used the coefficient omega (ω) to assess reliability because Cronbach's alpha reliabilities have been found to underestimate scale reliability. Cronbach's alpha was built on an essentially tau-equivalent model assumption, where the factor loadings were required to be equivalent for all items (Dunn et al., 2014; Lucke, 2005). However, this assumption was difficult to achieve in the Set-ESEM model. In comparison, ω allowed the factor loadings to vary across items (Graham, 2006). ω can be understood as the proportion of the variance explained by a latent construct relative to the observed-score variance (Dunn et al., 2014). The cutoff values for ω were the same as Cronbach's alpha. Values of ω greater than 0.7 were considered acceptable, while those above 0.8 were regarded as high (Kline, 2000). However, all cutoff values about reliabilities are arbitrary, and "the nature of the decision being made on the basis of a test should be the guide for the acceptable level of reliability" (Cho & Kim, 2015; p.218). The values of ω ranging from 0.65 to 0.7 were also considered acceptable given that each variable only included a few items and the low reliability of some variables in the original MSLQ (Pintrich et al., 1991).

2.4.1.4 | *Nomological network*

The correlations between MSLQ-C constructs and mathematics achievement were assessed.

2.4.2 | Phase 2: Developing and validating the short form: MSLQ-CS

2.4.2.1 | *Creating the short form*

Based on MSLQ-C, we retained three items for each variable (except for help-seeking: two items)[1] to create the short form given that three items are the minimum number of items to identify a one-factor model (Kline, 2015). The Bhargava-Ishizuka method (also known as BI-method) was used to create the short form (Leung & Sachs, 2005). This method uses the trace information (the sum of all diagonal elements of the variance-covariance matrix) as the criteria to select items, which could keep most of the information in the original scale. Compared with factor analytic methods, which pool all dimensions together, the BI-method is more appropriate for shortening items within a specific dimension because it only considers the correlations of items within the specific dimensions. In contrast, items that measure other dimensions are not considered. More details of the BI-method can be found in Supplementary Materials.

2.4.2.2 | *Construct validity*

Set-ESEM with target rotation was used to investigate the construct validity of the MSLQ-CS.

2.4.2.3 | *Reliability*

Coefficient omega (ω) was assessed the reliability of the MSLQ-CS.

2.4.2.4 | *Reproduced information*

The amount of reproduced information was assessed by the correlation between the MSLQ-C and MSLQ-CS. Levy's (1967) correction was used to remove the overlapping error variance caused by the same items in MSLQ-C and MSLQ-CS.

2.4.2.5 | *Nomological network.*

The correlations between MSLQ-CS constructs and mathematics achievement were explored. As the correlation between MSLQ-C and mathematics achievement and the correlation between MSLQ-CS and mathematics achievement were calculated in Phase 1 and Phase 2, their difference and corresponding significance (measured by *p*-value) were calculated.

[1]In the original MSLQ, four items were developed to measure help-seeking. However, two negatively worded items with low item-total correlation were deleted, which resulted in two items for measuring help-seeking.

3 | RESULTS

3.1 | Phase 1: Adapting and validating the long form: MSLQ-C

3.1.1 | Initial examination of item performance

Table S2 presents the descriptive statistics of all items. The mean of all items ranged from 4.06 to 9.32, and their SDs were from 1.36 to 3.41. The items were normally distributed with skewness ranging from −2.51 to 0.32 and kurtosis ranging from −1.22 to 7.51. Meanwhile, the item-total correlations of all negatively worded items (i.e., item 33, 37, 40, 57, 52, 60, 77, 80) were lower than the accepted cutoff of 0.30, showing that these items were inconsistent with other items within the construct (Traub, 1994). Hence, as shown in Table 1, we excluded all negatively worded items in our subsequent analysis.

3.1.2 | Construct validity

Set-ESEM was conducted to examine the construct validity of the MSLQ. In this stage, items were excluded when: (1) items corresponding to the designated factors lower than 0.4 (Hair et al., 2010); (2) items within a set with cross-loadings in different factors that were higher than 0.4; (3) high correlation with other items indicated by modification indices, which means the item was redundant with another item. For example, for item 6 ("I'm certain I can understand the most difficult course material presented in the readings for the math course") and item 15 ("I'm confident I can understand the most complex material presented by the instructor in the math course"), difficult material and complex material are too similar to be distinguished for students. Hence, item 6 was deleted. The details of these excluded items can also be found in Table 1.

Finally, the 14-factor first-order model demonstrated accepted model fit with RMSEA = 0.039 (90% CI, 0.037–0.042), CFI = 0.917, TLI = 0.902.[2] Factor loadings of items on targeted variables ranged from 0.41 to 0.95. Meanwhile, all of the cross-loadings within sets were smaller than 0.4. The factor loadings can be found in Table 2.

TABLE 1 Overview of the excluded items

Stage	Excluded items	Rationale
Initial examination of item performance	33, 37, 52, 57, 77, 80, 60, 40	Reversed-coded items with low item-total correlation
Set-ESEM	3, 21, 30, 36, 48, 53, 54, 55, 56, 58, 61, 73, 74, 78	Factor loadings < 0.4, cross-loading items
	6, 12	High correlation with other items indicated by modification indices, which means the item was redundant with other items

Note: Item number is consistent with that in the original MSLQ developed by Pintrich et al. (1991).

[2]It should be noted that the variable of effort learning was not identified in this study. In the original version of MSLQ, this variable has two positively and two negatively worded items. Negative items were reversed before averaging with the positive items. However, the reverse of the negative may be different from the positive items. Since the number of negatively and positively worded items is 2 versus 2, no "majority" of items from both sides can dominate the meaning of the factor. This makes the interpretation of this scale difficult with low reliability. Hence, effort regulation was removed.

TABLE 2 Standardized factor loadings of the Set-ESEM model for MSLQ-C

	Value			Expectancy		Affect	Cognitive and metacognitive strategies					Resource management		
Items	IGO	EGO	TV	CLF	SE	TA	RE	ELA	ORG	CT	MSR	TE	PL	HS
1	**0.79**	−0.01	0.14											
16	**0.88**	0.04	−0.04											
22	**0.55**	0.12	0.18											
24	**0.65**	−0.08	0.04											
7	0.00	**0.60**	0.14											
11	-0.12	**0.70**	−0.05											
13	0.24	**0.54**	−0.05											
4	0.31	0.05	**0.42**											
10	-0.24	0.33	**0.59**											
17	0.01	−0.12	**0.91**											
23	-0.11	−0.05	**0.93**											
26	0.11	−0.19	**0.82**											
27	0.19	0.22	**0.41**											
2				**0.41**	0.25									
9				**0.68**	−0.12									
18				**0.77**	0.08									
25				**0.85**	−0.07									
5				0.17	**0.61**									
15				0.01	**0.76**									
20				−0.07	**0.83**									

(Continues)

TABLE 2 (Continued)

Items	Value			Expectancy		Affect	Cognitive and metacognitive strategies					Resource management		
	IGO	EGO	TV	CLF	SE	TA	RE	ELA	ORG	CT	MSR	TE	PL	HS
29				−0.01	**0.86**									
31				0.00	**0.87**									
8						**0.44**								
14						**0.61**								
19						**0.95**								
28						**0.85**								
39							**0.81**	−0.09	−0.07	0.10	−0.05			
46							**0.86**	−0.04	−0.01	−0.06	−0.02			
59							**0.54**	0.20	0.04	−0.05	0.14			
72							**0.48**	0.12	0.21	−0.02	0.00			
62							0.10	**0.66**	−0.10	0.10	0.01			
64							0.01	**0.74**	−0.14	0.04	0.19			
67							0.15	**0.63**	0.15	0.01	−0.02			
69							−0.01	**0.60**	0.19	0.07	0.05			
81							−0.03	**0.60**	0.22	0.13	−0.07			
32							0.04	0.22	**0.69**	0.06	−0.12			
42							0.00	0.05	**0.68**	−0.09	0.25			
49							0.08	0.12	**0.67**	0.13	−0.18			
63							0.08	−0.20	**0.73**	0.00	0.24			
38							0.08	−0.18	0.08	**0.78**	−0.13			

TABLE 2 (Continued)

Items	Value			Expectancy		Affect	Cognitive and metacognitive strategies					Resource management		
	IGO	EGO	TV	CLF	SE	TA	RE	ELA	ORG	CT	MSR	TE	PL	HS
47							−0.10	−0.02	0.03	**0.88**	−0.01			
51							0.04	0.09	−0.05	**0.70**	0.15			
66							0.06	0.21	−0.08	**0.60**	0.17			
71							−0.06	0.06	0.00	**0.79**	0.02			
41							0.01	0.01	0.01	0.09	**0.72**			
44							0.08	−0.07	0.11	0.18	**0.49**			
76							0.16	0.05	0.05	0.05	**0.49**			
79							−0.09	0.24	0.13	0.03	**0.54**			
35												**0.63**	0.06	0.00
43												**0.91**	0.05	−0.10
65												**0.44**	0.01	0.08
70												**0.55**	−0.10	0.15
34												0.21	**0.48**	0.02
45												−0.08	**0.62**	0.18
50												−0.02	**0.94**	−0.08
68												0.00	0.19	**0.68**
75												0.05	−0.09	**0.85**

Note: The items that loaded on the factors (>0.4) are presented in bold.

Abbreviations: CLF, control of learning beliefs; CT, critical thinking; EGO, extrinsic goal orientation; ELA, elaboration; HS, help seeking; IGO, intrinsic goal orientation; MSLQ-C, Motivated Strategies for Learning Questionnaire-Chinese version; MSR, metacognitive self-regulation; ORG, organization; PL, peer learning; RE, rehearsal; SE, self-efficacy for learning and performance; Set-ESEM, set exploratory structural equation modeling; TA, test anxiety; TE, time and study environment management; TV, task value.

3.1.3 | Reliability

Table 3 shows that the reliabilities of variables on MSLQ-C were acceptable, ranging from ω = 0.65 (extrinsic goal orientation) to ω = 0.90 (self-efficacy for learning and performance) with a mean of ω = 0.80 for all variables.

3.1.4 | Nomological network

Table 3 displays the correlations between mathematics achievement and variables on MSLQ-C. The correlations ranged from $r = -.01$ (text anxiety) to $r = .34$ (self-efficacy for learning and performance).

3.2 | Phase 2: Development and validation of the short form: MSLQ-CS

We retained three items for each variable to create the MSLQ-CS, which was composed of 41 items in total. The retained items can be found in Supplementary Materials (see Supplemental questionnaire). Next, we tested whether MSLQ-CS displayed a similar factor structure compared with MSLQ-C. Our results indicated that the MSLQ-CS showed an accepted model fit for the 14-factor first-order model with RMSEA = 0.033 (90% CI, 0.029 to 0.037), CFI = 0.949, TLI = 0.933. As shown in Table 4, factor loadings of items on targeted variables ranged from 0.41 to 0.93, and all of the cross-loadings within sets were smaller than 0.4.

3.2.1 | Reliability

Table 3 shows acceptable reliabilities of MSLQ-CS, ranging from $\omega = 0.67$ (time and study environment management) to $\omega = 0.82$ (self-efficacy for learning and performance) with a mean of $\omega = 0.75$ for all variables.

3.2.2 | Reproduced information

As shown in Table 3, the correlations between the MSLQ-C and MSLQ-CS were high, ranging from $r = .93$ (task value) to $r = .98$ (intrinsic goal orientation and organization) with a mean of $r = .97$. Because the MSLQ-CS in the study was embedded in the MSLQ-C, we then computed Levy's correction correlation that excluded the shared error variance, which ranged from $r = .66$ (control of learning beliefs and metacognitive self-regulation) to $r = .78$ (self-efficacy for learning and performance, organization, and critical thinking). The average Levy's corrected correlation was $r = .72$, indicating that most information obtained from full scale could be reproduced by the short form.

3.2.3 | Nomological network

As shown in Table 3, the correlations between mathematics achievement and variables on MSLQ-CS ranged from $r = -.04$ (text anxiety) to $r = .34$ (time and study environment management). The mean absolute differences in correlations obtained from the MSLQ-C and MSLQ-CS were marginal and nonsignificant, ranging from 0 to 0.07. These results showed that both MSLQ-C and MSLQ-CS displayed similar patterns with mathematics achievement, further supporting the validity of the MSLQ-CS.

TABLE 3 Number of items, reliabilities, reproduced information, and nomological network of MSLQ-C and MSLQ-CS

	Number of items		Reliabilities		Reproduced information		Correlation with mathematics achievement		
	MSLQ-C	MSLQ-CS	MSLQ-C	MSLQ-CS	Without correction	Levy's correction	MSLQ-C	MSLQ-CS	Δr
Intrinsic goal orientation	4	3	0.74	0.77	0.98	0.75	0.30**	0.28**	0.02
Extrinsic goal orientation	3	3	0.65	0.69	1.00	1.00	0.00	0.00	0.00
Task value	6	3	0.87	0.72	0.93	0.67	0.32**	0.28**	0.04
Control of learning beliefs	4	3	0.79	0.69	0.96	0.66	0.18**	0.19**	-0.01
Self-efficacy for learning and performance	5	3	0.90	0.82	0.97	0.78	0.34**	0.33**	0.01
Test anxiety	4	3	0.82	0.74	0.97	0.71	−0.01	-0.04	0.03
Rehearsal	4	3	0.80	0.77	0.97	0.73	0.02	0.01	0.01
Elaboration	5	3	0.85	0.74	0.97	0.70	0.24**	0.21**	0.03
Organization	4	3	0.84	0.81	0.98	0.78	0.10*	0.10*	0.00
Critical thinking	5	3	0.89	0.81	0.97	0.78	0.21**	0.18**	0.03
Metacognitive self-regulation	4	3	0.71	0.70	0.96	0.66	0.28**	0.21**	0.07
Time and study environment management	4	3	0.74	0.67	0.96	0.70	0.31**	0.34**	-0.03
Peer learning	3	3	0.76	0.76	1.00	1.00	0.15**	0.15**	0.00
Help seeking	2	2	0.77	0.77	1.00	1.00	0.11**	0.11**	0.00

Note: Reproduced information analysis was calculated by the correlations between Motivated Strategies for Learning Questionnaire-Chinese version (MSLQ-C) and Motivated Strategies for Learning Questionnaire-short form (MSLQ-CS); Δ*r* (95% confidence interval) is the difference between correlations of self-regulation variables and mathematics achievement as obtained from the MSLQ-C and MSLQ-CS; For peer learning and help seeking, the number of items for MSLQ-C and MSLQ-CS is identical, hence the reliability, reproduced information, and correlation with mathematics achievement are same.

*$p < .05$; **$p < .01$.

TABLE 4 Standardized factor loadings of the Set-ESEM model for MSLQ-CS

	Value			Expectancy		Affect	Cognitive and metacognitive strategies					Resource management		
Items	IGO	EGO	TV	CLF	SE	TA	RE	ELA	ORG	CT	MSR	TE	PL	HS
16	**0.77**	0.03	0.04											
22	**0.63**	0.09	0.15											
24	**0.72**	−0.03	−0.04											
7	0.06	**0.60**	0.10											
11	−0.08	**0.82**	−0.10											
13	0.18	**0.49**	0.05											
10	−0.30	0.11	**0.76**											
17	0.24	−0.17	**0.67**											
27	0.14	0.06	**0.53**											
2				**0.57**	0.12									
9				**0.68**	−0.15									
18				**0.70**	0.07									
5				0.14	**0.64**									
15				−0.08	**0.81**									
31				0.00	**0.86**									
8						**0.58**								
14						**0.78**								
19						**0.73**								
39							**0.83**	−0.04	−0.12	0.06	0.02			
46							**0.82**	−0.04	0.02	−0.07	0.04			
72							**0.41**	0.13	0.28	−0.01	−0.02			
62							0.09	**0.61**	−0.09	0.07	0.13			

TABLE 4 (Continued)

Items	Value			Expectancy		Affect	Cognitive and metacognitive strategies					Resource management		
	IGO	EGO	TV	CLF	SE	TA	RE	ELA	ORG	CT	MSR	TE	PL	HS
69							−0.02	**0.41**	0.28	0.18	0.08			
81							0.02	**0.79**	0.06	0.05	−0.01			
32							0.16	0.38	**0.47**	0.06	−0.13			
42							−0.03	0.05	**0.78**	−0.04	0.13			
63							0.08	−0.17	**0.78**	0.06	0.08			
38							0.09	−0.12	0.04	**0.78**	−0.14			
47							−0.09	0.01	−0.02	**0.90**	0.00			
66							0.00	0.23	−0.05	**0.49**	0.26			
41							−0.02	0.03	−0.02	0.00	**0.81**			
44							0.08	0.02	0.03	0.09	**0.58**			
76							0.07	0.04	0.16	0.00	**0.49**			
43												**0.87**	0.08	−0.10
65												**0.42**	0.02	0.08
70												**0.56**	−0.10	0.15
34												0.22	**0.49**	0.01
45												−0.08	**0.62**	0.18
50												−0.03	**0.93**	−0.07
68												0.00	0.19	**0.67**
75												0.05	−0.09	**0.86**

Note: The items that loaded on the factors (>0.4) are presented in bold.

Abbreviations: CLF, control of learning beliefs; CT, critical thinking; EGO, extrinsic goal orientation; ELA, elaboration; HS, help seeking; IGO, intrinsic goal orientation; MSLQ-CS, Motivated Strategies for Learning Questionnaire-short form; MSR, metacognitive self-regulation; ORG, organization; PL, peer learning; RE, rehearsal; SE, self-efficacy for learning and performance; Set-ESEM, set exploratory structural equation modeling; TA, test anxiety; TE, time and study environment management; TV, task value.

4 | DISCUSSION

The MSLQ has been extensively used to explore the role of self-regulated learning in academic settings. To generalize the application of the MSLQ to the Chinese context and the domain of mathematics, the first goal of this study was to adapt and validate the MSLQ for Chinese senior secondary students in mathematics learning (i.e., MSLQ-C). The second goal was to develop the short form of MSLQ that can be used to measure students' self-regulations when short measures are necessary (i.e., MSLQ-CS). The results demonstrated satisfactory psychometric properties for both MSLQ-C and MSLQ-CS.

For construct validity, both MSLQ-C and MSLQ-CS achieved an acceptable fit for the 14-factor correlated model, which corroborates the original factor structure proposed by Pintrich et al. (1993). This study extends the existing research by exploring the factor structure of MSLQ with Set-ESEM. Compared with EFA, CFA, and ESEM, Set-ESEM considers the relationship across and within each domain, making the factor structure more rigorous (Marsh et al., 2020).

Acceptable reliability was found for each variable, which is consistent with previous research (e.g., Pintrich et al., 1993). This finding suggests that both MSLQ-C and MSLQ-CS possess acceptable internal consistencies in the Chinese context. It is not surprising that the reliabilities of the MSLQ-CS were slightly lower than MSLQ-C as true variance increases more rapidly than error variance when the number of items increases (Embretson & Reise, 2000). For example, Kruyen et al. (2013) analyzed the 137 pair of long scales and their corresponding short form, and they found the mean reliabilities in internal consistency decreased from α = .84–.77. However, intrinsic and extrinsic goal orientation are two exceptions because the short form' reliabilities were marginally higher than full scale, presumably because problematic items (i.e., items with correlated errors) were deleted during the development of the short form.

We found that all variables, except for extrinsic goal orientation, test anxiety, and rehearsal, had significant and low-to-medium correlations with mathematics achievement. These findings are in accordance with the evidence reported in previous studies (e.g., Ocak & Yamac, 2013; Shores & Shannon, 2007), which revealed the applicability of MSLQ-C and MSLQ-CS to be associated with academic achievement. Furthermore, both MSLQ-C and MSLQ-CS showed similar correlations with mathematics achievement with marginal and nonsignificant differences. Hence, our results demonstrated that MSLQ-C and MSLQ-CS are embedded in a similar nomological network and could help researchers draw similar results when connecting it with mathematics achievement.

Our study also indicated that the MSLQ-C and MSLQ-CS were highly correlated, which showed that a large amount of information measured by the MSLQ-C could be reproduced by MSLQ-CS (Girard & Christensen, 2008; Levy, 1967). This implies that the items in the short form are the most representative of the full scale and could assess the complexity of the theoretical construct of self-regulated learning.

Compared with previous research that developed short forms by removing variables (e.g., Pintrich & de Groot, 1990), our study selected subsets of items within each variable. This method extends previous research by keeping almost all variables within the self-regulated theoretical framework proposed by Pintrich and Zusho (2002). With MSLQ-CS, researchers could explore the relationship between self-regulated learning behaviors with less burden placed on students than the MSLQ-C.

5 | CONTRIBUTIONS, LIMITATIONS, AND FUTURE DIRECTIONS

The present study makes three significant contributions. First, we adapted the MSLQ for Chinese secondary students in mathematics learning. The adapted questionnaire extends the application scope of the MSLQ to measure Chinese students' mathematics learning, which could help researchers extend self-regulated learning research in the Chinese context.

Second, the MSLQ-CS exhibited acceptable psychometric properties, which provide an alternative for researchers to capture the students' self-regulation with fewer items. The MSLQ-CS with fewer items is practical and user-friendly. It is easier to be administered due to the fewer constraints of administration time and less space in the overall survey package. Furthermore, it might improve the quality of research data because it could reduce participants' fatigue, frustration, and boredom brought by long response time and redundant items.

Third, the present study would help measure and potentiall improve Chinese secondary students' mathematics learning. This study has demonstrated the close relationship between self-regulated learning and mathematics achievement (Dent & Koenka, 2016). Using this psychometrically sound instrument, researchers and educators could better understand the current status of students' self-regulated learning and develop intervention targets to help them develop a high level of self-regulation in mathematics learning.

Despite the above-mentioned contributions, a few limitations need to be addressed in future studies. First, negatively worded items were removed from the original MSLQ according to the results of item performance, which is consistent with previous research (Law et al., 2008; Rao & Sachs, 1999; Sachs et al., 2001). Credé et al. (2009) argued that positively and negatively worded items might measure different constructs. Many studies on MSLQ have indicated that Chinese students had some problems responding to the negatively worded items, which were clustered to form a separate "method" scale and removed (Law et al., 2008; Rao & Sachs, 1999; Sachs et al., 2001). However, some researchers may argue that negatively worded items are essential to control for acquiescence response style (Nunnally & Bernstein, 1994), and a balance of positively and negatively worded items might increase the validity of the measures (Kam & Meyer, 2015). Hence, more advanced statistical methods (e.g., factor mixture modeling; Kam & Fan, 2020) are recommended in future studies to explore the role of negatively worded items in the MSLQ.

Second, the data were collected at the same time point. Hence, this study was cross-sectional in nature. We did not conduct the predictive validity given that the best way to establish predictive validity is through conducting a longitudinal study. We encourage future studies to adopt a more rigorous research design by collecting longitudinal data to examine the predictive validity of the MSLQ. Furthermore, the test-retest reliability information obtained from repeated assessments would also be useful.

Third, in line with previous research (e.g., Gogol et al., 2014; Sánchez et al., 2021), our short form was administrated as part of the corresponding full scale. This may overestimate the relationship between short form and full scale because of the shared correlated measurement error. Although Levy's correction (1967) used in our study accounted for shared error, it would be advisable to assess agreement between the full scale and the short form with independent samples.

Fourth, the participants of this study were all drawn from Guangdong province, which is more economically advanced than other provinces in China. We encourage future studies to replicate our research in other regions of China to examine the generalizability of the findings.

Fifth, we deleted the redundant items mainly based on the psychometric properties of the items (i.e., factor loading, modification indices, and item-total correlation). This kind of data-driven decision might ignore the differences in the content. Hence, we encourage future studies to delete the redundant items with a combination of data-driven and theory-driven approaches. For example, a qualitative interview can be conducted to explore students' nuanced understanding of the similarities and differences in the redundant items.

6 | CONCLUSION

A reliable and valid instrument is an essential step to effective measurement, intervention, and improvement. This study adapted and validated the MSLQ for Chinese secondary students in mathematics learning. The MSLQ-C demonstrated acceptable construct validity, reliability, and concurrent validity. More importantly, we developed a short form, the MSLQ-CS, which is psychometrically sound and able to replicate the information obtained from the longer form of the MSLQ-C. The short form can reduce participants' burden and be used when the test time and space are limited, providing a practical tool for mathematics education researchers.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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