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Theoretical and Factorial Validity of Shearer's Revised Logical-Mathematical Intelligence Scale and Its Relationship with Academic Achievement

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Abstract: The factorial validity of Logical Mathematical Intelligence Scale (LMIS) developed by Shearer (1994) was explored in this study by resorting to schema theory. To this end, its 17 interrogative sentences were rendered declarative and six heterogeneous alternatives offered for each sentence were reduced to four homogenous choices. The revised LMIS was then administered to 376 undergraduate and graduate students who had taken various courses offered in the English language. When the participants' responses were subjected to Principal Axis Factoring and Varimax with Kaiser Normalization five factors appeared showing that the cognitive domain of logical-mathematical intelligence measured by the LMIS consists of five latent variables representing mathematical, logical, witty, ingenious, and inquisitive genera. Correlating the scale and its factors with the students' GPA established a significant but negative relationship between the logical genus and academic achievement. The results are discussed and suggestions are made for future research.

Keywords: Logical-mathematical intelligence; Schema theory; Domain; Factor analysis.

1. Introduction

The concept or "schema" (Anderson and Pearson, 1984) represented by the word "intelligence" has been widely explored in psychology (Solso *et al.*, 2005; Sternberg, 1997) due to its broad and vague nature (Jensen, 1998). Legg and Hutter (2006), for example, collected 35 different definitions offered by psychologists to capture its various and multidimensional aspects. Woolfolk *et al.* (2003) definition of intelligence, however, seems to be accepted by all, i.e., "ability or abilities to acquire and use knowledge for solving problems and adapting to the world" (p. 108).

Spearman (1904b) was the first scholar who took the necessary step to categories abilities considered "intelligence" as Linnaeus (1737) did with organisms in biology. His classification of abilities called intelligence was, however, not as comprehensive and theoretically sound as Linnaeus' categorization of organisms because he approached intelligence as a deductively established concept whose existence depends on two unique capacities whereas Linnaeus studied organisms inductively and put them into groups whose members shared certain features with each other and differed from other groups in certain distinctive features.

More specifically, Spearman (1904a) assumed that human beings tackle whatever problems they face in their personal life by utilizing two abilities, i.e., fluid intelligence and crystallized intelligence. While fluid intelligence represents the set of mental abilities which are basically inherited and utilized when individuals do not already know what to do Horn and Cattell (1966), crystal intelligence is acquired through education or interaction with the environment. Other scholars such as Hebb (1942) basically accepted the dichotomous classification but referred to the abilities differently, e.g., intelligence A and B. Others still added other intelligences to the list and provided Gardner (1983) with the necessary literature to propose his theory of multiple intelligences.

In contrast to psychologists such as Spearman (1904b) who divided human abilities into two distinct groups, Linnaeus (1737) resorted unconsciously to schema theory to categorize organisms within a hierarchical system whose members interacted with each other at various levels. He called the broadest concept placed at the apex of system *domain* and broke it successively into *kingdom*, *phylum*, *class*, *order*, *family*, *genus* and *species*. The modern men and extinct Neanderthals and Denisovans, for example, form the three *species* of Homo *genus*. Chimpanzees and gorilla join men to establish the family of *Homnidae* having upright posture and large brain as their common properties. Homnidae, in turn, broaden to constitute the *order* of primates, the *class* of mammalia, the *phylum* of chordate and *kingdom* of animalia containing all multicellular organisms other than plants.

Khodadady (1997) believed that although (Linnaeus, 1737) developed his taxonomy to study organisms systematically, it is equally applicable to study words and the concepts they represent in applied linguistics and psychology, respectively. According to Khodadady (2013), the basic units of language are words which represent specific concepts stored in mind, i.e., schemata. One of these concepts, i.e., intelligence, is used once, i.e., schema type, or repeatedly, i.e., schema tokens, with certain concepts to specify its species, genus, family, order, class, phylum, kingdom and domain as conceived by individuals. (Some of these levels have still remained unknown in cognitive psychology.)

Khodadady and Yazdi (2014), for example, studied the factorial validity of cultural intelligence and concluded that as a cognitive domain it consists of 19 species and four genera for advanced English language learners in Iran. Similarly, Khodadady and Tabriz (2012) showed that the domain of emotional intelligence as conceived by Bar-On (1997) consists of 112 species and 15 genera for Iranian English language instructors. Future research must show whether the domain of intelligence contain family, order, class, phylum and kingdom levels as well. These hierarchical levels are generally established by utilizing two types of tests: Schema-Based Tests and Species-Based Tests.

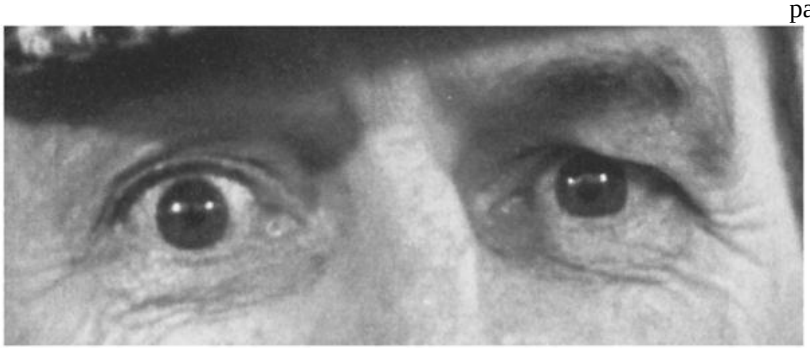
1.1. Schema-Based Tests

Schema-Based Tests (SCBT) are measures of ability in which a specific domain is treated as the apex of a hierarchical system whose base consists of certain schemata represented by words. They are presented as stimuli for which a certain number of responses are offered as alternatives. The more the number of responses identified correctly by test takers, the higher their ability is accepted to be. Baron-Cohen *et al.* (2001), for example, designed Reading the Mind in the Eyes Test (RMET) to study "social intelligence" as a domain consisting of certain schemata. They developed 36 pictures as pictorial stimuli for each of which four schemata were offered as alternatives.

Figure 1, for example, portrays the picture of a "panicked" man. Baron-Cohen *et al.* (2001) presented it as a stimulus to their autistic and normal RMET takers to decide whether they could choose the most appropriate response, "panicked", from among three inappropriate alternative schemata "jealous", "arrogant" and "hateful". Their results showed that normal adults scored significantly higher than the autistic ones on the RMET, indicating that the latter lacked social intelligence. Similarly, Khodadady and Herriman (2000) developed an SCBT on an authentic text which consisted of 40 keyed responses to be chosen from among 120 alternatives. Their results showed that their test was an empirically validated measure of English language proficiency domain because of its high correlation with the Test of English as a Foreign Language (TOEFL).

Figure-1. SCBT Item Testing the Ability to Identify a "Panicked" Individual

jealous panicked



arrogant hateful

Hezareh (2015) analyzed the RMET and argued that it measures "social intelligence" as a cognitive domain consisting of 32 schemata portrayed by 36 photos, i.e., "accusing", "anticipating", "cautious", "concerned", "confident", "contemplative", "decisive", "defiant", "desire", "despondent", "distrustful", "doubtful", "fantasizing", "flirtatious", "friendly", "hostile", "insisting", "interested", "nervous", "pensive", "playful", "preoccupied", "reflective", "regretful", "serious", "skeptical", "suspicious", "tentative", "thoughtful", "uneasy", "upset", and "worried". The four schemata "cautious", "fantasizing", "interested" and "preoccupied" were measured two times by two different photos, i.e., they had a token of two.

SCBTs such as the RMET are, therefore, fairly simple because the hierarchical system of whatever they measure consists of only two levels, i.e., domain and schemata. Similarly, the linguistic structure of alternatives used in the SCBTs is simple because they are limited in terms of groups to which their constituting words belong. Seventy seven semantic words, for example, represent the schemata brought up by Baron-Cohen *et al.* (2001). They believed that if the RMET takers mapped these words with 36 photos and chose the 32 schemata presented in the paragraph above, they possessed "social intelligence" as a cognitive domain. In other words, the language through which Baron-Cohen *et al* bring up and measure the domain is linguistically simpler because it consists of only "content" (Crystal, 1991) or "semantic" (Khodadady, 2008) words, i.e., adjectives and nouns.

1.2. Species-Based Tests

In contrast to SCBTs such as the RMET which are developed on pictorial or orthographic stimuli to be mapped with different linguistically controlled schemata offered as alternatives, the Species-Based Tests (SPBTs) consist of sentence-long orthographic stimuli offered with a set number of alternatives having the same schemata. The SCBT also differ from the SPBTs in terms of the people whose schemata are measured. While the SCBTs measure their takers understanding of *other people's* attitudes, feelings and experiences, the SPBTs require their takers to relate the content expressed by the stimulus sentences, i.e., species, to their *own* personal attitudes, feelings and experiences. In other words, while SCBTs are other or designer dependent measures of domains, the SPBTs are self or participant dependent.

The very distinctive feature of being self-dependent, i.e., test takers evaluate themselves, requires the SPBT designers to employ sentences rather than words as their stimuli. In contrast to words which represent basic concepts, i.e., schemata, each sentence, brings up a composite concept which is much broader and more complex than its constituting words, i.e., species. The cognitive complexity of species is reflected in the linguistic analysis of their representative sentences. They consist not only of semantic words as the SCBTs such as the RMET do but also of syntactic and parasyntactic words such as pronouns and numerals. [Interested readers can find a fairly elaborate description of these words in Khodadady and Lagzian (2013) study.

King (2008), for example, composed 24 sentences such as "I am able to deeply contemplate what happens after death", to validate his Spiritual Intelligence Self-Report Inventory (SISRI) with five alternatives which consisted of the same words for all sentences. After reading each sentence on the SISRI, its takers have to decide whether the species expressed by each sentence is 1) not at all, 2) not very, 3) somewhat, 4) very, and 5) completely true of them. He kept the schemata represented by the five alternatives the same for all the species constituting the SISRI so that its takers' understanding of species could be determined consistently. The alternatives offered for SCBTs such as the RMET, however, differ from each other because they must be based on other-dependent stimulus such as photos taken from people.

Khodadady and Moosavi (2015) analyzed the 24 sentences constituting the SISRI and reported that they consist of 16 adjectives (12.8%), five adverbs (4.0%), 43 nouns (34.4%), 21 verbs (16.8%), five conjunctions (4.0%), six determiners (4.8%), 10 prepositions (8.0%), nine pronouns (7.2%), one syntactic verb (0.8%), two abbreviations (1.6%), six para-adverbs (4.8%) and one particle (0.8%). King (2008) used some of these words several times, i.e., their tokens were more than one. The pronoun representing the schema "I", for example, has a token of 23 indicting that all the adjectives, adverbs, nouns and verbs constituting the SISRI dealt with SISRI takers' own spiritual experiences rather than other people's such as those photographed in Baron-Cohen *et al.* (2001) study.

Khodadady and Moosavi (2015) also argued that since species constituting the domain of the spiritual intelligence are different in terms of their constituting schema types, they combine with each other in varying numbers to produce concepts-broader-than-species called genera. The genera are represented by factors which are extracted from the responses given to measures such as the SISRI. King (2008), for example, administered the SISRI to 619 undergraduate university students in Canada and established four genera via factor analysis, i.e., Critical Existential Thinking, Conscious State Expansion, Personal Meaning Production, and Transcendental Awareness. The SPBTs are thus cognitively more complex than the SCBTs because in addition to schemata, they specify the species and genera of a specific domain.

For example, sentence seven along with sentences 11, 15, 19, and 23 represent the species, "I am able to define a purpose or reason for my life", "When I experience a failure, I am still able to find meaning in it", "I am able to make decisions according to my purpose in life.", and "I am able to find meaning and purpose in my everyday experiences", respectively. These five sentences loaded acceptably on a single factor to represent Canadian university students' genus of Personal Meaning Production. This genus does in fact bring up an aspect in the students' spirituality which had stayed unknown before King (2008).

The necessity of keeping alternatives the same for SPBTs has, however, been violated by Shearer (1994) who developed his Multiple Intelligences Developmental Assessment Scales (MIDAS) to measure interpersonal, intrapersonal, kinesthetic, linguistic, logical-mathematical, musical, naturalist and spatial intelligences. The present study has, therefore, been developed to revise Shearer's Logical-Mathematical Intelligence Scale (LMIS) in the light of the discussions brought up in this study. The other intelligences measured by the MIDAS have not been explored to control its scope.

1.3. Logical-Mathematical Intelligence Scale: A Species-Based Test

Inspired by Gardner (1983); (Gardner and Hatch, 1989), Shearer (1994) developed his MIDAS to find out whether multiple intelligences theory could be employed to help students learn educational materials by identifying and developing their various intelligences. It consists of eight scales one of which is the main focus of this study, i.e., Logical-Mathematical Intelligence Scale (LMIS). Exploring the theoretical and factorial validity of the MIDAS and its constituting scales is important because researchers have employed them to measure individuals' multiple intelligences in relation to variables such as writing and listening abilities.

Ahmadian and Hosseini (2012), for example, administered the MIDAS to 33 female Iranian EFL learners and correlated it with their scores on two writing tasks. They could not, however, find any significant relationship between the logical-mathematical intelligence (LMI) measured by the LMIS and writing ability. Similarly, Mahdavy (2008) administered the MIDAS to 268 university students who majored in English as a foreign language in Iran.

One hundred fifty one and 117 of these students took the listening tests of the TOEFL and International English Language Testing System (IETLS), respectively, as well. When the sores on the LMIS, TOEFL and IELTS were correlated with each other, no significant relationships could be found between the LMI and listening comprehension ability.

By resorting to schema theory, Khodadady and Dastgahian (2013) [henceforth K&D] hypothesized that no significant relationship between the LMI and writing and listening comprehension abilities is found because the LMIS is not an SCBT to consist of a domain and schemata alone. To test their hypothesis, they administered the Persian LMIS to 205 participants who also took a TOEFL held by the Ministry of Science, Research and Technology in Iran. When they subjected the participants' responses on the LMIS to Principal Axis Factoring (PAF) and rotated their results via Varimax with Kaiser Normalization (VKN), they found that out of 17 sentences comprising the LMIS, 16 loaded acceptably on six factors, indicating that the LMIS was a SPBT which measured the genera of the LMI domain as well.

However, K&D argued that their extracted factors might have been influenced by the interrogative nature of sentences and their heterogeneous alternatives. The example question raised by Shearer (1994), for example brings up the species, "Can you sing 'in tune'?" This sentence, according to Quirk *et al.* (1985) is a yes-no question which requires "affirmation or negation" (p. 806) on the part of its reader. The LMIS takers must, however, decide whether they can sing in tune, A= A little bit. B= Fair, C= Well, D= Very Well, E= Excellent, F= I don't know. As a second example, a yes-no question like "Are you good at multiplying three digit numbers in your head?" is presented with six other alternatives four of which are different from those given to example one, i.e., A= No, B= Fairly good, C= Good, D= Very good, E= Excellent, and F= I don't know. As can be seen, only the last two alternatives, i.e., E and F, are common to both questions. K&D treated the alternatives of these two sentences as synonyms, i.e., they were expressing the same concepts and thus assigned the same value to two alternatives offered "A= A little" and "A= No".

The present study was, therefore, designed to follow two objectives. First, it follows Mohamadpur (2014) and tries to find out whether changing Shearer (1994) yes-no questions into declarative sentences and presenting them with four alternatives consisting of the same words will result in the acceptable loading of the sentences on factors other than those extracted by K&D. Secondly, it aims to find out whether the LMI domain as measured by the revised LMIS and its constituting genera relate significantly to undergraduate and graduate university students' academic achievement if the scale and its factors are correlated with the students' GPA.

2. Methodology

2.1. Participants

Three hundred seventy six, 236 male (62.8%) and 140 female (37.2%), students took part voluntarily in the present study. Their age ranged between 17 and 47 (mean = 22.03, SD = 4.52). They were majoring in English language and literature, English translation and teaching English as a foreign language. They had taken the courses grammar 1 (n = 98, 26.1%), linguistics 1 (n = 97, 25.8%), material development (n = 23, 6.1%), research methods and principles (n = 63, 16.8%), and teaching methods and principles (n = 17, 4.5%) offered in English as the language of instruction. The sample also included 52 (13.8%) and 26 (6.9%) students of agriculture and veterinary medicine, respectively. They had taken general English taught via Schema-Based Instruction (SBI). The SBI approach is based on presenting a specific number of words as representative of basic cognitive concepts which are combined with each other to broaden their scope within the linguistic context of sentences, paragraphs and texts standing for the broader concepts of species, genera and domains (Khaghaninejad, 2015; Khodadady *et al.*, 2011; Khodadady and Elahi, 2012). The courses were offered at bachelor (n = 266, 70.7%), master (n = 87, 23.1%) and PhD (n = 23, 6.1%) levels at Ferdowsi University of Mashhad and Imam Reza University, in Mashhad, Iran, in four semesters, i.e., September 2013 and 2014 and January 2014 and 2015. The participants spoke Persian (n = 367, 97.6%), Turkish (n = 6, 1.6%), Kurdish (n = 1, .3%), Lori (n = 1, .3%), and Arabic (n = 1, .3%) as their mother language.

2.2. Instruments

Three measures were employed in this study, i.e., demographic scale, LMIS and GPA.

2.2.1. Demographic Scale

The demographic scale consisted of three open-ended questions dealing with participants' age, course of study and mother language. It also contained multiple-choice items to determine their gender and academic level.

2.2.2. LMIS

The 17 yes-no questions composed in English by Shearer (1994) were changed into declarative sentences to revise the LMIS. The yes-no question representing the species, "Can you sing 'in tune'?", was, for example, rewritten as "I can sing in tune". In addition to rendering interrogative sentences declarative, the number of alternatives with which the sentences were presented to test takers was reduced from six to four, i.e., "mostly disagree", "slightly disagree", "slightly agree" and "mostly agree". [The species are not given in this study because of their developer's instruction (personal communication, June 23, 2014)].

While K&D employed the Persian version of the LMIS, its revised English version was administered in the present study. The administration of English version was based on the fact that the participants had taken the courses whose language of instruction was English. However, to secure complete comprehension on the part of participants, the Persian equivalents of English schemata whose meaning seemed difficult were also provided in parentheses appearing immediately after the English schemata. The transliterated Persian equivalent of prepositional phrase "in tune", for example, followed it immediately, i.e., "I can sing in tune (HAMAHANG). The descriptive statistics and reliability estimates of the Persian LMIS and its revised English version will be provided in the results section shortly.

2.2.3. Grade Point Average

The grade point average (GPA) of participants was employed as a measure of their academic achievement. Their GPAs were taken from their academic profile available to the instructor with whom they had taken courses. Securing high GPAs is important in Iran because the first three students who have the highest GPAs are admitted to graduate programs without sitting for any entrance examinations.

2.3. Procedures

At the very beginning of academic semesters, the importance of research was explained to the participants and they were encouraged to take part in the research projects conducted by the present author. They were told that during the semester, some tests and questionnaires would be administered at the end of certain teaching sessions. Whoever volunteered to take all the measures will be rewarded by receiving two extra scores which would be added to their total scores on the final examination. To secure their active participation, the domains upon which the measures were developed were also brainstormed. They were, for example, asked what they knew about the LMI domain. After listening to their responses, the LMIS was described as its measure and a brief summary of the findings dealing with the domain was presented to them the week before they took the LMIS. The summary proved to be very helpful because in almost all classes some students raised questions regarding the findings and thus helped the whole class take the scale very enthusiastically. For taking the LMIS, the researcher read one sentence at a time and waited for the participants to choose the alternative which best described the participants' experiences with the species it stood for. If any participant raised a question on any species it was described in more details and translated into Persian if necessary. Then they moved to the next sentence. After reading all the sentences and ensuring that the participants had chosen the alternatives most appropriate to them, the LMIS was collected.

2.4. Data Analysis

Since PAF provides a true factor analysis as compared to Principal Component Analysis (Bentler and Kano, 1990; Floyd and Widaman, 1995; Gorsuch, 1990; Loehlin, 1990; MacCallum and Tucker, 1991; Mulaik, 1990; Widaman, 1990;1993), it was employed along with VKN to extract the rotated factors underlying the LMIS. Factors extracted by PAF comprise sentences which represent the most logically related species (Khodadady, 2009; Khodadady and Ghahari, 2011). Following Tabachnick and Fidell (2001) the sentence loading at the minimum magnitude of 0.32 (and higher) was accepted as contributive to the factor upon which it loaded acceptably because it equates to approximately 10% of overlapping variance with the other sentences loading on that factor. The eigenvalues of one and higher were employed to determine the number of factors underlying the revised LMIS. Cronbach's alpha was utilized to estimate the reliability level of the scale and its factors. The relationships between the scale, factors and GPA were explored by resorting to Pearson correlations. All statistical analyses were run via IBM SPSS Statistics 20 to test the hypotheses below.

H1. The number of factors extracted from the revised LMIS differs from that of K&D.
H2. The sentences loading acceptably on the factors of this study differ from those of K&D.
H3. There is no significant relationship between the LMI domain and academic achievement.
H4. There are no significant relationships between the genera constituting the LMI domain and academic achievement.

3. Results

Table 1 presents the descriptive statistics, communalities and the percentage of times with which the four alternatives offered for sentences (S) have been chosen. As can be seen, sentence one has the highest mean (3.50) because the first and second highest percentage of participants have slightly (SA) and mostly agreed (MA) with the species it represented, i.e., 23% and 65%, respectively. In contrast, species 16 has the lowest mean (2.13) because the highest percentage of participants has mostly (MD) and slightly disagreed (SD) with it, i.e., 29% and 39%, respectively. Among the 17 sentences, only sentence eight has the lowest extraction communality (.14) and thus fails to contribute factorially to LMI domain as will be discussed shortly.

Table-1. Descriptive Statistics, Communalities and Percentage of Participants' Selection of Alternatives

Ss	Descriptive Stat		Communalities		Alternatives			
	Mean	SD	Initial	Extraction	MD%	SD%	SA%	MA%
1	3.50	.780	.254	.222	3	9	23	65
2	2.62	1.018	.571	.744	17	27	33	23
3	2.30	1.055	.527	.632	28	29	26	16
4	2.83	.898	.336	.396	8	25	41	25
5	2.45	.962	.296	.437	19	31	35	14
6	2.99	.785	.287	.388	4	20	50	26
7	2.45	.948	.211	.303	19	31	36	14
8	2.66	.874	.166	.141	9	33	40	18
9	2.97	.932	.260	.664	8	21	37	34
1	2.76	.832	.369	.443	6	31	44	19
11	3.14	.779	.227	.378	2	19	43	36
12	2.49	.909	.215	.229	15	34	38	13
13	3.07	.914	.216	.300	7	17	38	38
14	2.52	.971	.193	.526	17	31	35	17
15	2.41	.890	.509	.547	15	40	33	12
16	2.13	.938	.343	.336	29	39	22	10
17	3.11	.783	.211	.213	3	15	48	34

Table 2 presents the KMO and Bartlett's Test of the data collected in this and K&D's study. As can be seen, the KMO index of this study is .83 which is noticeably higher than .76 reported by K&D. According to Kaiser (1974) the KMOs in the .80s and .70s are "meritorious" and "middling" (DiLalla and Dollinger, 2006), respectively, indicating that the common factors in this study explain the observed correlations among the variables better than those in K&D's study. However, the significant Bartlett's Test of Sphericity in both studies are significant, i.e., X^2=1510.527 and 903.180, df=136, p<.001, indicating that the correlation matrix was not an identity one.

Table-2. KMO and Bartlett's Test

		This study	K&D's study
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.828	.761
Bartlett's Test of Sphericity	Approx. Chi-Square	1510.527	903.180
	df	136	136
	Sig.	.000	.000

Table 3 presents the rotated factor matrix of acceptable loadings. As can be seen, out of 17, 16 sentences loaded acceptably on five factors and thus *confirmed* the first hypothesis that *the number of factors extracted from the revised LMIS differs from that of K&D*, i.e., six. Sentences 4, 13 and 16, however, loaded acceptably on two factors. These sentences were considered contributive only to those factors upon which they had their higher loadings, i.e., factors 3, 5 and 1. They were, therefore, removed from the structure of other factors, i.e., 4, 3 and 2, respectively. Among the 17 sentences, only sentence 8 does not load acceptably on any factor due to its lowest initial and extraction communalities (see Table 1).

Table-3. Rotated Factor Matrix[a]

Ss	Factors					Ss	Factors				
	1	2	3	4	5		1	2	3	4	5
1	.433	*	*	*	*	10	*	*	*	.461	*
2	.844	*	*	*	*	11	*	*	.594	*	*
3	.766	*	*	*	*	12	*	*	.331	*	*
4	.344	*	.487	*	*	13	*	*	.363	*	.399
5	*	.605	*	*	*	14	*	*	*	*	.709
6	*	.578	*	*	*	15	.606	*	*	*	*
7	*	.419	*	*	*	16	.399	.374	*	*	*
8	*	*	*	*	*	17	*	*	.345	*	*
9	*	*	*	.797	*		*	*	*	*	*

a. Rotation converged in 7 iterations

* Loadings less than .32

Table 4 presents the sentences which have loaded acceptably on the factors extracted in the present and K&D's study. Rendering the interrogative sentences affirmative and presenting them with four homogenous alternatives has decreased the number of factors from six to five and increased the reliability of the scale from .79 to .81. With the exception of factor four whose constituting sentences are the same, the other four factors consist of different

sentences. These results thus largely *confirm* the second hypothesis that *the sentences loading acceptably on the factors of this study differ from those of K&D*. Factor four, however, remains the same in the two studies.

Table-4. Sentential Structures of Factors Underlying the LMIS and Their Reliability Estimates

F	No of Ss	Declarative Sentences	α	Rotation Sums of Squared Loadings			No of Ss	Interrogative sentences	α
				Total	% of Variance	Cumulative %			
1	5	1, 2, 3, 15, 16	.79	2.451	14.416	14.416	3	1, 2, 3	.70
2	3	5, 6, 7	.59	1.409	8.287	22.703	5	5, 6, 7, 8, 17	.62
3	4	4, 11, 12, 17	.60	1.261	7.417	30.120	3	11, 13, 14	.57
4	2	9, 10	.61	.972	5.719	35.838	2	9, 10	.66
5	2	13, 14	.49	.807	4.746	40.584	2	15, 16	.68
6	-	-	-				1	12	-
LMIS	16		.81				16		.79

Table 5 presents the correlations between the factors underlying the LMIS and the participants' GPA. As can be seen, the LMIS does not correlate significantly with the GPA (r = .06, *ns*). This result confirms the third hypothesis that *there is no significant relationship between the LMI domain and academic achievement*. This finding is to some extent in line with that of K&D in which no significant relationship could be established between the LMI domain as measured by the Persian LMIS and English language proficiency (r = -.04, *ns*) either. More research projects are, however, required to find out how the revised LMIS relates to the proficiency.

Table 5. Correlations between Factors Underlying the LMIS and GPA (N = 376)

	GPA	MLIS	Factors				
			1	2	3	4	5
GPA	1	-.021	.057	-.113*	.049	-.093	-.061
MLIS	-.021	1	.805**	.670**	.747**	.562**	.412**
Factor 1	.057	.805**	1	.356**	.480**	.332**	.075
Factor 2	-.113*	.670**	.356**	1	.360**	.332**	.218**
Factor 3	.049	.747**	.480**	.360**	1	.268**	.260**
Factor 4	-.093	.562**	.332**	.332**	.268**	1	.120*
Factor 5	-.061	.412**	.075	.218**	.260**	.120*	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

As it can also be seen in Table 5 above, only factor two correlates significantly but *negatively* with the participants' GPA (r = -.11, $p<.05$), partially *rejecting* the fourth hypothesis that *there are no significant relationships between the genera constituting the LMI domain and academic achievement*. None of the six factors underlying the Persian LMIS having interrogative and heterogeneous alternatives, however, correlated significantly with English language proficiency in K&D's study. Future research must show whether the proficiency relates significantly to the factors underlying the revised LMIS.

4. Discussions and Conclusions

Shearer (1994) provided researchers with a scale to explore the relationship between logical-mathematical intelligence (LMI) and a host of variables such as the English language proficiency (ELP). However, K&D questioned Shearer's measurement of the LMI domain by addressing its constituting species and showed the domain contains a number of genera as well. They did the same with the ELP and treated it as a cognitive domain which consisted of listening, structure and reading genera. The very identification of genera constituting the domains of LMI and ELP proved to be educationally informative because when K&D measured the two domains by the LMIS and a TOEFL, they did not relate to each other significantly. The fifth factor underlying the Persian LMIS did, nonetheless, relate significantly but negatively to the reading genus of ELP domain (r = -.16, $p<.05$)

The present study highlighted and removed the main shortcoming of the LMIS which bears directly on its theoretical as well as factorial validity. By rendering the interrogative sentences declarative and presenting them with homogenous alternatives it showed that the LMI domain consists of five genera. In other words, changing the linguistic structures of sentences and presenting them with alternatives consisting of the same rather than different words helped the present researchers show that the explanatory power of the LMI domain depends on a number of factors chief among which are the theoretical approach adopted, linguistic and cognitive properties of sentences and alternatives constituting the LMIS, and the sample to whom it is administered.

The presentation of 17 declarative sentences with the same four alternatives to the participants of the present study showed that 16 sentences combine with each other in specific numbers to constitute five factors called mathematical, logical, witty, ingenious, and inquisitive genera. These findings are in line with those of K&D who established six genera for the LMI domain. The two studies do, however, differ from each other in terms of their

participants. Unfortunately, the present researchers could not administer the revised LMIS to K&D's participants because of their being anonymous. The differences in the results reported in the two studies must, therefore, be accepted with caution. It is, however, suggested that the present study be replicated with similar samples to test the findings further.

The results of this study show that the linguistic and cognitive properties of sentences influence the validity of the LMIS. The English interrogative sentence representing the species "Have you ever had interest in studying science or solving scientific problems?" for example, did not load on any factors in K&D's study because it basically calls for a "yes" or "no" response. None of their participants, therefore, gave a "no" response to this question (p. 62). Revising the same sentence as a declarative species, "I am interested in studying science or solving scientific problems" in this study has, however, resulted in its loading on the second factor representing the logical genus.

It must, however, be reiterated that the revised LMIS needs to be studied in a similar research project with a sample whose educational background is similar to those of K&D. The majority of participants in this study were majoring in English language and literature, English translation and teaching English as a foreign language at both undergraduate and graduate levels. These fields are subcategorized under humanities (79.3%) in Iran whereas only 16.4% of participants in K&D's study had subsumed their fields of study under humanities. The participants of two studies also differed at their educational level. K&D's study included 76.8% master or professional doctorate students or graduates. The percentage dropped to 23.1% in this study.

The LMI domain measured by the revised LMIS consists of 118 words and 16 sentences and five factors. It does not relate significantly to university students' academic achievement because the domain depends basically on reading course-related materials. As the main variable involved in academic achievement, reading does not relate to fluid intelligence either. Khodadady *et al.* (2013), for example, administered the Standard Progressive Matrices (SPM) developed by Raven *et al.* (1977) to 130 undergraduate and graduate university students who also took a TOEFL test. When they correlated the scores on the SPM and reading comprehension subtest of the TOEFL, they found no significant relationship between the domain of fluid intelligence and reading as a genus of language proficiency domain. Khodadady *et al.* concluded "The SPM … assesses its takers' ability to solve problems faced in unexpected situations requiring no education at all and thus must not relate to education-dependent tests such as the TOEFL" (p. 18).

In contrast to the SPM which is criterion-dependent, i.e., the correct alternative is determined by Raven *et al.* (1977), the revised LMIS is self-dependent, i.e., the participants determine their own LMI domain. Five out of 17 sentences comprising the LMIS loaded on the first factor in this study because it represents the *mathematical* genus of university students who have had extra interest in math, do well in advanced math classes, enjoy collecting things, easily learned math operations in childhood and have good systems for certain tasks. The genus does not relate to academic achievement significantly and thus calls for further research to find out whether it correlates significantly with specific attainments such as learning mathematics.

The second factor represents *logical* genus of LMI domain via 20 semantic, syntactic and parasyntactic words combined with each other in three sentences. It characterizes logically intelligent students as individuals who are interested in solving scientific problems. They are also good at playing chess and games. These characteristics seem not to be favored within tertiary educational contexts because the logical genus correlates significantly but *negatively* with GPA. Future research projects are required to find out whether a significant but positive relationship will be found between logical genus and more specific abilities such as English language achievement measured by different types of tests.

Khodadady and Dastgahian (2015), for example, employed the English Language Teachers' Attribute Scale (ELTAS) developed by Khodadady *et al.* (2012) and validated it with 1483 grade four senior high school (G4SH) students in Mashhad, Iran. Their results showed that the domain of teacher effectiveness as measured by the ELTAS consists of qualified, social, proficient, humanistic, stimulating, organized, pragmatic, systematic, prompt, exam-wise, and lenient genera at G4SHs. Among these genera, the qualified genus correlated the highest with the students' final English examination held at the end of grade three ($r = .29$, $p<.01$), indicating that the more qualified their English teachers are, the more the students achieve in their English course.

However, Khodadady and Dastgahian (2015) administered the schema-based cloze multiple choice item test (SCBT) developed by Khodadady and Ghergloo (2013) to some of G4SHS students as well. [The SCBT was developed on the reading passages of *Learning to Read English for Pre-University Students* (Birjandi *et al.*, 2012) taught as their course book.] When Khodadady and Dastgahian correlated the scores on the SCBT with the students' answers on the ELTAS, the qualified genus of teacher effectiveness domain related significantly but *negatively* with English language achievement ($r = -.11$, $p<.05$). These results may indicate while academic achievement relates negatively to the logical genus of LMI domain, other specific attainment tests such as SCBTs may reveal significant and positive relationships with the logical genus and achievement in specific courses such as mathematics.

The *witty* genus of the LMI domain is represented by the *third* factor consisting of four sentences and 40 words. University students having this genus often play games such as Scrabble, are good at projects requiring math, use good common sense and have a good memory for numbers. Witty genus is, however, more mathematical than logical because its correlation with the former is noticeably higher than the latter ($r=.48$ and $.36$, $p<.01$, respectively). Because of its being strongly related to students' mathematical ability, their witty genus does not relate significantly to their academic achievement. Future research is needed to find out whether the mathematical and witty genera relate to more specific attainments requiring the genus specifically, i.e., achievement in mathematics.

Twenty one words comprising two sentences loaded acceptably on the fourth factor extracted from the revised LMIS, representing the ingenious genus of the LMI domain. Since the two sentences loaded on the same factor in K&D's study, they call for further research to find out why their syntactic differences, i.e., being interrogative and declarative, respectively, does not affect their factorial structure. The genus represents ingenious university students who are good at inventing systems and enjoy working with numbers. Although it relates to both mathematical and logical genera at the same level (r=.33, p<.01), the ingenious genus does not show any significant relationship with academic achievement.

Two sentences consisting of 21 words loaded acceptably on the last factor representing the inquisitive genus of LMI domain. It typifies university students as individuals who are curious about nature. They are also good at figuring numbers in their heads. Being inquisitive in universities is of no help, if any, however, because it does not relate to academic achievement significantly. These findings may help study educational materials, settings and objectives from various perspectives, especially when they are compared to others found in the same context.

Khodadady and Ghahari (2011), for example, studied the factorial structure of Cultural Intelligence Scale (CQS) designed by Van Dyne *et al.* (2008) within a foreign language context. They translated the scale into Persian and administered it to 854 university students. The subjection of data to PAF and VKN showed that cultural intelligence consists of the same four genera established by Van Dyne*et al.*, i.e., cognitive, motivational, behavioral and metacognitive. In a separate study, Khodadady and Ghahari (2011) administered the Persian CQS along with a disclosed TOEFL to 145 undergraduate students majoring in various fields offered in Persian. The correlation of the two measures showed that English language proficiency relates significantly but *negatively* not only to cultural intelligence (r= -.37, p<.1), but also to its cognitive (r= -.35, p<.1), motivational (r= -.38, p<.1), behavioral (r= -.23, p<.1) and metacognitive (r= -.21, p<.01) genera.

Although the LMI domain does not relate to academic achievement, it does not show any negative relationship with it either as the cultural intelligence domain does with English language proficiency. The findings of the present study thus show that spending time, budget and energy to improve the LMI domain within a foreign language context will not bring about any effective educational results and should, therefore, be avoided. They also emphasize deliberate avoidance of logical genus within a tertiary education level where the more logical the students become, the less they will achieve academically. Future research is, however, needed to find out whether the LMI domain and genera have any relevance to achievement in other educational levels such as primary and secondary education.

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