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Methodology

Validation of the Shortened Version of the Metacognitive Awareness Inventory in Spanish University Students

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ABSTRACT

Background: The Metacognitive Awareness Inventory (MAI) is used all over the world to identify metacognitive components that are relevant to learning. However, there is not enough evidence confirming its factorial structure or the suitability of its Shortened Version, proposed by various authors. Also, to date, the MAI has not been validated in the Spanish context. **Method:** After adapting the MAI to Spanish, it was administered to 1076 university students from different regions of Spain. Different structures of the MAI Shortened Version, with 19 items, were compared with the structures of the original 52-item MAI. Indexes of validity and reliability were analyzed, considering the factorial structure and relationships to other validated questionnaires. **Results:** Only the MAI Shortened Version that differentiates between knowledge and regulation of cognition achieved a good fit. These two scales showed good convergent and divergent validity, high criterion validity in relation to academic achievement, high test-retest reliability, and high internal reliability. **Conclusions:** results support the traditional differentiation between knowledge of cognition and regulation of cognition, but only for the Shortened Version of the MAI. This instrument allows quick evaluations and identification of these components in Spanish contexts with adequate metric properties.

Validación de la Versión Abreviada del Inventario de Conciencia Metacognitiva en Estudiantes Universitarios Españoles

RESUMEN

Antecedentes: El Inventario de Conciencia Metacognitiva (MAI) se utiliza internacionalmente para identificar componentes metacognitivos relevantes para el aprendizaje. Sin embargo, hay escasa evidencia sobre su estructura factorial y la validez de su Versión Reducida, propuesta por diversos autores. Asimismo, hasta el momento, no ha sido validado en el contexto español. **Método:** Tras adaptar los ítems del MAI al español, se administró a 1076 estudiantes universitarios de diferentes regiones de España. Se compararon varias estructuras de la Versión Reducida del MAI, con 19 ítems, y del MAI original, con 52 ítems. Se analizaron la validez y fiabilidad, considerando las estructuras factoriales y las relaciones con otros cuestionarios ya validados. **Resultados:** Sólo la Versión Reducida del MAI que diferencia conocimiento y regulación de la cognición alcanzó un ajuste aceptable. Estas dos escalas mostraron buena validez convergente y divergente, alta validez de criterio en relación al rendimiento académico, alta fiabilidad test-retest y alta consistencia interna. **Conclusiones:** los resultados apoyan la diferenciación tradicional entre conocimiento de la cognición y regulación de la cognición, pero solo con la adaptación al español de la Versión Reducida del MAI. Este instrumento permite evaluaciones cortas y la identificación de estos componentes con propiedades métricas adecuadas en contextos españoles.

Palabras clave:
Evaluación de la metacognición
Autoinforme
Análisis factorial confirmatorio
Regulación y conocimiento metacognitivos
Autorregulación del aprendizaje

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Metacognition is recognized as one of the most important aspects for learning effectively (Bjork et al., 2013). Sometimes defined as the ability to *think about thinking*, it refers to the mental processes that we employ to recognize and control our own thoughts (Brown, 1987; Flavell, 1979). Within this context, it is vital to have reliable and easy-to-administer measuring instruments that help identify the metacognitive components that are functional for learning.

Measurement of metacognition is, however, a complex task. It can involve several types of internal processes which are difficult to categorize and are not directly observable. As Norman et al. (2019, p. 3) argued, "as we think, speak, argue, solve problems, or simply search for the right words in a conversation, we constantly monitor our own thinking. We evaluate it, we judge it, we sometimes even try to influence it. Only rarely do we rest in the moment without engaging in metacognition". These processes can occur with higher or lower levels of awareness. They can even occur subconsciously (Veenman et al., 2006). However, there is an agreement defining some metacognitive components that can have important implications in people's day-to-day functioning, and are relatively observable and measurable from what people say or do.

One of these components is *knowledge of cognition (or metacognitive knowledge)*, defined as the extent to which we are aware of our own mental capacities, the available mental strategies we can use, and the ways we apply these strategies in different contexts (Brown, 1987; Schraw & Dennison, 1994). Another metacognitive component is *regulation of cognition (or metacognitive regulation)*, which refers to how often we put into action different types of mental strategies to recognize and control our thinking (Brown, 1987; Schraw & Dennison, 1994). These can include planning strategies before a mental task is begun, monitoring strategies during the task, or evaluation of the process once the task is finished (Baker, 1989; Schraw & Dennison, 1994). Interventions grounded in these two metacognitive components have led to the promotion of learning, academic self-concept, and academic achievement in areas such as mathematics, comprehensive reading, and science (Antúnez et al., 2020; de Boer et al., 2018; Dignath et al., 2008; Donker et al., 2014; González-Cabañes et al., 2020), with effects persisting over time (de Boer et al., 2018). In addition, from a descriptive and comparative viewpoint, metacognition has demonstrated to help distinguish groups with different mathematics and writing abilities (Garcia, Betts, et al., 2016; Garcia et al., 2015; Garcia, Rodriguez, et al., 2016), even in populations with learning problems (Rodríguez et al., 2017).

Despite that, there are still some limitations in the available measures for evaluating metacognitive components. In this sense, metacognition can be measured through online protocols that ask people about the mental processes they experience at a given moment, such as think-aloud protocols (Heirweg et al., 2020; Whitehead & Jackman, 2021). However, these measures are not suitable in all contexts because they can interfere with the learning processes and are costly and hard to apply in large groups.

Thus, it is also important to have reliable self-reports, which, although more subject to memory and interpretation bias (McNamara, 2011), are cost-effective and easy to administer in larger samples (Veenman et al., 2006). Some examples are the *Metacognitive Awareness Inventory* (MAI) (Schraw & Dennison, 1994), the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993), the Learning and Study Strategies Inventory (LASSI) (Weinstein et al., 1987), and the Questionnaire to Assess Learning Strategies in University Students (CEVEAPEU) (Gargallo et al., 2009). However, according to a recent review (Craig et al., 2020), for the available self-report questionnaires there are few validation studies confirming the specific metacognitive components measured in them, or the convergent validity between these tools and other metacognitive measures.

Among these self-reports, the MAI is of great importance in university and high school contexts because its original construction was based on well-established theories about metacognition and metacognitive components that are functional for learning (Baker, 1989; Brown, 1987; Flavell, 1987). Also, it is adaptable to a great variety of educational contexts, including problem-solving activities and different learning activities. However, there is still limited evidence confirming its internal and convergent validity (Craig et al., 2020).

Specifically, the MAI was originally conceived with 52 items distributed between the two components of *knowledge of cognition* and *regulation of cognition*, across eight subcomponents (Schraw & Dennison, 1994) (see Table 1 for a description of its structure).

Table 1.
Operational Definitions of Content Included in the MAI and Corresponding Items.

Categories	Subcategories	Definition	Items
Knowledge of Cognition	Declarative Knowledge	Knowledge about one´s skills, intellectual resources, and abilities as a learner	5, 10, 12, 16, 17, 20, 32, 46
	Procedural Knowledge	Knowledge about how to implement learning procedures	3, 4, 27, 33
	Conceptual Knowledge	Knowledge about when and why to use learning procedures	15, 18, 26, 29, 35
Regulation of Cognition	Planning	Planning, goal setting, and allocating resources prior to learning	4, 6, 8, 22, 23, 42, 45
	Information Management	Skills and strategy sequences used on-line to process information more efficiently (e.g., organizing, elaborating, summarizing, selective focusing)	9, 13, 30, 31, 37, 39, 41, 43, 47, 48
	Monitoring	Assessment of one´s learning or strategy use	1, 2, 11, 21, 28, 34, 49
	Debugging	Strategies used to correct comprehension and performance errors	25, 40, 44, 51, 52
	Evaluation	Analysis of performance and strategy effectiveness after a learning episode	7, 19, 24, 36, 38, 50

Note. The table has been adapted from Schraw and Dennison (1994). Items in the shortened version of Harrison and Vallin (2018) are in bold.

Compared to other widely used metacognitive self-reports, such as the metacognitive scales in CEVEAPEU, MSLQ, and LASSI, one important feature of the MAI is the inclusion of a scale that specifically addresses the component of knowledge of cognition as differentiated from the component of regulation of cognition, which is a structure supported by most validation studies (Craig et al., 2020).

Another advantage of the MAI is that the items are short and easy to interpret. Respondents are asked to indicate how much different statements, such as "I set specific goals before I begin a task", apply to their own learning experiences. In the original version from 1994, respondents answered by marking how much they identified with each item on a 100 mm false-to-true line. In a posterior adaptation of the scale by Harrison and Vallin (2018), with the purpose to adjusting it to the expression of the items and reducing acquiescence bias, respondents answered following a 5-point Likert-type scale (from 1 = not at all typical of me to 5 = very typical of me). This aspect suggests that it is a scale that attracts the attention of researchers in the field of psychological measurement still today.

Also, items from the MAI refer to general situations, which makes it easier to apply the questionnaire in a variety of contexts. In addition to being used in typical domains of studying (Abdelrahman, 2020; García et al., 2020), the MAI has also been used in contexts related to problem-solving activities (González-Cabañes et al., 2021; Hargrove & Nietfeld, 2015; Turan et al., 2009), collaborative learning tasks (Çini et al., 2020), foreign language acquisition (Pishghadam & Khajavy, 2013), and searching for information online (Reisoglu et al., 2020), among others.

Nevertheless, one potentially significant limitation of the MAI is the scarce, less-than-conclusive evidence confirming its factor-structure. Some studies have provided support for the originally hypothesized two factor-structure differentiating between knowledge of cognition and regulation of cognition (Lima-Filho & Bruni, 2015; Magno, 2010; Schraw & Dennison, 1994) (Table 1, Column 1). Other studies have provided support for the eight-factor structure (also hypothesized originally) differentiating the eight subcomponents of the two aforementioned factors (Akin et al., 2007; Magno, 2010; Pour & Ghanizadeh, 2017) (Table 1, Column 2). Alternative structures were also suggested, result of the adaptation of the MAI to different languages and cultures (Favieri, 2013; Teo & Lee, 2012), although without theoretical bases to justify them (Teo & Lee, 2012), or based on specific math learning contents hardly generalizable (Favieri, 2013). This lack of consistent results has led to questions among researchers and professionals about the appropriate way to score the MAI (i.e., factor structure) and about the validity of the scores (Harrison & Vallin, 2018). In practice, all of the above structures have been used, as well as a unidimensional structure with a single indicator of general metacognition (see Harrison & Vallin, 2018, for a review).

As far as we are aware, the only study that compared several factor-structures of the MAI was by Harrison and Vallin (2018). This study did not provide clear support for any of the originally hypothesized two- and eight-component models (Schraw & Dennison, 1994), or a single-component model. However, they did find support for the two-factor structure after removing problematic items, leading to a Shortened Version of the MAI (with 19 items) that maintain representation of all the scales and subscales originally hypothesized by Schraw and Dennison (1994). A shorter version is definitely an advantage that can reduce the time needed to administer a questionnaire and reduce error due to elusive items. However, the results of that study, and specifically the new proposal of a Shortened Version of the MAI, have not been confirmed in other samples. This is one of the objectives of the present study.

Another limitation of the MAI is the scarce evidence of convergent validity. A prior study has shown weak or moderate correlations for predicting most MAI scales from other metacognitive self-reports (Muis et al., 2007). Also, associations with academic achievement and the MAI scales were generally weak or moderate (Abdelrahman, 2020; Ohtani & Hisasaka, 2018; Pishghadam & Khajavy, 2013), similar to when academic achievement is predicted with other metacognitive self-reports (Dent & Koenka, 2016; Ohtani & Hisasaka, 2018). However, it is important to bear in mind that these associations were calculated from MAI scales that, as previously commented, count with little support for their internal validity. It is important to continue providing this predictive evidence after further examination of the scoring models.

Lastly, one practical limitation of the MAI is that there is no validated version in the Spanish cultural context. Although the MAI has been adapted into Spanish in the Argentinian context (Favieri, 2013), different expressions in the Spanish cultural context can create problems for instrument validity (Muñiz et al., 2013). In addition, as previously noted, the study by Favieri (2013) did not compare the hypothesized factor-structures of the MAI.

In summary, considering the absence of an adaptation to the Spanish context, and, in general, the lack of agreement in the ways to score the MAI and the potential implications it has for predicting other measures, the present study has three main aims: first, to adapt the MAI to the linguistic and cultural context of Spanish university students; second, to examine the factor structure of the questionnaire, comparing different scoring models proposed in the literature across both the original MAI and its Shortened Version; and third, to provide evidence of validity and reliability, including convergent validity, divergent validity, criterion validity in relation to final grades in university courses, internal reliability, and test-retest reliability.

Method

Participants

The sample comprised 1076 university students (ages ranging from 17 to 54 years old, 65.83% female), whose detailed demographic information is shown in table 2. They belonged to 199 class groups taught by 77 different teachers and were studying 54 different degree courses in 20 Spanish Universities. Although the initial sample comprised 1145 students, the responses from 69 of the students were eliminated because they did not properly respond to items designed to control for a lack of attention when completing the questionnaire (see Instruments section).

Most of the students in the sample were found using a multistage cluster sampling method (n = 701), where teachers were contacted primarily, and those who agreed to collaborate invited their students to participate. To do this, 20 universities were randomly selected from the population of Spanish universities. Random teachers from a random selection of departments were then contacted. However, because of the low rate of teacher and student responses, the number of teachers and departments selected in each university was increased as data collection advanced, which led to higher representation of students in some universities. In addition, because of the low response, that sampling method was complemented with convenience sampling (n = 375), asking university teachers known to the researchers to ask their students to complete the questionnaire, and to facilitate administration during class-time where possible (n = 339).

Within the full sample completing the MAI, there were three sub-samples who also completed additional evaluation measures. One subsample made up of 323 students also completed the CEVEAPEU questionnaire (Table 2, Subsample 1). Another subsample of 311 students provided access to their academic grades (Table 2, Subsample 2). Finally, 85 students completed the MAI a second time, 2 months after the initial administration (Table 2, Subsample 3).

Instruments

The main instrument in this study was the Metacognitive Awareness Inventory (MAI) adapted to Spanish, which is available in Open Science Framework (https://osf.io/zthdj). This adaptation included all of the original 52 items in the MAI, and the updated response scale proposed by Harrison and Vallin (2018) to reduce acquiescence bias (Likert type scale from 5 = "very typical of me" to 1 = "not at all typical of me"). The distribution of items across the different theoretical metacognitive components is shown in Table 1. This table also shows the distribution of items in the reduced version proposed by Harrison and Vallin (2018). Previous studies have shown high levels of reliability for the different proposed scales (α = .66-.88) (Abdelrahman, 2020; Harrison & Vallin, 2018; Muis et al., 2007; Schraw & Dennison, 1994).

The *CEVEAPEU* questionnaire (Gargallo et al., 2009) was used to evaluate convergent and divergent validity of the Spanish version of the MAI. This questionnaire addresses self-regulation of learning and comprises 88 items distributed across several scales referring to self-regulation, including: Motivation Strategies (20 items, e.g. "I study because I am interested in learning"), Affective Components (eight items, e.g., "I am able to relax and maintain peace of mind in stressful situations like exams, exhibitions, or having to speak in public"), Metacognitive Strategies (15 items, e.g., "I plan my time to work on the course subjects throughout the academic year"), Context Control Strategies (10 items, e.g., "I normally study in a place where it is possible to concentrate on my work"), Informa-tion Search Strategies (eight items, e.g., "I am capable of separating the basic information to prepare the course subjects from that which is not"), and Information Processing Strategies (27 items, e.g., "I create simple graphs, figures, or tables to organize the study materials"). Respondents answer on a Likert-type scale from 1 (totally disagree) to 5 (completely agree). High reliability was found in our sample for these scales (respectively, α values were .706, .713, .800, .791, .697, .875). These indexes of internal reliability were similar to the ones found in the original validation in a sample of Spanish University students (Gargallo et al., 2009). In the present study, the CEVEAPEU scales of "metacognitive strategies", "information search strategies" and "information processing strategies", were used to provide evidence of convergent validity of the Regulation of Cognition scale in the Spanish version of the MAI.

Also, course grades from the final exams for four class groups were used to evaluate criterion validity. All of the groups were taking courses at a university in Northern Spain. Two of the class groups were in the fourth year of a Psychology degree, other was in first year of a Pre-Primary Education degree, and the other group in second year of the same degree. Grades in these four courses were scored from 0 to 10. Descriptive statistics of all the study variables are provided in Table 2.

Last, four items to control for lack of attention bias when completing the questionnaires were included. (two per questionnaire). All of these items were worded in the same way: "In this question you have to select option x", only differing in the option required to be chosen.

Table 2.
Descriptive Information for the Sample Completing the MAI and Subsamples Providing Additional Measures.

		General Sample (MAI) N = 1076	Subsample 1 (MAI + CEVEAPEU) n = 323	Subsample 2 (MAI + grade scores) n = 311	Subsample 3 (MAI + 2nd Adm. MAI) n = 85
Age	M (SD)	22.46 (6.54)	21.14 (5.73)	21.17 (3.98)	22.17 (4.87)
Gender	Male	367 (34.2%)	65 (20.1%)	51 (16.4%)	16 (18.8%)
	Female	707 (65.8%)	258 (79.9%)	259 (83.3%)	69 (81.2%)
Year	1st year	310 (28.8%)	135 (41.8%)	85 (27.3%)	85 (100%)
	2nd year	205 (19.1%)	70 (21.7%)	28 (9%)	-
	3rd year	165 (15.3%)	19 (5.9%)	-	-
	4th year	337 (31.3%)	99 (30.7%)	198 (63.7%)	-
	higher	59 (5.5%)	-		-
Knowledge area	Health Sciences	244 (22.7%)	130 (40.2%)	198 (63.7%)	85 (100%)
	Social Sciences	412 (38.3%)	149 (46.1%)	113 (36.3%)	-
	Natural Sciences	138 (12.8%)	20 (6.2%)	-	-
	Technical Sciences	194 (18.0%)	10 (3.1%)	-	-
	Humanities	88 (8.2%)	14 (4.3%)	-	-

Procedure

The study was approved by the Ethical Committee for the Investigation of the Principality of Asturias (Reference: 79/19). After obtaining permission from the original authors (Schraw & Dennison, 1994), the MAI items were adapted to the Spanish culture and language. Three independent translations were made separately by two experts in educational research and a pro-fessional translator. The three translations were then discussed by a committee made up of the same translator and professionals in the field, following the principles in Hambleton and Zenisky (2010) for adaptations of tests for Cross-Cultural Assessments. Once agreement was reached about all the items, a back translation to English was performed and evaluated by the research team. No significant changes in meaning were identified. This Spanish version was piloted in 6 graduate students who were asked to report potential ambiguities or confusions, which led to minor changes in word choice, grammar, and punctuation. This produced the MAI items adapted to Spanish used in the study (https://osf.io/zthdj).

Respondents were given detailed information about the aims and scope of the study. Subsequently, after providing informed consent, they completed the Spanish MAI items and the other assessments included in the study online. The MAI items were completed first, followed by the CEVEAPEU for those students who participated in that evaluation. Finally, students provided information about their demographic characteristics. As part of this final section, students who agreed to allow access to information about their academic grades provided their student numbers so that their teachers could anonymously provide that information.

Data analysis

Confirmatory Factor Analysis (CFA) was used to examine the factor structure of the MAI. Five different models were tested. From the original extended 52-item version of the MAI (Schraw & Dennison, 1994) it was tested the unidimensional model, the bidimensional model differentiating between knowledge and regulation of cognition, and the eight dimensional model with the eight factors from the eight second-order scales by Schraw & Dennison (1994). From the19-item Shortened Version of the MAI (Harrison & Vallin, 2018) a unidimensional and the bidimensional model of knowledge and regulation of cognition were tested. The data did not follow a normal distribution (Mardia coefficient = 83.23). Thus, maximum likelihood estimation with robust standard errors (Satorra & Bentler, 1988) was used in the CFA. The goodness of fit of the models was reported in terms of Chi Square (χ^2) and its associated degrees of freedom (*df*), the χ^2/df ratio, the Comparative Fit Index (CFI), the Standardized Root Mean Square Residual (SRMR), the Root Mean Square Error of Approximation (RMSEA), and the Akaike Information Criterion (AIC). The cut-off criteria to determine adequate fit were SRMR $\leq$ .08, RMSEA $\leq$ .06 (Hu & Bentler, 1999), and CFI $\geq$ .90 (Marsh et al., 2005). AIC was used as an indicator to compare the models, with lower values being preferable. Lastly, the standardized factor weights were evaluated to analyze homogeneity in the scales. Typically, standardized factor weights higher than .30 are considered acceptable (Izquierdo et al., 2014).

Convergent validity was evaluated by means of Pearson correlations between the Regulation of Cognition scale in the MAI and three CEVEAPEU scales that address the same metacognitive strategies construct: Information Search Strategies, Information Processing Strategies, and Metacognitive Strategies. Requirements of normality, linearity and homoscedasticity were fulfilled.

Discriminant validity was also evaluated through the Hetero-trait-Monotrait (HTMT) ratio, which is generally considered acceptable when is lower than .9 (Henseler et al., 2015). Additionally, discriminant validity was explored by looking at Pearson correlations between the MAI scales and the CEVEAPEU scales that do not directly address metacognition (Motivational Strategies, Affective Components, and Context Control Strategies).

Criterion validity was explored by means of Spearman correlations between the MAI scales and the course grades. This non-parametric statistic was used because course grades failed to follow normal distributions.

Finally, reliability was analyzed in terms of internal consistency and test-retest reliability. For internal consistency, Cronbach alpha (α) and composed reliability (CR) (Fornell & Larcker, 1981) were reported, with values higher than .70 indicating good reliability. For test-retest reliability, Pearson correlations were calculated to explore associations between the two administrations of the MAI two months apart.

The majority of the analysis was done using the R software version 4.0.4 (R Core Team, 2021). The R package MVN version 5.9 (Korkmaz et al., 2014) was used for multivariate normality analyses; The R package lavaan version 0.6.9 (Rosseel, 2012) for calculations of the CFA, fit indexes, and CR; and the R package semTools version 0.5-5 (Jorgensen et al., 2021) was used to calculate the HTMT ratio. SPSS version 23 was used to calculate Pearson correlations, α indexes, and descriptive statistics.

Results

Model Fit Factorial Analyses

Table 3 shows the goodness-of-fit indices for the five models used to score the MAI. None of the three models with the MAI of 52 items reached adequate fit. Specifically, standards were not fulfilled for the CFI. The unidimensional model with the MAI Shortened Version of 19 items reached better fit than all of these models with the MAI of 52 items, according to all fit indicators. However, still the CFI did not reach adequate fit.

The only model reaching adequate fit was the bidimensional model from the Shortened Version of 19 items differentiating between the components of knowledge of cognition and regulation of cognition. The fit of this model was the best according to all fit indexes. Therefore, this model was retained for further analysis of validity and reliability, henceforth referred as the Spanish version of the MAI (MAI-SP).

Homogeneity of the MAI-SP was explored in terms of how much the different factors were explained by their corresponding items. Figure 1 shows that all standardized regression coefficients were between .40 and .70, suggesting acceptable levels of homogeneity for the two scales, but also that these levels were moderate.

Convergent validity

Support for convergent validity of the MAI-SP Regulation of Cognition factor was found in terms of strong correlations with the CEVEAPEU scales that also address this component: information search strategies, information processing strategies, and metacognitive strategies (r = .52-.71) (Table 4). The MAI-SP factor referred to Knowledge of Cognition was not analyzed in relation to the CEVEAPEU scales, because these scales do not directly address this construct.

Discriminant Validity

As indicated in Figure 1, the two scales, Knowledge of Cognition and Regulation of Cognition, exhibited a strong correlation with each other (latent correlation = .83; manifest Pearson correlation = .65). However, in spite of this strong correlation, the HTMT ratio was lower than .90 (HTMT = .82), indicating that correlations between items pertaining to the same MAI-SP scales were substantially higher than correlations between items across different MAI-SP scales. Therefore, no discriminant validity problems were identified.

Table 3.
Goodness-of-fit Estimates of the four MAI scoring models.

	χ^2 (df)	χ^2/df	CFI	RMSEA	SRMR	AIC
Unidimensional (52 items)	6076.93 (1274)	4.77	.650	.059	.063	149406.23
Knowledge & Regulation (52 items)	5705.53 (1273)	4.48	.677	.057	.062	148966.81
Eight dimensional (52 items)	5148.95 (1246)	4.13	.715	.054	.063	148393.92
Unidimensional (19 items)	677.35 (152)	4.45	.867	.057	.062	54617.57
Knowledge & Regulation (19 items)	542.01 (151)	3.59	.902	.049	.044	54458.93

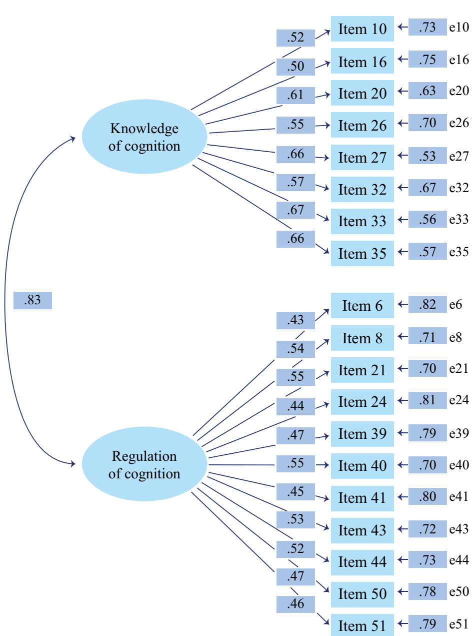

Figure 1.
Factorial Structure of the MAI-SP.

Discriminant validity of the MAI-SP scales was also supported by the pattern of relationships between the MAI-SP scales and the CEVAPEU scales (Table 4). The two MAI-SP factors were just moderately associated with motivational and affective components measured via CEVEAPEU. These associations were weaker than the associations between MAI-SP factors and CEVEAPEU scales that address the same constructs (as described in the previous section).

Criterion Validity

The MAI-SP scales were able to significantly predict academic achievement in most university courses included in this study, but not all. As Table 5 shows, both MAI-SP factors were significantly and moderately associated with grades in the 4th year of psychology and the 1st year of Pre-Primary Education degrees. The only year where these correlations were not significant (2nd year Pre-Primary Education course), the sample size was very small (*n* =28).

Reliability

The two MAI-SP scales demonstrated good internal consistency using both the Cronbach alpha and the CR indicators (Knowledge of cognition: α = .812, *CR* = .813; Regulation of cognition: α = .772, *CR* = .777). In addition, similarly high levels of internal reliability were found in the second administration of the MAI (Knowledge of Cognition: α = .817; Regulation of Cognition: α = .817).

Concerning test-retest reliability after two months, results showed good consistency of students' responses to the questionnaire over time, with strong correlations between the two administrations of the MAI-SP for both the Knowledge of Cognition (r = .754, p < .001) and the Regulation of Cognition (r = .820, p < .001) scales.

Table 4.
Correlations between MAI-SP Scales and CEVEAPEU Scales.

CEVEAPEU scales	MAI-SP scales	
	Knowledge of Cognition	Regulation of Cognition
Information Search Strategies	.53	.52
Information Processing Strategies	.58	.71
Metacognitive Strategies	.49	.58
Motivational Strategies	.39	.42
Affective Components	.40	.27
Context Control Strategies	.36	.24

Note. All correlations were significant at the level p < .001.

Table 5.
Correlations between the MAI-SP Scales and Course Grades.

Courses of the Grades Name (year)	n	Scales in the MAI-SP	
		Knowledge of Cognition rho (p)	Regulation of Cognition rho (p)
4th year psychology (2018)	94	.21 (.039)*	.27 (.009)**
4th year psychology (2019)	100	.26 (.008)**	.17 (.084)
2nd year Pre-Primary Education	28	.16 (.407)	.17 (.387)
1st year Pre-Primary Education	87	.30 (.005)**	.36 (.001)**

Note. rho = Spearman correlation; *Significant at the level p < .05; ** Significant at the level p < .01

Discussion

The aim of the present study was to present the structure and psychometric characteristics of an adaptation of the MAI to the Spanish context (MAI-SP), by validating it in a sample of Spanish university students. The results from the present study show that the best fitting model corresponded to the Shortened Version of the MAI proposed by Harrison and Vallin (2018), made up with 19 items distributed in two scales: *Knowledge of Cognition* (8 items), which refers to the awareness of our mental strategies and how to apply them (Brown, 1987; Schraw & Dennison, 1994); and *Regulation of Cognition* (11 items), referring to how often we put different mental strategies into action (Baker, 1989; Schraw & Dennison, 1994).

In line with Harrison and Vallin (2018), only this Shortened Version demonstrated adequate fit. In addition, the fit for this model was substantially higher than for the other models that used the extended version with all of the original 52 items. It is particularly noteworthy that the eight dimensional model, which could provide greater capacity to differentiate between metacognitive components, did not exhibit an adequate fit. In general, for all three extended versions, measurement error can be increased by elusive items, as discussed by Harrison and Vallin (2018). Based on these results, the adaptation of the Shortened Version of the MAI differentiating between *knowledge of cognition and regulation of cognition* (Harrison & Vallin, 2018) constituted the final version of the MAI adapted to Spanish (MAI-SP).

The MAI-SP demonstrated high levels of validity and reliability. In terms of convergent validity, the scale of Regulation of Cognition exhibited strong correlations with other scales in the CEVEAPEU questionnaire addressing the same construct, even though these scales in the CEVEAPEU referred to more specific components of regulation of cognition. These correlations were stronger (all strong correlations) than other correlations found in a previous study (Muis et al., 2007) that also explored convergent validity of the MAI in relation to other questionnaires, albeit using the eight-dimensional model of the original version of the MAI.

However, it is important to note that when homogeneity of the scales was evaluated in terms of internal association between items of the same MAI-SP scales, these associations were only moderate. This is consistent with previous MAI validation studies, which also found standardized factor weights below .70 for most of the items (Favieri, 2013; Lima-Filho & Bruni, 2015; Pour & Ghanizadeh, 2017; Schraw & Dennison, 1994; Teo & Lee, 2012). These moderate associations might be explained by the variety of components that the MAI scales might include (Schraw & Dennison, 1994), even if we failed to reliably identify them as subscales.

The MAI-SP also showed acceptable discriminant validity. Although there was a strong association between the two MAI-SP scales, the items that pertained to the Knowledge of Cognition scale clearly correlated more strongly with each other than with items in the Regulation of Cognition scale and vice versa. It is also important to note that CEVEAPEU scales addressing the same components as the MAI-SP scales had stronger correlations with these MAI-SP scales than with other CEVEAPEU scales addressing different components such as motivation or affective dispositions.

Regarding criterion validity, both metacognitive components measured in the MAI-SP predicted academic achievement in several courses, with weak and moderate correlations. As far as we know, this is the first time the Shortened Version of the MAI has been used to predict academic achievement, either using this Spanish version or the English version (Harrison & Vallin, 2018). The strength of these correlations was similar to correlations in other studies where academic achievement was predicted by scales from the original version of the MAI (Ohtani & Hisasaka, 2018), or with other metacognitive self-reports (Dent & Koenka, 2016; Ohtani & Hisasaka, 2018).

Lastly, the MAI-SP demonstrated high levels of reliability, both in terms of internal consistency and test-retest reliability. Specifically, and in coherence with Harrison and Vallin (2018), the items pertaining to the same MAI-SP scale were highly correlated with each other. As in the mentioned study, students from the current sample exhibited consistency in how they responded over time, even with two months between the two test administrations.

Given these results, the present study has important theoretical and practical implications. From a theoretical point of view, it provides support for the differentiation between two metacognitive components that are related to learning, *knowledge of cognition and regulation of cognition* (Brown, 1987; Schraw & Dennison, 1994). Although both components include a wide variety of mental processes (Schraw & Dennison, 1994), they are the most specific components that self-report questionnaires of metacognition are generally able to identify (Craig et al., 2020), and our study was no exception. However, this should not be interpreted as them being the only existing metacognitive components (Craig et al., 2020). Further developments of the MAI or other self-report questionnaires might facilitate identification of more specific metacognitive components. From a practical viewpoint, this study provides professionals in the field of Psychology and Education from the Spanish context with a brief, valid and reliable tool to evaluate metacognitive components. The MAI-SP is a concise questionnaire, it is quick and easy to implement in large samples, and has adequate metric properties. Furthermore, the way it is scored has a direct correspondence with the validated Short Version of the MAI in English by Harrison and Vallin (2018), which can facilitate inter-cultural studies.

In summary, results suggest that the Shortened Version of the MAI adapted to Spanish is a reliable and valid way to identify the two metacognitive components, *Knowledge of Cognition* and *Regulation of Cognition*. However, this study is not exempt of limitations. Being a self-report, memory biases and social desirability could influence participant responses (McNamara, 2011). In addition, convergent validity was not evaluated in relation to on-line measures of metacognition, which could give an idea of how much these subjective bias influence the responses. Lastly, the sample was not fully representative. Students from some universities and class groups were more represented than others. In this sense, specially limited are the Subsamples 1 and 2 that were mostly composed by women, used respectively to evaluate validity in relation to other questionnaires and criterion validity in relation to grades. Also, Subsample 3, which was used to evaluate test-retest reliability, was specially limited because of its size and composition (i.e. mostly women studying in the field of health sciences and in the first year of university). Future studies should continue evaluating the validity of the MAI in the Spanish context while addressing these limitations.

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