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Article

Measurement Invariance of the Learning and Study Strategies Inventory-Second Edition (LASSI-II) across Gender and Discipline in Egyptian College Students

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Abstract

Validating the intended interpretations for proposed uses of tests scores is paramount for making valid inferences in educational and psychological research. Ascertaining measurement invariance for measurement instruments is an assumption for comparing means. If measurement invariance does not hold for groups of interest, comparison of means will be invalid since making valid inferences presupposes that the instrument measures the same construct across subgroups. One of the most widely used instruments for measuring learning strategies for college students is the *Learning and Study Strategies Inventory*-second edition. The inventory has 10 subscales namely, information processing, selecting main ideas, test strategies, anxiety, attitude, motivation, concentration, self-testing, study aids, and time management with eight items for each subscale. Although it is stated that the learning and study strategies inventory is internationally adopted to measure students' use of learning and study strategies, little is known about its measurement invariance across gender (males/females) and discipline (science/humanities) in Egyptian college students. The authors utilize an adapted Arabic version of the *Learning and Study Strategies Inventory* administered to 522 Egyptian college students to investigate if the adopted model has measurement invariance across gender (males/females) and discipline (science/humanities). Results revealed that the effort-related activities, goal orientation, and cognitive activities model was confirmed for these students. Using multiple-group confirmatory factor analyses, results also showed that the factorial structure of the adopted model had partial measurement invariance across gender and full measurement invariance across discipline. Centers for teaching and learning at universities can use the validated instrument to measure students' learning and study strategies across gender and discipline. More implications and suggestions for future research are also addressed.

Keywords

Measurement invariance • LASSI-II • gender • discipline • college students

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Students' learning and study strategies are key factors for their development and academic success (Catrysse et al., 2018; Díaz, Zapata, Diaz, Arroyo, & Fuentes, 2019; Ghiasvand, 2010; Muelas & Navarro, 2015; Renzulli, 2015; Ruffing, Wach, Spinath, Brünken, & Karbach, 2015; Sankaran & Bui, 2001; Valaei, Rezaei, Khairuzzaman, & Ismail, 2017; Vermunt & Donche, 2017; Yip, 2012), since students' academic performance relies on the effective use of these strategies. Accordingly, centers for teaching and learning at many universities measure students' use of learning strategies to predict their academic success. Such centers develop and implement training programs for students who have deficiencies or low profiles on learning strategies to increase their chance of being successful students. Thus, a strong psychometrically validated and group invariant instrument is needed to measure learning and study strategies of college students.

Development of the Learning and Study Strategies Inventory

Late in 1980s, Weinstein and Palmer developed the first version of the *Learning and Study Strategies Inventory* (later known as the LASSI-I) to measure learning strategies utilized by students in their undergraduate studies. This version consisted of 77 items distributed over 10 subscales. In 1990, Weinstein and Palmer developed the high school version known as LASSI-HS. In 2002, they revised and updated the first version designed for undergraduates and developed the second version (later known as the LASSI-II) adding three items to accommodate recent technological advances in the study aids subscale. Weinstein and Palmer (2002) defined learning and study strategies as students' awareness of their effective use of such strategies in relation to the skill, will and self-regulation as components of strategic learning to achieve better learning outcomes.

The LASSI-II has been widely used across different countries (Flowers, Bridges, & Moore, 2012; Iqbal, Sohail, & Shahzad, 2010; Yip, 2013). Since its development, "the LASSI has been used in more than 1,700 colleges and universities to measure the extent to which students make use of study skills to learn new information" (Flowers, 2003, p. 32). Students who complete the LASSI-II develop greater awareness of their learning and study strategies since they obtain a diagnostic profile of their strengths and weaknesses. Participants in programs or courses focusing on learning and study strategies use the LASSI-II as a pre-post measure for ascertaining improvement. It is also used as an advising or counseling measure for college orientation programs, advisors, developmental education programs, and learning assistance programs and centers (Weinstein & Palmer, 2002). Given that this instrument is so widely used, it is worthwhile to assess its measurement invariance relative to an Egyptian population of college students. Such a study may contribute to the use of this tool especially in the Arab world.

Weinstein and Palmer (2002) indicated that the LASSI-II measures three components of strategic learning: *skill*, *will*, and *self-regulation* (S-W-SR), known here as the original model. First, the *skill* component has three subscales: information processing, selecting main ideas, and test strategies. The *information processing* subscale measures students' learning strategies such as the use of imagery and verbal elaboration, organization strategies, and reasoning skills to help learn new information via relating them to previously learned knowledge (*Do students try to relate what is being presented in class to their prior knowledge?*). The *selecting main ideas* subscale measures students' skills to identify important information from supporting details (*Can students decide what is important to underline in a textbook?*). The *test strategies* subscale measures students' test preparation and test-taking strategies (*Do students review their answers to essay questions?*).

Second, the *will* component has three subscales: anxiety, attitude, and motivation. The *anxiety* subscale measures the extent to which students' worry about their learning in college and academic performance (*Do students worry so much that it is hard for them to concentrate?*). The *attitude* subscale measures students' attitudes and interests in achieving academic success in college (*Is school really important or worthwhile to the student?*). The *motivation* subscale measures students' desire and willingness to exert the effort necessary to complete academic tasks successfully (*Do students easily give-up in difficult classes?*).

The *self-regulation* component has four subscales: concentration, self-testing, study aids, and time management. The *concentration* subscale measures students' ability to direct and keep their attention on academic tasks (*Can students direct their attention to school tasks?*). The *self-testing* subscale measures students' use of reviewing and comprehension monitoring strategies to determine their level of understanding of the information or task being learnt (*Do students stop periodically to review the content?*). The *study aids* subscale measures the extent to which students seek materials or resources to help them learn and remember new information (*Do students create or use organizational aids?*). The *time management* subscale measures students' ability to manage their time wisely for academic tasks (*Do students anticipate scheduling problems?*).

Gender and Discipline

Gender is one of the most investigated grouping variables in educational and psychological research and students are often compared across many educational variables based on this demographic variable. Similarly, discipline (whether a college student is in the scientific or humanities track) is another grouping variable that some researchers investigate in higher education research (Khadivzadeh, Seif, & Valayi, 2004). In addition, there is a need to compare students' use of learning and study strategies across disciplines to identify those with weak profiles and plan intervention training programs accordingly (Ahmed, 2010; Rashed & Eltayeb, 2009).

To identify students' profiles on learning and study strategies and hold meaningful comparisons across gender and discipline, measurement instruments must measure the same construct across subgroups. Kane (2013) confirmed that strong inferences and claims could only be made when using instruments with substantial evidence for valid interpretations and uses of scores. Valid comparisons across subgroups cannot be made when the instrument behaves differently (e.g., measure different things) for the subgroups being compared. Male and female students may utilize leaning and study strategies differently in their studies. Similarly, students at the science track may differ from those at the humanities track in their learning and study strategies (Ahmed, 2010; Rashed & Eltayeb, 2009). However, these claims cannot be confirmed if the instrument used is not invariant across gender and discipline subgroups. Thus, the present study seeks to ascertain measurement invariance for the LASSI-II given that it is one of the most commonly used instruments for measuring learning and study strategies.

Testing Measurement Invariance

Ascertaining measurement invariance is necessary for measurement instruments to make valid and meaningful comparisons across groups. Vandenberg and Lance (2000) indicated that failure to achieve measurement invariance is considered as dangerous to interpretations as failure to verify reliability and validity evidence. Milfont and Fischer (2010, p. 111) noted "the establishment of measurement invariance is a prerequisite for meaningful comparisons across groups". Huck (2012) asserted when measurement invariance is confirmed, it is reasonable to compare and interpret group means meaningfully. Albano and Rodriguez (2013, p. 837) noted "a lack of invariance would invalidate score interpretations and comparisons in these contexts". Thus, testing for measurement invariance helps researchers ascertain that the instrument measures the same construct across all subgroups.

Measurement invariance occurs when examinees from different groups have different expected observed scores on an instrument when they have the same latent score for the construct of interest. There can be several causes for measurement invariance and one can use constraints in confirmatory factor analysis (CFA) to test each type. Configural invariance (pattern invariance) is satisfied when the items load on the same factors across groups; same pattern of loadings, but the loadings are not required to be the same. This can be tested within a CFA framework by allowing each group to have its own factor structure and then constraining the structures to be equivalent with respect to fixed (set to 0) and estimated parameters. If the constraint increases the error significantly, then one structure is not sufficient. Metric invariance goes a step further and tests not only if the factors are similar (same fixed and estimated parameters), but if all factor loadings are equal for the groups. Here the factors are not only qualitatively the same, but quantitatively the same as well. In this instance, all items must load on the same factor(s) to the same degree for each of the groups. CFA can also be used to constrain factor loadings to be equal for each group. This new constrained structure can be tested against the one for configural invariance (all items load on the same factors, but not necessarily to the same degree). If this constraint leads to a significant increase in error, one knows that the factor loadings differ by group. Third, scalar invariance adds another constraint for the item intercepts to be equal across groups. This new constrained structure can be tested against the one for metric invariance. If this constraint leads to a significant increase in error, one knows that the item intercepts differ by group. For this to happen, the means of the latent variables would have to differ by group. The fourth type of invariance is the residual or full invariance. One can constrain the error variances to be equal across groups. This final test allows one to ascertain if the variances of the latent variables are the same for all groups. It, can also be tested in CFA with added constraints (Chen, Sousa, & West, 2005; Cheung & Lau, 2012; Milfont & Fischer, 2010; Schoot, Lugtig, & Hox, 2012; Vandenberg & Lance, 2000).

Note that full invariance is unlikely to hold in practice (Milfont & Fischer, 2010). Byrne, Shavelson, and Muthén (1989) introduced the idea of partial measurement invariance. A researcher can have partial invariance in two ways. The first is when measures are invariant across some but not all groups. The second is when some but not all the parameters are invariant across groups. It is therefore possible in psychological constructs that partial invariance holds. Millsap (1998) indicated that if evidence is established for metric and scalar invariance, this means the instrument has measurement invariance across groups. Putnick and Bornstein (2016, p. 71) noted "most tests of measurement invariance include configural, metric, and scalar steps; a residual invariance step is reported for fewer tests".

Previous Research on the Learning and Study Strategies Inventory

In an attempt to examine the underlying factor structure for the LASSI and its high school version, there were three main streams of research. The first stream of research was represented in S-W-SR model proposed by the test authors. Unfortunately, they did not use factor analysis to confirm the factor structure of the proposed subscales. Their model was only confirmed by Yip (2013) who examined its underlying factor structure in 612 university students from Hong Kong.

The second and dominant stream of research was led by Olaussen and Braten (1998) who investigated the underlying factor structure of the subscales of the LASSI-I among 173 first year and 176 second year Norwegian college students. They obtained a three-latent factor model that was different from the S-W-SR model. Based on the refinement of the model proposed by Olejnik and Nist (1992), they labeled the latent factors *effort–related activities* (motivation, time management, concentration, attitude, and test strategies), *goal orientation* (concentration, attitude, test strategies, anxiety, selecting main ideas, and information processing) and *cognitive activities* (selecting main ideas, information processing, study aids, and self-testing). In subsequent studies, this model was known as the ER-GO-CA.

Given that two structures are presented in the literature, S-W-SR and ER-GO-CA, more research was needed to ascertain which of the structures (if either) is more viable. Samuelstuen (2003) examined the underlying factor structure of the LASSI-HS subscales for Norwegian students. These results confirmed the ER-GO-CA model but with different subscales on the second latent factor namely *goal orientation* (i.e, test strategies, anxiety, attitude, concentration, and selecting main ideas). Stevens and Tallent-Runnels (2004) studied the underlying factor structure of the LASSI-HS subscales. They also tried to examine the measurement invariance across gender and ethnicity. They obtained the same model identified by Olaussen and Braten (1998). Results also indicated that the model is invariant across gender but not ethnicity. Prevatt, Petscher, Proctor, Hurst, and Adams (2006) investigated the factor structure of the LASSI-II subscales among 297 college students. They compared the ER-GO-CA model to the original model. Their data supported the ER-GO-CA model. Finch et al. (2016) used the LASSI-HS in 6083 undergraduates and their results were also consistent with the ER-GO-CA model. Abdelsamea and Bart (2019) investigated the factor structure and reliability of an adapted Arabic version of the LASSI-II in 303 Egyptian undergraduates. Results indicated that the data fit the ER-GO-CA model.

The third stream of research provides different labels for the LASSI components. Cano (2006) investigated the latent structure of the LASSI-I subscales among university students. He obtained a three-factor model but labeled them differently: *affective strategies* (motivation, time management, concentration, attitude, and self-testing), *goal strategies* (concentration, attitude, anxiety, test strategies, and selecting main ideas) and *comprehension monitoring strategies* (selecting main ideas, information processing, study aids, and self-testing).

Based on the studies reported above, the original model for the LASSI-II, proposed by Weinstein and Palmer (2002), was not confirmed by most researchers. In contrast, the ER-GO-CA model proposed by Olaussen and Braten (1998) was confirmed by several researchers (Abdelsamea & Bart, 2019; Cano, 2006; Prevatt et al., 2006; Samuelstuen, 2003; Stevens & Tallent-Runnels, 2004). Accordingly, the ER-GO-CA model (see Figure 1) was adopted for the present study especially because it was confirmed in an Egyptian sample.

Rationale

A thorough review of the current literature shows limited investigation of LASSI-II compared to the LASSI-I and LASSI-HS in different populations (Cano, 2006; Olaussen & Braten, 1998; Samuelstuen, 2003; Stevens & Tallent-Runnels, 2004). It was also noted that only one study investigated the measurement invariance of the LASSI-HS across gender and ethnicity (Stevens & Tallent-Runnels, 2004). No study has yet investigated measurement invariance of the LASSI-II among Egyptian college students. Thus, much remains to be known about the psychometrics of the LASSI-II given its widespread and various uses. Frist, we will confirm the ER-GO-CA model of the LASSI-II with our population. This will add to the literature on the validity evidence based on the internal structure of the LASSI-II. Also, to date, no study has investigated the measurement invariance of the LASSI-II across gender (males/females) and discipline (science/humanities) in Egyptian college students. This is the second objective of the current manuscript. The results of this study could enhance our understanding of the measurement invariance for the LASS-II subscales across gender and discipline. Testing measurement invariance for the LASSI-II for Egyptian college students may contribute to the educational and psychological literature in terms of a new population. Thus, the results may help compare groups on the latent variables in future studies.

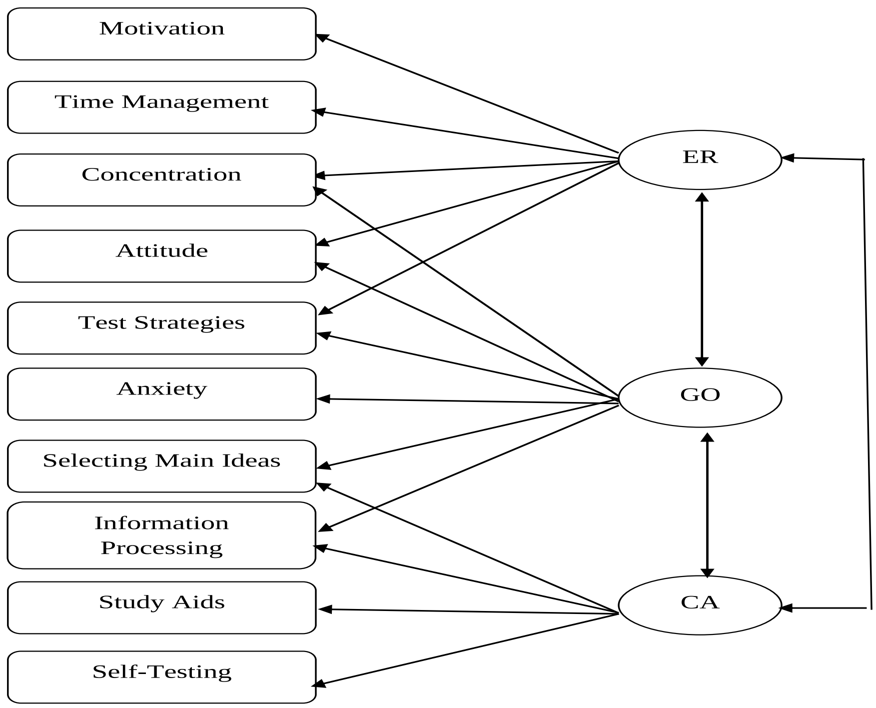

Figure 1. The baseline model (ER-GO-CA) of the LASSI-II

Note. ER = effort-related activities; GO = goal orientation; CA = cognitive activities.

Methods

Participants

Participants were 522 third year college students (369 females [70.69%] and 153 males [29.31%]). Their ages ranged from 20-27 years (M_{age} = 20.96, SD_{age} = 0.61). Two hundred and ninety-one (55.75%) of the participants were from humanities colleges (Education and Arts) and 231 (44.25%) were from science colleges (Veterinary Medicine, Engineering, and Science). As noted, the percentage of females is more than twice that of males in the study. When utilizing a convenience sample, it should represent the population of interest based on the relative size of each subgroup to increase generalizability of the results (Abulela & Harwell, 2019).

Instruments

An adapted Arabic version of the LASSI-II was used to measure learning and study strategies of Egyptian college students (Abdelsamea & Bart, 2019). The LASSI-II has 80 items, eight for each subscale. Participants judged to what degree each item applied to them on a 5-point rating scale ranging from *totally applicable for me* to *totally inapplicable for me*. Omega coefficients for the reliability of scores ranged from a low of .65 (*Study aids*) to a high of .86 (*Self-testing*) with most of the coefficients falling between .70 and .80.

Procedure

We contacted the proper authorities (sometimes referred to as the human subjects' review board) to seek permission to administer the instrument. Teaching assistants distributed the Arabic version of the LASSI-II to the students in their various classes. Students were informed of the purpose of the study and how to complete the instrument based on the direction sheet provided. Students were also informed that their participation was voluntary, and they would obtain free diagnostic information for their learning and study strategies. All ethical guidelines were followed for conducting human research especially that students have the right to decline participation or withdraw from the study. There is no specific time limit to respond to the LASS-II. It took students 15-20 minutes to respond to the inventory.

Data Analysis

A round of data screening and cleaning was done to ensure accuracy of the data. Fortunately, no missing data were found as students participated enthusiastically in the study to obtain free diagnostic information for their learning and study strategies profile.

To test measurement invariance, single-group confirmatory factor analysis (SGCFA) was used to examine if the hypothetical factor structure provides good fit to the four groups (males, females, science, humanities). The second stage is to move from SGCFA to multiple-group confirmatory factor analysis (MGCFA) to establish measurement invariance across gender (males/females) and discipline (science/ humanities). We conducted MGCFA based on the means and covariance matrices (see Appendix). All analyses were perfomed using LISREL 8.80 for windows with maximum likelihood (ML) estimation (Jöreskog & Sörbom, 2006). The second stage had four hierarchical invariance models. Configural invariance tests for the presence of the same factor structure across male and female students as well as across science and humanities groups. Metric invariance was tested by further constraining these same factors to have equal factor loadings across the gender and discipline groups. Scalar invariance was tested by adding another constraint that the item intercepts be equal across groups. Finally, full measurement invariance was tested by adding a fourth constraint; that error variances be the same across groups.

In the present study, model fit was evaluated by means of a chi-square test for statistical significance. The null hypothesis is that the data fits the model. The null hypothesis will be rejected if the data does not fit the imposed model. Specifically, the chi-square test indicates the difference between observed and reproduced covariance matrices. Given that the reproduced covariance matrices have equality constraints to implement the different gradations of invariance (configural, metric, scalar, and residual), the degree to which the corresponding parameters are not equal in the groups will lead to poorer fitting reproduced matrices resulting in the rejection of the null hypotheses for all groups being measured the same. Note that the power of a test is related to the sample size. As the number of subjects increases, the chi-square test can be significant with minor differences due to the added constraints (Chen, 2007). Thus, several descriptive indices were also used to assess invariance.

The first descriptive index to be used was χ^2/df. Given that the expected value of a chi-square under a null hypothesis of no difference (invariance) is its degrees of freedom, the more this index increases from one, the larger differences in the actual parameters for the different groups. While there is no universal agreement on the threshold to use for this index, many will claim non-invariance when the index exceeds 5 (Davenport, 2019). We also used the Goodness of fit index (GFI). It is the ratio of the sum of squared discrepancies to the original variance, similar to R^2 in regression. Acceptable fit for GFI is $\geq .90$. The Comparative Fit Index (CFI) is an incremental fit index that assesses the extent to which the tested model is superior to an alternative model in reproducing the observed covariance matrix (Chen, 2007). Unlike some incremental fit indices, it is not affected by sample size and has a penalty for the number of parameters estimated. Acceptable fit for CFI is ≥ .90. The Relative fit index compares the chi-square for the hypothesized model to one from a "null" (assuming no correlations of the items) model. Acceptable fit for RFI is ≥ .90. The final descriptive index used was the Root Mean Square Error of Approximation (RMSEA). It is an absolute measure of fit and one of the most popular and commonly reported in confirmatory factor analysis literature. It shows the discrepancy between the hypothesized (invariant) model, with optimally chosen parameter estimates, and the population covariance matrix. We also provided a 90% confidence interval for RMSEA. Acceptable fit for RMSEA is ≤ .08 (Brown, 2006; Hu & Bentler, 1999; Steiger, 1990; Chen, 2007). Finally, given that the models for invariance are nested (each adding another constraint), one can test the difference between the models. Therefore, based on Chen's recommendation, we have provided change scores for adjacent models (e.g., configural to metric, metric to scalar, and scalar to residual) for several of the indices: χ^2, df, CFI, and RMSEA. Use of the chi-square difference and the difference in degrees of freedom will allow one to provide a statistical test of whether the added constraint leads to significantly more error. The criteria for acceptable fit are ΔCFI ≤ -.01 and ΔRMSEA ≤ .015 (Chen, 2007).

Results

Table 1 shows the results of the single-group confirmatory factor analysis. Note that we fit each structure to the ER-GO-CA model.

Table 1. *Goodness-of-fit indices of the single-group confirmatory factor analysis*

Group	*χ2*	*df*	*χ2/df*	*GFI*	*CFI*	*RFI*	*RMSEA*	*90 % CI*
Males	39.61	27	1.47	.95	.98	.95	.055	(.041 - .080)
Females	82.58**	27	3.05	.96	.98	.95	.075	(.057 - .093)
Science	45.12	27	1.67	.96	.99	.95	.055	(.030 - .082)
Humanities	83.65**	27	3.10	.95	.97	.93	.085	(.056 - .13)

Note. χ^2 = chi-square statistics; df = degrees of freedom; GFI = goodness-of- fit index; CFI = comparative fit index; RFI = relative fit index; RMSEA = root mean square error of approximation; 90 % CI = RMSEA confidence intervals. ***p* < .01

As shown in Table 1, the empirical data provided good fit for the male group (χ^2 = 39.61, *df* = 27, χ^2/df = 1.47, GFI = .95, CFI = .98, RFI = .95, RMSEA = .055, 90% CI = .041 - .080) as well as for the science group (χ^2 = 45.12, *df* = 27, χ^2/df = 1.67, GFI = .96, CFI = .99, RFI = .95, RMSEA = .055, 90% CI = .030 - .082). Note that the chi-square test was not statistically significant for either of these groups (at $p <$ .01) indicating close model fit statistically. The data also provided acceptable fit for the female group (χ^2 = 82.58, *df* = 27, χ^2/df = 3.05, GFI = .96, CFI = .98, RFI = .95, RMSEA = .075, 90% CI = .057 - .093). While still acceptable, some of the fit measures here were not as good for the other two groups. The humanities group had the worst fit, but its fit was still reasonable (χ^2 = 83.65, *df* = 27, χ^2/df = 3.10, GFI = .95, CFI = .97, RFI = .93, RMSEA = .085, 90% CI = .056 - .13). Note for the latter two groups, model fit did not hold statistically as the chi-square test for model fit for both female students as well as the humanities group were statistically significant indicating that the null hypothesis of model fit was rejected. Also, for the humanities group RMSEA > .08.

Table 2. *Goodness-of-fit indices of the measurement invariance models across gender (males/females)*

Invariance Model	χ^2	*df*	χ^2/df	*GFI*	*CFI*	*RFI*	*RMSEA*	*90 % CI*	*Model comparison*	$\Delta\chi^2$ (Δdf)	Δ*CFI*	Δ*RMSEA*
1- Configural	126.55[a]	54	2.34	.95	.98	.94	.070	(.053 - .086)	-	-	-	-
2- Metric	168.07[a]	68	2.47	.92	.97	.94	.073	(.059 - .088)	1 vs. 2	41.52[a] (14)	-.01	.003
3- Scalar	191.86[a]	75	2.56	.91	.97	.93	.075	(.062 - .089)	2 vs. 3	23.79[a] (7)	.00	.002
4- Full	330.03[a]	85	3.88	.81	.93	.90	.12	(.11 - .13)	3 vs. 4	138.17[a] (10)	-.04	.045

Note. χ^2 = chi-square statistics; df = degrees of freedom; GFI = goodness-of-fit index; CFI = comparative fit index; RFI = relative fit index; RMSEA = root mean square error of approximation; 90 % CI = RMSEA confidence intervals, $\Delta\chi^2$ (Δdf) = change in chi-square and degrees of freedom for the model comparison; ΔCFI = change in CFI for the model comparison; ΔRMSEA = change in RMSEA for the model comparison.

[a] $p < .01$

Table 3. *Goodness-of-fit indices of the measurement invariance models across discipline (science/humanities)*

Invariance model	χ^2	*df*	χ^2/df	*GFI*	*CFI*	*RFI*	*RMSEA*	*90 % CI*	*Model comparison*	$\Delta\chi^2$ (Δdf)	Δ*CFI*	Δ*RMSEA*
1- Configural	130.55[a]	54	2.42	.96	.98	.94	.073	(.057 - .090)	-	-	-	-
2- Metric	170.77[a]	68	2.51	.94	.97	.93	.075	(.061 - .089)	1 vs. 2	40.22[a] (14)	-.01	.002
3- Scalar	194.30[a]	75	2.59	.94	.96	.93	.077	(.064 - .091)	2 vs. 3	23.53[a] (7)	-.01	.002
4- Full	202.67[a]	85	2.38	.94	.97	.94	.071	(.058 - .084)	3 vs. 4	8.37 (10)	.01	-.006

Note. χ^2 = chi-square statistics; df = degrees of freedom; GFI = goodness-of-fit index; CFI = comparative fit index; RFI = relative fit index; RMSEA = root mean square error of approximation; 90 % CI = RMSEA confidence intervals, Δχ2 (Δdf) = change in chi-square and degrees of freedom for the model comparison; ΔCFI = change in CFI for the model comparison; ΔRMSEA = change in RMSEA for the model comparison.

[a] $p < .01$

Table 2 shows the results of the MGCFA of the ER-GO-CA three-factor model across gender (males/females). Based on the chi-square test of significance, data for male and female students appear different given each of the four criteria for invariance (configural, metric, scalar, residual). The descriptive indices gave a different picture. The descriptive indices supported configural invariance (χ^2/df = 2.34, GFI = .95, CFI = .98, RFI = .94, RMSEA = .070, 90% CI = .053 - .086).

ΔCFI and ΔRMSEA were within the acceptable range for each of the models except the residual invariant model. (The change chi-squares and degrees of freedom showed that the additional constraints were statistically significant indicating differences between the groups in factor loadings, means, and error variances). The metric invariance model had reasonable fit given the descriptive indices (χ^2/df = 2.47, GFI = .92, CFI = .97, RFI = .94, RMSEA = .073, 90%CI = .059 - .088, ΔCFI = -.01 ΔRMSEA = .003). Additionally, the data supported scalar invariance for these indices (χ^2/df = 2.56, GFI = .91, CFI = .97, RFI = .93, RMSEA = .075, 90%CI = .062 - .089, ΔCFI = .00, ΔRMSEA = .002). Constraining the subscales residuals to be the same across both groups affected the fit indices and therefore the error variances were not invariant (χ^2/df = 3.88, GFI = .81, CFI = .93, RFI = .90, RMSEA = .12, 90% CI = .11 - .13, ΔCFI = -.04, ΔRMSEA = .045). Based on the results of the configural, metric, and scalar invariance models, the data had partial measurement invariance across gender.

Table 3 shows results of the MGCFA of the ER-GO-CA three-factor model across discipline (science/humanities). Again, all chi-square tests were significant ($p < .01$) indicating a lack of invariance. However, the descriptive indices provided another view. For these indices, all four invariances were supported. The values for configural invariance were (χ^2/df = 2.42, GFI = .96, CFI = .98, RFI = .94, RMSEA = .073, 90% CI = .057 - .090). Note too that the chi-square change statistic and corresponding degrees of freedom showed significant differences going from the configural to the metric model and the metric model to the scalar model. Going from the scalar to the residual invariant model was non-significant suggesting the error variances may be invariant.

Constraining the factor loadings to be equal across groups also showed reasonable fit as the descriptive fit indices of the metric invariance model were within the recommended guidelines (χ^2/df = 2.51, GFI = .94, CFI = .97, RFI = .93, RMSEA = .075, 90% CI = .061 - .089, ΔCFI = -.01, ΔRMSEA = .002). Scalar invariance was also supported by the descriptive indices (χ^2/df = 2.59, GFI = .94, CFI = .96, RFI = .93, RMSEA = .077, 90% CI = .064 - .091, ΔCFI = -.01, ΔRMSEA = .002). The error variances also had reasonable fit (χ^2/df = 2.38, GFI = .94, CFI = .97, RFI = .94, RMSEA = .071, 90% CI = .058 - .084, ΔCFI = .01; ΔRMSEA = -.006). Based on the results of the four invariance models for discipline, we conclude that the factor structure had full measurement invariance across discipline.

Discussion

The Learning and Study Strategies Inventory-second edition is universally used to assess students' profiles of learning strategies. Centers for teaching and learning at educational institutions utilize such measurement instruments to obtain diagnostic profiles of students. One of the most effective roles of such centers is to implement training programs for students with low profiles in learning strategies since they are key factors for success in all college disciplines.

Ascertaining that a test has measurement invariance should be a prelude to all group comparisons based on that instrument. It is important to ensure that the measurement instrument behaves similarly across subgroups to make valid interpretations of scores, and hence trustworthy comparisons. Based on its widespread use for assessing learning and study strategies in different populations, various researchers, as cited above, investigated the latent structure of the LASSI in different populations and reported inconsistent results. The ER-GO-GA model proposed by Olaussen and Braten (1998) was the most common among research findings and provided adequate fit for our data. Given the paucity of published investigations of the measurement invariance of the LASSI-II, the present study tested the measurement invariance of an adapted Arabic version of the learning and study strategies inventory-second edition (LASSI-II) across gender (males/females) and discipline (science/humanities).

Results of the single-group confirmatory factor analysis supported the ER-GO-GA model for the four subgroups (males, females, science, humanities). These results are in line with the results obtained by most researchers who investigated the underlying factor structure of the LASSI-II (Abdelsamea & Bart, 2019; Cano, 2006; Prevatt et al., 2006; Samuelstuen, 2003; Stevens & Tallent-Runnels, 2004). In the present study, data supported partial measurement invariance across gender, as the error variance was not invariant across male and female students. This partial invariance across gender may be informative to researchers in the sense that they should try to figure out how male and female students interpret learning and study strategies after administering the LASSI-II. On the other hand, the present data supported full measurement invariance across discipline (science/humanities). These results were partly consistent with those reported by Stevens and Tallent-Runnels (2004) who reported that the LASSI-HS was invariant across gender. Results of gender invariance are in line with Byrne et al. (1989) as well as Milfont and Fischer (2010) who discussed the concept of partial measurement invariance. Results of discipline invariance are consistent with Putnick and Bornstein (2016) who indicated that few measurement instruments have residual invariance.

Findings of the present study present robust evidence about the measurement invariance of the LASSI-II in a non-western educational context. It is the first study that addressed measurement invariance of the LASSI-II across gender and discipline. Accordingly, it is hoped that the results of the present study will be useful for those who are interested in using an adapted Arabic version of the LASSI-II for group comparisons. The present study contributes to the existing literature on the learning and study strategies of Egyptian college students in several ways. First, this study confirmed the ER-GO-CA interpretation of the LASSI-II. Second, it tested the measurement invariance of the underlying factor structure of an adapted version of the LASSI-II subscales among Egyptian college students. The present study highlights the importance of testing measurement invariance prior to comparing means on the latent constructs. These results should inspire other researchers to test the assumption of measurement invariance before comparing means. Third, it provides the Arab educational and psychological literature with an adapted Arabic version of the LASSI-II that is valid for comparing means on the latent constructs. Fourth, the results may set the stage for future research on the LASSI-II. For instance, researchers may compare the latent means of the LASSI-II based on gender and discipline subgroups.

In summary, using raw scores of measurement instruments without testing their measurement invariance to compare groups may yield untrustworthy results. Thus, testing measurement invariance of the LASSI-II in Egyptian college students may help faculty members, stakeholders, and researchers compare the means of the LASSI-II in male versus female students as well as science versus humanities students. Practitioners can be more confident that their comparisons are valid given our results for invariance of the LASSI-II across gender and discipline at the latent mean level. Comparing these latent means based on a valid instrument will help obtain results that will allow appropriate inferences and claims. Comparing means of these latent constructs will also help faculty members as well as stakeholders identify the profiles of college students' learning and study strategies and act accordingly. For example, when male and female students are compared on how well they process information while completing assigned academic tasks, results may direct practitioners and stakeholders to the types of training programs that may be most useful. If male students are found to have lower scores on this scale, specific intervention programs can be designed for this group given the fact that the effective use of these strategies affect learning outcomes. Similarly, if students at the humanities track perform better on selecting main ideas than students in the science track, practitioners can more confidently ascribe this to real differences between students on the two tracks because the instrument used is invariant across both groups.

The present study has some limitations. One limitation is that it only assessed measurement invariance across gender and discipline. Another limitation is that this study tested the measurement invariance of the LASSI-II on the subscale level and not the item level. Accordingly, research is needed to investigate the measurement invariance of the LASS-II on the item level. Future research may assess measurement invariance of the LASSI-II across other grouping variables such as SES subgroups. Future research on the LASS-II may also include participants across college level (freshmen to seniors) to increase our understanding of the effect of college level on learning and study strategies as well as on measurement invariance. Finally, given the wide use of the LASSI-II (Weinstein & Palmer, 2002), more work needs to be done with other cultures where the inventory is used.

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Appendix

Summary statistics for the groups of interest

Table 1. *Covariance components, means, and standard deviations of the LASSI-II subscales for female students* (*n = 369*)

Subscale	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1- INP	32.24									
2- SMI	9.36	20.99								
3- TST	7.84	14.04	25.75							
4- ANX	2.10	8.31	9.49	22.95						
5- ATT	7.92	9.47	9.11	3.91	18.61					
6- MOT	14.57	10.51	9.90	1.79	10.08	26.92				
7- CON	11.49	12.51	11.42	7.27	10.10	11.89	22.19			
8- SFT	19.88	7.77	6.50	0.56	7.46	15.19	10.17	29.82		
9- STA	15.93	6.49	4.87	-0.02	7.77	12.03	9.94	14.25	25.08	
10- TMT	10.81	10.43	12.30	7.09	8.12	14.19	13.41	11.76	8.21	23.84
Means	26.03	22.07	25.78	18.95	24.06	28.83	22.47	25.21	25.28	22.17
SD	5.68	4.58	5.07	4.79	4.31	5.19	4.71	5.46	5.01	4.88

Note. INP = Information processing; SMI = Selecting main ideas; TST = Test strategies; ANX = Anxiety; ATT = Attitude; MOT = Motivation; CON = Concentration; SFT = Self-testing; STA = Study aids; TMT = Time management; SD = Standard deviation.

Table 2. *Covariance components, means, and standard deviations of the LASSI-II subscales for male students* (*n = 153*)

Subscale	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1- INP	29.19									
2- SMI	8.68	17.62								
3- TST	6.38	12.93	24.56							
4- ANX	3.55	9.60	9.81	35.93						
5- ATT	6.64	6.28	7.84	5.63	19.69					
6- MOT	4.81	3.41	8.56	-2.36	10.26	25.34				
7- CON	5.82	7.63	8.97	8.54	6.11	6.68	20.05			
8- SFT	7.48	1.84	4.62	-4.83	5.28	12.04	5.05	26.28		
9- STA	5.75	2.89	4.96	6.95	6.46	6.74	3.27	9.06	22.54	
10- TMT	5.51	4.28	10.90	3.50	8.50	12.11	8.20	11.91	5.61	23.60
Means	27.16	22.48	26.15	21.09	23.52	28.30	22.80	24.75	24.85	22.07
SD	5.40	4.20	4.96	5.99	4.44	5.03	4.48	5.13	4.71	4.86

Note. INP = Information processing; SMI = Selecting main ideas; TST = Test strategies; ANX = Anxiety; ATT = Attitude; MOT = Motivation; CON = Concentration; SFT = Self-testing; STA = Study aids; TMT = Time management; SD = Standard deviation.

Table 3. *Covariance components, means, and standard deviations of the LASSI-II subscales for humanities students* (*n = 291*)

Subscale	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1- INP	33.60									
2- SMI	9.79	20.23								
3- TST	7.36	13.69	24.96							
4- ANX	4.81	9.84	10.60	26.84						
5- ATT	8.32	8.38	6.96	5.00	17.66					
6- MOT	13.18	8.86	8.66	1.12	8.50	24.22				
7- CON	11.27	11.50	10.46	9.55	8.98	9.58	22.39			
8- SFT	18.50	6.33	5.60	0.83	5.40	13.06	8.44	26.75		
9- STA	13.04	4.97	4.70	1.27	4.98	7.97	6.35	9.33	20.27	
10- TMT	10.63	9.64	12.35	8.34	8.01	12.82	12.85	11.64	6.36	25.26
Means	25.84	21.97	26.02	19.11	24.28	29.04	22.31	24.74	24.54	22.43
SD	5.80	4.50	5.00	5.18	4.20	4.92	4.73	5.17	4.50	5.03

Note. INP = Information processing; SMI = Selecting main ideas; TST = Test strategies; ANX = Anxiety; ATT = Attitude; MOT = Motivation; CON = Concentration; SFT = Self-testing; STA = Study aids; TMT = Time management; SD = Standard deviation.

Table 4. *Covariance components, means, and standard deviations of the LASSI-II subscales for science students* (*n = 231*)

Subscale	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1- INP	28.33									
2- SMI	8.27	19.67								
3- TST	7.88	13.90	25.97							
4- ANX	-0.05	7.37	8.84	28.17						
5- ATT	6.84	8.85	10.75	3.63	20.25					
6- MOT	10.14	8.02	10.54	-0.14	11.92	29.02				
7- CON	7.81	10.47	11.16	5.22	9.07	11.56	20.37			
8- SFT	12.68	5.37	6.44	-4.24	9.10	16.28	8.64	31.11		
9- STA	11.70	5.57	5.31	-2.85	11.18	14.42	9.52	16.51	28.46	
10- TMT	6.90	7.53	11.18	3.43	8.21	14.25	10.86	12.33	9.31	21.66
Means	27.02	22.45	25.72	20.16	23.43	28.20	22.90	25.51	25.93	21.77
SD	5.32	4.43	5.10	5.31	5.00	5.39	4.51	5.58	5.33	4.65

Note. INP = Information processing; SMI = Selecting main ideas; TST = Test strategies; ANX = Anxiety; ATT = Attitude; MOT = Motivation; CON = Concentration; SFT = Self-testing; STA = Study aids; TMT = Time management; SD = Standard deviation.