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Psychometric Properties of the Saudi Version of the Mathematics Confidence Scale Using the Modern Test Theory

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Abstract

The aim of the study was to analyze the psychometric properties of the Arabic version of the Math Confidence Rating Scale (MCS), using Item Response Theory (IRT) and Exploratory Factor Analysis (EFA). The participants were (315) from Imam Mouhammad Ibn Saud Islamic University; They are distributed into (92) female and (223) male, selected through a convenience sampling. The EFA models indicated that the one-dimensional structure better represents the data, and the pairs of items were considered locally independent, IRT findings indicate that all items had a very high discrimination parameter and all items had acceptable threshold parameters, And that MCS is more informative for mid-level ability of Math confidence. The MCS in Arabic has adequate psychometric properties to be used as a short measure of Math confidence.

Keywords: *Math Confidence, Math Confidence Rating Scale (MCS), Exploratory Factor Analysis (EFA),IRT.*

Introduction

Confidence in the academic context is one of the essential factors that affect students' learning processes, academic success, and future life choices (Akbari & Sahibzada,2020). As an element of academic self-efficacy, mathematics confidence can exert a positive influence on the choices of subjects and specialty areas (Macun & Işık2022; Zhang & Wang, 2020). Many researchers have sought to understand the issue of mathematics confidence, though few studies have examined it from the scale development and validation perspective (Primi et al.2020).

Many children and adults are not confident in their ability to do mathematics, And there for Mathematics confidence may directly impact mathematics anxiety. Anxiety in mathematics has been shown to develop when a student lacks confidence. This lack of confidence is often due to repeated failures in mathematics at school and at home. A lack of student confidence in mathematics may also stem from teacher discouragement. For example, when students hear teachers describing mathematics as difficult, it may lead them to make the same conclusions (Finlayson, 2014).

Math teachers in many nations throughout the world are nearly forced to seek assistance in order to address the problem of many students who detest or fear mathematics in their courses. They are encouraged to collaborate with professional school counselors in addressing the numerous math-averse children in today's classrooms. Teachers must better equip all students to succeed with and be confidence in their ability to do mathematics in order to compete worldwide in the age of STEM (Science, Technology, Engineering, and Mathematics). It has truly become an epidemic in our society, with so many young people and adults harboring unfavorable views about mathematics training and having had awful prior experiences with it (Beilock & Willingham, 2014; Boaler, 2008; Dowker, Sarkar, & Looi, 2016; Geist, 2010).

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Students with higher mathematical qualifications were often more confident and successful in arithmetic. The findings imply that, after attending to the mathematics syllabi, lecturers might try to raise students' confidence in their mathematical abilities as a way to improve student performance at schools. Self-confidence, self-efficiency, and success expectancies, as well as their links to success, are among the most researched mathematical beliefs about oneself. To this end, students of the Mathematics Education Study Program as prospective mathematics educators who are outstanding, creative, superior, professional, and globally competitive, must also pay attention to non-cognitive factors that will maximize their mathematical competence (Dewanti, Ayriza& Setiawati,2020). Zan, Brown, Evans & Hannula (2006) suggested that the most important research about mathematical attitudes is on understanding the mutual relationship between attitude and achievement. Several other studies show that there is a strong relationship between various domains of attitude (enjoyment of mathematics, motivation to carry out mathematical activities, confidence in mathematics, and perception of mathematical values) and mathematical achievement (Minato & Yanase, 1984; Foire, 1999; Bouchey & Harter, 2005; Samuelsson & Granstrom, 2007).

Recent research in the field of mathematics education underscores the significance of students' self-confidence in both mathematical skills and the learning process as a key predictor of their overall achievement in mathematics courses. The level of success or failure in these courses typically aligns with the individual's self-confidence in mathematics. Consequently, it has been observed that successful mathematics students generally exhibit higher levels of self-confidence compared to their counterparts (Hackett, 1985; Hackett & Betz, 1989; Honicke & Broadbent, 2016; Hosein & Harle, 2018; Pajares & Miller, 1994). Furthermore, a noteworthy finding is that heightened self-confidence in mathematics not only correlates with increased mathematics achievement but also serves to mitigate math anxiety, a factor known to impact overall success in mathematics (Feldman & Kubota, 2015; Klassen, 2004; Kvedere, 2014).

In global assessments like PIRLS, PISA, and TIMSS, which comprehensively evaluate students' mathematical knowledge and skills, the role of self-confidence in mathematics has been explored as a crucial dimension impacting mathematics achievement. The International Mathematics and Science Trends Survey, known as TIMSS, is conducted by the International Association for the Evaluation of Educational Achievement (IEA) at four-year intervals. TIMSS assesses the knowledge and skills of 4th- and 8th-grade students in mathematics and science. It also aims to assess and compare differences between national education systems worldwide. To achieve these objectives, TIMSS utilizes mathematics and science achievement tests, along with surveys involving students, teachers, and schools (Yildiz&Ciftci,2019). The mathematics achievement test covers various learning areas, including numbers, algebra, geometry, data, and probability, incorporating items related to the cognitive processes of knowledge, implementation, and reasoning for each learning area. Furthermore, TIMSS mathematics student surveys delve into investigating the relationship between mathematics achievement and students' attitudes, values, and self-confidence.

Numerous studies, research, and international test results (TIMSS) have indicated a significant decline in students' performance in mathematics. The reason for this decline may be associated with students' anxiety, lack of confidence, and fear of the mathematics subject (Suren& Kandemir,2020). Regarding the negative long-term impacts of math anxiety, it is important to have validated scales that fully capture the math confidence levels of students for identifying those students and providing specific interventions based on the needs of each student. To achieve this aim, the examination of the psychometric characteristics of the math confidence scales is critical at the item level. To our knowledge, however, previous research on the math confidence scales has predominantly relied on factor analysis for validation. and such an approach is at the total score level based on the sum of the responses to all the items of a scale. Because this factor analysis approach does not provide information at the item level, it assumes equal contribution of different items to a scale, indicating an important disadvantage of this approach due to lack of determining the extent to which a single item contributes to the scale(Ölmez& Ölmez,2019). Therefore, the purpose of this study was to examine the psychometric characteristics of the MCS, for measuring the students' math confidence at the item level using the Graded Response model.

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Item Response Theory

Item Response Theory (IRT), also known as latent trait theory, has swiftly become mainstream as the foundation for psychological measurement. IRT involves model-based measurement where trait level estimates depend on both the person's response and the properties of the administered items. Numerous new or revised tests, particularly ability tests, have emerged based on IRT principles. However, due to the unfamiliarity of most test users with IRT, test manuals often mention its application briefly or in a technical appendix. Consequently, test users are largely unaware of the fundamental changes in the psychometric basis of testing. IRT has been widely used in the validation of psychological scales and measures and has been widely used in the validation of psychological scales and measures (Wilson, 2023). It is a valuable tool for assessing the psychometric properties of assessment instruments and has been extensively applied in the field of educational and psychological measurement (El-Den et al.2020).

In this new model-based version of test theory, IRT introduces significant deviations from some well-known rules of measurement. Indeed, the new rules of measurement differ fundamentally from the old rules, necessitating the revision, generalization, or abandonment of many established principles. One such rule pertains to the standard error of measurement. In the old rule of Classical Test Theory (CTT), the standard error of measurement applied uniformly to all scores within a specific population. However, in the new rule of IRT, the standard error of measurement varies across scores but generalizes across populations.

Item Response Theory (IRT) models, trait scores are estimated separately for each score or response pattern, while controlling for the characteristics of the administered items. Standard errors are minimized when the items are optimally suitable for a specific trait score level and when item discrimination is high (Embretson & Reise, 2000).

Item Response Theory relies on a set of assumptions that must be met in the data to yield accurate results. The most critical of these assumptions is unidimensionality, signifying that a single characteristic explains the examinee's performance on the test (i.e., the examinee's score reflects only the characteristic that the test measures). Various statistical methods, such as factor analysis, are employed to assess data adherence to this assumption. The second assumption is termed local independence, requiring that respondents' test responses be statistically independent at a particular ability level. In simpler terms, an examinee's response to one item should not influence their answer to other items (Crocker & Algina, 1986). This assumption holds true only when the test is unidimensional, meaning that an individual's performance on one item is not influenced by their performance on another item. The third assumption, known as the Item Characteristics Curve (ICC), entails a mathematical association linking the probability of an examinee's success on an item with the ability measured by a group of items comprising the test. The last assumption is speediness, asserting that the speed factor does not impact test responses; in other words, incorrect item answers result from ability and not the allotted test time. (Hambleton & Swaminathan, 1985).

In this theory, it becomes possible to correlate item characteristics with measured ability on one hand and the probability of a correct answer on the other hand through several mathematical models, including the three logistic models: the one-parameter logistic model, the two-parameter logistic model, and the three-parameter logistic model (Hambleton, Swaminathan & Rogers, 1991; Embretson & Reise, 2000).

In dichotomous and polydomous models, researchers analyze the different response patterns for test items, which can provide valuable insights into the underlying constructs being measured. For example, in dichotomous models, researchers focus on the probability of a correct response to each item, while in polydomous models, they consider the probability of a correct response across multiple categories. In dichotomous models, the response options are limited to two choices, typically true or false. Polydomous models, on the other hand, involve multiple response options for each item(Carlson,2020). there are few dichotomous models such as the Rasch model and the two-parameter logistic model, and the three-parameter logistic model, Additionally, there are polydomous models which allow for more complex relationships between items and student abilities. For example, the partial credit model and the rating scale model are two commonly used polydomous models in educational assessment, and graded response model

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can be applied to assess student abilities and item characteristics in a more nuanced way. The dichotomous models assume that there are only two response categories for each item, while polydomous models allow for multiple response categories and varying levels of partial credit(Robitzsch,2021). In the context of this study, the use of polydomous models provides a more comprehensive understanding of student abilities and item characteristics. By accounting for the varying levels of difficulty and discrimination among the items, polydomous models allow for a more nuanced analysis of student performance

Purposes of the Study

The main purposes of this study are:

Create an Arabic-language version of the mathematics confidence scale.

Using exploratory factor analysis, examine the scale's factor structure, and then present additional validation of the scale using IRT.

Method

Participants and Procedures

The participants were (315) from Imam Mohammad Ibn Saud Islamic University; They are distributed into (223) male and (92) female.

Instrument

To achieve the objectives of the research, Math Confidence Rating Scale(MCS) developed by (Hendy et al., 2014) was translated to measure confidence levels in mathematics among individuals. The MCS is a 7-item Likert-type scale with answers ranging from 1 (strongly disagree) to 5 (strongly agree). These items include mathematics behaviors where students may be expected to vary in confidence, such as understanding mathematics concepts, earning good grades, and practicing problems on their homework. The internal reliability, convergent validity, and test-retest reliability of the MCS are reported as acceptable. Hendy et al (2014) conducted a study with 368 participants and the self-reported mathematics confidence was as follows: M = 3.79, SD = .90. Permission to use this scale was obtained from its original authors.

Scale Translation Procedures

First, To verify the equivalence of the translation of the MCS Scale between the English and Arabic text, the researcher presented the scale in its English form to two faculty members in the College of Languages and Translation at Imam Muhammad bin Saud Islamic University who spoke both English and Arabic, and asked them to translate it into Arabic , then asked two other members of the same department to translate it into English, then the researcher examined the results of the two translations to obtain equivalence between them, where he found that the percentage of agreement between the two translations of the scale amounted to (90%), while the percentage of agreement between the translators of the scale from Arabic into English (85%). Looking at the results of the two translations, it became clear to the researcher that the two translations did not deviate from the content.

Second, the Arabic translation of the scale, and its reverse translation (from Arabic to English) were shown to five faculty members specializing in translation and Psychology, and they were asked to ensure that the translation from English to Arabic, and the translation from Arabic to English and compared it with the original scale And judging the scale in terms of the clarity of the phrases and the soundness of their formulation, and the scale phrases won at least 90% of the arbitrators' consensus.

Third, the researcher conducted an exploratory study on (50) participants to verify the clarity of the scale phrases, as it was found after applying the scale that the formulation of the scale items was clear to the

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sample members, and this made the researcher reassure of the possibility of applying it to the basic rationing sample.

Fourth, the last version translated into Arabic was approved after ensuring that the translation into Arabic and the reverse translation matched the original scale.

Statistical Analysis

To verify the assumptions of one-dimensionality, local independence, By performing an exploratory factor analysis using SPSS v28 software, and by calculating the value of $\chi 2$ for local independence using IRTPro v5 software.

The discrimination parameter (a) and the difficulty threshold parameters (b1, b2, b3, b4) for the Math Confidence items were estimated according to their Graded Response Model was verified using IRTPro v5 software.

The graph of the curve of item information functions and test information function was calculated according to the different estimates of the individuals' ability.

Results

Firstly, the parameters estimation accuracy in IRT depend on varied mathematical model assumptions, specifically: test dimensionality and local independents.

Unidimensional

In this study, the researchers examined the unidimensional assumption and local independence of the Graded Response Model (GRM). Unidimensional Assumption was examined by Exploratory factor analysis (EFA) based on the principal axis factoring technique for the correlation matrix of the 7 measure items. KMO and bartletts test showed that the sample is suitable for EFA (KMO> 0.9, and Bartlett test is significant). The result showed the presence of one factor with Eigenvalue greater than one (4.22). The total cumulative variance explained by the factor was 60.23%. the scree plot in figure 1 Emphasizes on mathematics confidence scale unidimensionality. Moreover, items factor loading as shown in table 1 ranged from 0.735 (item 7) to 0.801 (item2 and item3).

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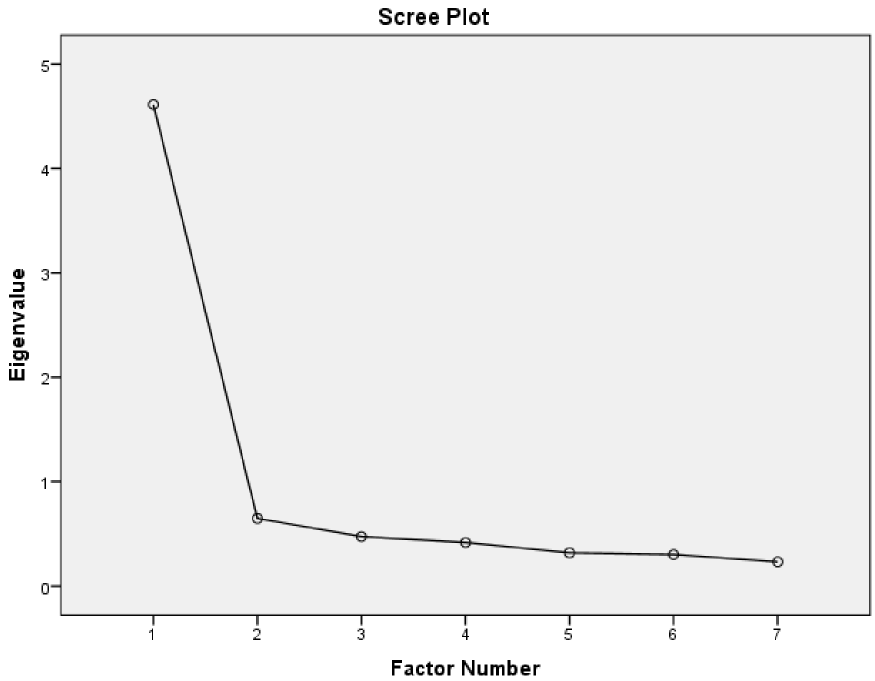

Figure 1. Scree Plot for Mathematics Confidence Scale Items

Table1. Items Factor Loading

Q1: I am confident that I can get an A in math	.752
Q2: I am confident that I can get a passing grade in math	.801
Q3: Math seems easy for me, and I am confident I will get a good grade in this math class	.801
Q4: Even if I do not understand a math problem at first, I am confident I will get it eventually	.800
Q5: If I miss a math class, I am confident that I can make up the work	.763
Q6: If I get a bad grade on a math test, I know I can do better next time with more practice	.778
Q7: I am confident I can practice math problems by myself until I understand them	.735

Local Independent

Table 2 contains Marginal fit (X^2) and Standardized LD X^2 Statistics. The Chen and Thissen´s (1997) χ2-LD statistics took values for each pair of items between 2.3 and 9.3, all values lower than the limit value of 10. Therefore, the pairs of items were considered locally independent to implement the GRM.

Table 2. Marginal fit (X^2) and Standardized LD X^2 Statistics

Math Confidence							
Items	X^2	1	2	3	4	5	6
1	1.1						
2	1.5	9.3					
3	2	8.7	4.1				
4	3.2	6.5	2.5	5.5			
5	1.6	4.7	2.6	2.3	8.8		
6	1.3	7.8	4.5	2.5	2.3	3.3	
7	1	9.1	4.4	5.4	5	4	3.9

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Secondly, the results found in the Exploratory Factor Analysis (EFA) support the assumptions of unidimensionality and local independence. Therefore, a Graduated Response Model (GRM) was used, specifically an extension of the 2-Parameter Logistic Model (2-PLM) for ordered polytomous items. Table 3 shows that the means ranged between 3.19 (item 3) and 3.94 (item 4),and that all items had a very high discrimination parameter (ai > 1), item 2 had the highest discrimination (3.24), and item 7 the lowest (2.44). Regarding the parameters of difficulty, all the estimators of the thresholds increased monotonically, That all items had acceptable threshold parameters (-3>bi>+3).

Table 3. Descriptive Statistics, Standardized Regression Weights, And GRM Parameter Estimation For MCS

Items	**M**	**SD**	**a**	**b1**	**b2**	**b3**	**b4**
1	3.36	1.30	2.60	-1.35	-0.81	-0.06	0.83
2	3.92	1.20	3.24	-1.63	-1.16	-0.66	0.26
3	3.19	1.33	3.18	-1.18	-0.49	0.05	0.91
4	3.94	1.18	3.13	-1.8	-1.1	-0.69	0.28
5	3.29	1.30	2.62	-1.38	-0.61	0	0.92
6	3.76	1.20	2.76	-1.61	-1.14	-0.53	0.53
7	3.36	1.21	2.44	-1.68	-0.75	-0.02	1.04

Thirdly, Table 4 shows values derived from the IIC and TIC for 15 levels of ability. As indicated, the scale and most of the results are more informative for mid-level ability, where the standard error (SE) in measurement is less than that for the higher ability levels. With regard to item information function, item 2 provides the largest amount of information at ability level -1.2 (3.21), then item 3 at -0.4 ability level (3.01) and Item 4 at ability level -0.8 (2.95). Marginal reliability for the scale was 0.91.

Table 4. Item and Test Information Function at θ from -2.8 to 2.8

Item/ θ	**-2.8**	**-2.4**	**-2**	**-1.6**	**-1.2**	**-0.8**	**-0.4**	**0**	**0.4**	**0.8**	**1.2**	**1.6**	**2**	**2.4**	**2.8**
1	0.15	0.39	0.89	1.58	2	2.05	1.99	1.96	1.88	1.83	1.37	0.71	0.29	0.11	0.04
2	0.22	0.73	1.88	2.97	3.21	3.13	2.72	2.67	2.53	1.32	0.46	0.13	0.04	0.01	0
3	0.06	0.2	0.65	1.69	2.7	2.87	3.01	2.96	2.64	2.7	2.07	0.91	0.3	0.09	0.02
4	0.39	1.12	2.28	2.77	2.91	2.95	2.52	2.48	2.41	1.34	0.49	0.15	0.04	0.01	0
5	0.16	0.42	0.95	1.63	1.95	2.02	2.08	2.03	1.9	1.88	1.52	0.84	0.36	0.14	0.05
6	0.26	0.69	1.47	2.16	2.35	2.3	2.12	1.89	2.01	1.68	0.9	0.36	0.13	0.04	0.01
7	0.34	0.75	1.31	1.64	1.68	1.75	1.78	1.74	1.61	1.62	1.48	0.97	0.47	0.2	0.08
Total	2.59	5.31	10.43	15.44	17.8	18.07	17.23	16.72	15.99	13.37	9.28	5.08	2.63	1.6	1.21
SE	0.62	0.43	0.31	0.25	0.24	0.24	0.24	0.24	0.25	0.27	0.33	0.44	0.62	0.79	0.91

Figure 2 shows the Information Curves for the seven items and the scale (IIC and TIC respectively). In the IIC, it can be seen that items 5, 4, and 3 are the most relevant and precise of the scale to evaluate the latent variable. In addition, the TIC shows that the test is more reliable (accurate) in the range of the scale between -0.5 and 3.

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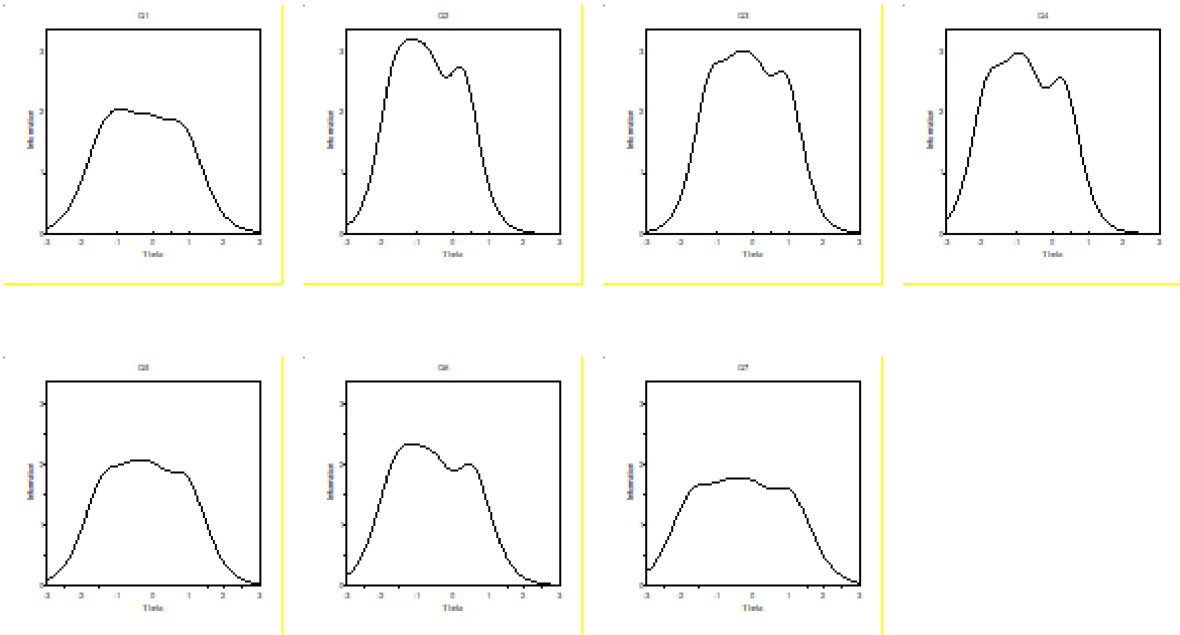

Figure 2. Information Function for MCS Items

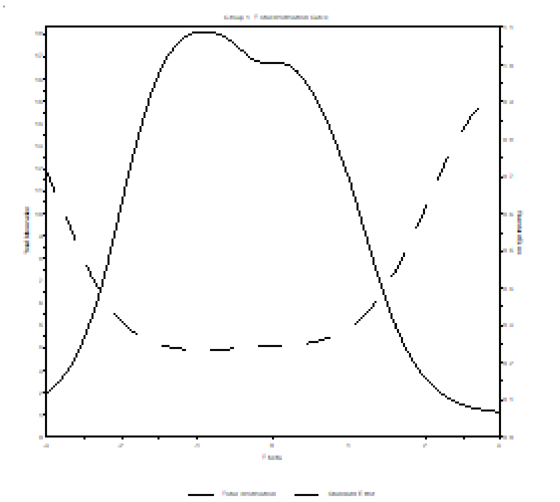

Figure 3. Test Information for the scale

Discussion

The purpose of this study was to examine the psychometric properties of the Arabic version of the Math Confidence Scale using the Graded Response Model. In general, EFA supports the presence of a one-dimensional model, items have high factorial loads and good reliability. further demonstrating that all items were adequate indicators of the construct (Math confidence) and that the scale has adequate psychometric properties, alongside a solid factor structure, These findings are similar to those reported in the original study (Hendy, et al., 2014). Additionally, once the dimensionality of the MCS was established, IRT models were estimated, the results show that all items present increasing monotonic values in the difficulty parameter, this means that a person with little or low confidence in Math will tend to choose the first or second response alternative and as he has a higher confidence level, he will choose a higher response alternative. This is an expected and positive behaviour in the instrument since it reflects that the

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content raised in each of the items allows to take advantage of the answer alternatives shown to the participants and there is no loss of information due to the approach of the measurement instrument, All the items have high discrimination values, which means that, when using the MCS, it will be easy to differentiate between the responses to the items of a person with high confident and those of someone with moderate or low confidence, including the general assessment of the latent variable expressed in total scores. According to the analysis of the information collected by the items, the scale can better and more accurately assess the Math confidence for individuals who have moderate levels of the latent variable in mention, being the items 2, 3, and 4 who better take advantage of this characteristic. Thus, the results of the IRT analysis support the use of the MCS as a meaningful assessment tool for the reliable measurement of mid-levels of confidence in Mathematics.

Limitations

The present study has several limitations. First, the participants were selected through convenience sampling; therefore, they do not represent the entire Saudi general population. Future research should consider working with a more representative sample. Secondly, the results of this study may not generalize to all students in schools and universities, because the sample used was mostly based on data collected from Imam Mouhammad Ibn Saud Islamic, Despite these limitations, our findings are largely consistent with the results of previous investigations and support the validity of the MCS-AR for measuring Math confidence in Saudi adults, and this can be considered a pioneering study within a recent line of research that develops and/or validates instruments that measure confidence symptoms associated with math. In this sense, this was the first study that rigorously evaluated the psychometric evidence of MCS in Arabic, using IRT models, therefore, this study represents a valuable contribution to the scientific literature. Findings of this study determined that the MCS could be used for diagnosis in clinical practice and in developing prevention programs. The MCS can also be administered quickly because it includes only seven items, possibly assisting clinicians in crowded clinical environments.

Conclusion

Altogether, our findings support the MCS Arabic version as a valid tool that exhibits appropriate psychometric properties in assessing math confidence among the students of Saudi Arabia. In conclusion, the Arabic version of the MCS seems to be a self-reporting instrument with sufficient evidence of reliability and validity to measure math confidence. Therefore, the MCS may be useful in clinical practice and research involving the students of Saudi and Arab.

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