The Reading Matrix: An International Online Journal
Volume 18, Number 1, April 2018

Reading Comprehension in English as a Foreign Language and some Cattell-Horn-Carroll Cognitive Ability Factors

Mona Tabatabaee-Yazdi
Purya Baghaei
Islamic Azad University

ABSTRACT

In this study the cognitive correlates of reading comprehension in English as a foreign language were studied. The Cattell-Horn-Carroll model of cognitive abilities was used as the theoretical grounding for the study. We examined the relationship between fluid intelligence, crystallized intelligence, verbal analogical reasoning, and speed of processing with second language reading comprehension. Measures of the relevant constructs were administrated to 84 undergraduate students of English as a foreign language. Only the verbal analogical reasoning measure had significant partial effects in the regression model.

Keywords: reading comprehension, cognitive abilities, fluid intelligence, crystallized intelligence, speed of processing

INTRODUCTION

Research on the cognitive correlates of reading comprehension (RC) in a second language (L2) is very limited. By cognitive abilities we specifically mean the abilities under the Cattell-Horn-Carroll (CHC) model (Schneider & McGrew, 2012) of intelligence. The CHC is the most comprehensive and empirically supported psychometric theory of the structure of intelligence. A considerable portion of the research in first language RC is devoted to establishing the cognitive correlates of reading and identifying the cognitive profiles of poor readers. The assumption is that if children are not suffering from visual, hearing, or motor impairments; mental retardation, or emotional problems; and are not disadvantaged by inadequate learning opportunities, low reading achievement can be attributed to cognitive disabilities (Benson, 2008). Nevertheless, the main focus in this line of research has been on reading decoding (the ability to recognize letter–sound correspondence) and phonological awareness (the ability to recognize and manipulate sound units in spoken language) with little attention to reading comprehension, specifically the ability to extract meaning from print (Floyd, Bergeron, & Alfonso, 2006; López-Escribano, Elosúa de Juan, Gómez-Veiga & García-Madruga, 2013).

Research on the cognitive correlates of RC in a second language (L2) is even more limited. Generally, research on individual differences in second language acquisition has mostly dealt with instructional, affective, and sociocultural factors with little attention to intelligence. The reason for this lack of attention to intelligence as a contributing factor to successful L2 learning might be due to the introduction of another rival construct in L2 learning referred to as 'language learning aptitude' (Carroll & Sapon, 1959). Language learning aptitude was conceptualized as a special ability for learning languages which overlapped to some extent with intelligence but was viewed as a distinct construct (Dörnyei, 2005). The construct of language aptitude is poorly understood and includes memory, phonetic coding ability, language analytic ability, and grammatical sensitivity, which all seem to be related to intelligence (Dörnyei, 2005). The conceptualization of language learning aptitude, in our view, sidetracked applied linguists from directly pursuing the role of intelligence in SLA research. Nevertheless, research on the role of aptitude in SLA was also neglected (Robinson, 2001).

The state of RC research in L2 is obviously like that of SLA research in general as RC falls under the broader SLA area. In defining the variables that affect the nature of L2 reading comprehension, Alderson (2000) distinguishes between two broad factors of 'reader variables' and 'text variables.' Under reader variables he lists as many as twelve factors including reader's background knowledge, language knowledge, metalinguistic knowledge, cultural knowledge, reader purpose, and reader motivation; and only in passing under "Other, stable, reader characteristics" (p. 56) mentions intelligence.

We stress that cognitive individual differences in reading comprehension is key to understanding the nature of RC in L2. We emphasize that attention and research efforts should be devoted to the role of cognitive abilities in SLA research in general and reading comprehension in particular. The field of SLA is in need of organized research on cognitive factors in relation to L2 RC as these factors might distinguish poor readers from competent readers.

Cognitive Abilities and Reading Comprehension in L1

Research in L1 reading has already demonstrated that RC is related to cognitive abilities, including fluid reasoning, short term memory, crystallized intelligence, and speed of processing with path loadings which ranged from .15 for processing speed to .83 for the general intelligence factor g. (Flanagan, 2000; McGrew, 1993). Cornoldi, De Beni, and Passaglia (1996) found that poor comprehenders have significantly lower performance than skilled comprehenders on measures of vocabulary knowledge and verbal reasoning, after matching them on sex, age, school, grade, reading decoding skills, and general intelligence. Likewise, Stothard and Hulme (1995, 1996) demonstrated that 7- and 8-year-old poor comprehenders perform lower than skilled comprehenders on verbal IQ.

Nation, Clarke, and Snowling (2002) demonstrated that poor and skilled readers are significantly different on nonverbal reasoning ability, a measure of numerical reasoning, and general intelligence as measured by BAS-II Non-verbal Ability composite (Elliot et al., 1996). Floyd, Bergeron, and Alfonso (2006) demonstrated that school-age average achievement comprehenders outperformed low achievement comprehenders in nine Cattell-Horn-Carroll (CHC) broad cognitive abilities as measured by Woodcock–Johnson III scales (Woodcock, McGrew, & Mather, 2001). The measures were: Comprehension-Knowledge, Long-Term Retrieval, Visual–Spatial Thinking, Fluid Reasoning, Processing Speed, Working Memory, and Phonemic Awareness (eta squared values ranged between .14 to .63 for different measures).

In this study we aim to identify the cognitive correlates of reading comprehension in English as a foreign language. We set out to determine the contribution of a number of select cognitive abilities to L2 RC. More specifically the associations of fluid intelligence (Gf), crystallized intelligence (Gc), verbal analogical reasoning, and speed of processing (Gs) were studied.

METHODOLOGY

Instrument

Pearson Test of English General

The reading comprehension section of one of the official past papers of the Pearson Test of English General was used to measure participants L2 reading comprehension. The test contained four passages with lengths 279, 299, 354, and 356 on which 24 three-option multiple-choice items were based. The Cronbach's alpha reliability of the reading test was 0.71. The mean and standard deviation of the sample on the RC test were 13.07 and 3.97, respectively.

Raven's Advanced Progressive Matrices

The short form of Raven's Advanced Progressive Matrices (APM) was used to measure Gf. The short form of APM contains 12 items of the 36-item original APM. The 12 items were selected by Arthur and Day (1994) on the basis of rigorous psychometric criteria with the aim of reducing administration time. The Cronbach's alpha reliability of APM was 0.70. The mean and standard deviation of the sample on the APM were 6.01 and 2.51, respectively. The APM was administered with a time limit of 15 minutes.

C-Test

A four-passage C-Test in the respondents' native language was constructed by the researchers as a measure of crystallized intelligence (Gc). A standard C-Test battery is composed of 4 to 6 short passages, where the second half of every other word is deleted. Baghaei and Tabatabaee (2015), based on theoretical and existing empirical evidence (Schipolowski, Wilhelm, & Schroeders, 2014) argue that the C-Test in the native language is a test of crystallized intelligence. For this study a C-Test containing four short passages each containing 25 gaps was constructed. Each passage was selected from a different domain of general knowledge (history, biology, psychology, and world culture) with the aim of covering the factual knowledge component of Gc. The Cronbach's alpha reliability of the C-Test considering each passage a super-item was 0.75 with a two-week retest reliability was 0.73 ($n=84$, $p<0.01$). Validity evidence was provided by fitting the Rasch (Rasch, 1960/1980) latent trait model (Borsboom, 2008). Masters' partial credit model considering each passage a ploytomous item showed that all items fit the Rasch model. Infit and outfit values were acceptable within 0.83-1.14. The mean and standard deviation of the sample on the C-Test test were 53.45 and 11.76, respectively.

Verbal Analogies

Forty-nine four-option multiple choice verbal analogies items in the form of 'A to B is as C to D' were constructed by the researchers. The English translation of a sample item is:

Mason to Wall is as….
1. Artist to Easel 2. Fisherman to Trout
3. Author to Book 4. Sculptor to Mallet

The relatively high correlation of the verbal analogies with the APM ($r=.53$, $p< .01$) is evidence of the validity of the test as a measure of verbal reasoning. Further analyses showed that the test fits the Rasch model after deleting eight items. Fit of the data to a latent trait model, such as the Rasch model, is evidence of validity (Baghaei, 2009; Baghaei & Tabatabaee-Yazdi, 2016). Kuncel, Hezlett, and Ones (2004) argue that analogical reasoning is a measure of g. The Cronbach's alpha reliability of the analogies was 0.77. Further evidence for the validity of the test was provided by fitting the data to the Rasch model (Rasch, 1960/1980). Infit and outfit values for the items were within the acceptable range of .70 to 1.30 (Bond & Fox, 2007) except for three items which were deleted. The overall fit of the test to the Rasch model was evaluated with the chi^2/df statistic (Baghaei, Yanagida, & Heene, 2017a; Baghaei, Yanagida, & Heene, 2017b). The mean and standard deviations of the sample on the verbal analogies test were 28.64 and 6.30, respectively.

Letter-Digit Substitution Test

The letter-digit substitution (LDS) test (van der Elst, van Boxtel, van Breukelen, & Jolles, 2006) was used as a measure of processing speed. The test was administered in paper and pencil format and 120 seconds were allotted to complete the test. The two-week test-rest reliability of the test was 0.76 ($n=31$, $p<0.01$). The mean and standard deviation of the sample on the LDG test were 46.85 and 15.79, respectively.

Simple Math Operations Test

Simple math operations (SMO) test was another processing speed test developed by the researchers. In this test participants were presented with 100 simple math problems and answers which included only addition, subtraction, multiplication, and division operations ($2+2=5$; $3\times2=6$). In this paper and pencil test respondents were allotted 120 seconds to decide if the answers for the operations were correct or wrong. The two-week test-rest reliability of the test was 0.78 ($n=35$, $p<0.01$). The mean and standard deviations of the sample on the SMO test were 41.82 and 14.00, respectively.

Participants

Eighty-four undergraduate students (74% females; mean age = 24.30 years, SD = 5.81) majoring in English as a foreign language from two universities in Iran were recruited for the study. The tests were administered in two consecutive sessions during normal class periods. Participation was voluntary and participants were provided with profiles of their cognitive abilities as a compensation for their cooperation.

RESULTS

Multiple regression was run to evaluate the explanatory power of the five independent variables in explaining L2 reading comprehension. Due to the low non-significant correlation between the letter-digit substitution test and the RC test (r=0.10, p=.16), this variable was left out of the analysis. Preliminary analyses showed no violation of the assumptions of normality, linearity, multicollinearity, and homoscedasticity.

Results showed that the model explains a significant portion of the variance in the reading comprehension scores (F (4, 79) = 6.66, p< .001, R^2 = .25, $R^2_{Adjusted}$ = .21, f^2 effect size=.33). The analysis showed that *Gf* did not significantly predict RC (Beta = 0.10, p=0.39), nor did *Gc* (Beta = .11, p =.33) and *Gs* (Beta = .15, p =.14). Only verbal analogical reasoning did significantly predict RC (Beta = .30, p< .05).

Table 1. Zero order correlations and beta weights for the variables in the regression analysis (N = 84).

	r						
Variable	1	2	3	4	5	RC	β
Raven	.70	.53*	.39*	.28*	.24*	.35*	.10
Analogy		.77	.46*	.19	.24*	.44*	.30*
C-Test			.75	.32*	.02	.34*	.11
SMO				.78	.30*	.27*	.15
LDM					.76	.10	-
Mean	6.01	28.64	53.45	41.82	46.85	13	
SD	2.51	6.30	11.76	14.00	15.79	3.97	

*p< .05; SMO: simple math operations; LDM: letter-digit matching; RC: reading comprehension; Reliabilities in the diagonal line

CONCLUSION

This study aimed to specify the cognitive correlates underlying L2 RC achievement. Since adult L2 learners do not have access to the 'innate' post-critical-period learning system referred to as 'language acquisition device,' which is deemed to direct L1 learning, they have to rely on their L1 knowledge and their problem solving abilities in L2 learning (Robinson, 2001). Therefore, the role of individual differences in cognitive abilities in L2 learning seems to be fundamental. In this study, reading comprehension in English as a foreign language was regressed on measures of Gf, Gc, Gs, and verbal analogical reasoning. Only the verbal reasoning measure had significant (p< .05) partial effects in the full model. The four variables could account for 21% of the variance in RC. The letter-digit substitution test was dropped from the analysis due to its small correlation with RC. It seems that speed measures which only focus on simple matching tasks have small associations with cognitive measures. When some cognitive load, such as simple arithmetic, is added to the speed task it becomes a better predictor of RC. Kuncel, et. al. (2004) state that analogical reasoning is a measure of g. McGrew (personal communication) states that such tests measure a mixture of Gf and Gc. Raven's test, which is a purely nonverbal measure of g, was not a predictor of RC while verbal analogical reasoning was. This finding clearly indicates that reasoning with language is a predictor of RC. Therefore, low reading achievement in L2 may be due to insufficient development of cognitive processes, if inadequate learning opportunities can be ruled out. The SLA literature does not provide us with information about the specific cognitive abilities that are prerequisite for RC in L2. The variance left unaccounted in our model can be explained by other factors such as subtypes of working memory capacity (a pivotal factor in RC in L1), decoding, and word recognition along with linguistic factors of L2 vocabulary knowledge and grammar (Aryadoust, & Baghaei, 2016).

This study only focused on a limited number of cognitive abilities, each measured with a single test. Future studies should consider a broader range of cognitive abilities as specified under CHC model and measure them with a wider selection of tests. A larger sample would allow latent trait modeling of the cognitive factors deemed to be influential in reading comprehension in L2. Using structural equation models to postulate and test hypotheses concerning the cognitive abilities and their relation to L2 RC yields new insights in SLA research and L2 reading comprehension.

Classroom Implications

The findings of the current study contribute to the understating of the factors underlying poor reading comprehension development. That is, poor reading performance in a foreign language could be due to underdeveloped cognitive abilities, especially poor verbal analogical reasoning. Reading comprehension books and classes are mostly covered with various activities with a focus on word meaning and sentence structure without much attention to reasoning and inference making skills. The findings suggest that analogical reasoning is one of the chief cognitive abilities in learning languages, which has a significant role in EFL reading comprehension. Verbal reasoning tasks provoke thinking, analyzing, and evaluating and help learners practice inference making based on concepts represented as words. Through verbal reasoning, learners interpret the relevance and coherence among vocabularies in the texts while focusing on comprehension of the words. Perhaps practicing with verbal analogies and other verbal reasoning tasks in the classroom can help poor readers improve their reading. This hypothesis needs to be tested with intervention studies, though.

Mona Tabatabaee Yazdi is a PhD student in TEFL, Teaching English as Foreign Language, at Azad University of Torbat-e-Heydarieh, Iran. She is also teaching English in Azad University of Mashhad, Iran. Her research interests focus on language teaching/learning assessment, effective/reflective teaching and teachers' professional development.
Email: Tabatabaee.mona@gmail.com

Purya Baghaei is Associated Professor in the English Department, Islamic Azad University, Mashhad Branch, Mashhad, Iran. He holds a PhD in applied linguistics from Alpen-Adria Universität, Klagenfurt, Austria. His major research interest is in foreign language proficiency testing with a focus on the applications of item response theory models in test validation. He is a scholar of the Alexander von Humboldt Foundation and has conducted post-doctoral research at universities of Vienna, Berlin, and Bamberg.
Email: pbaghaei@mshdiau.ac.ir

REFERENCES

Alderson, J. (2000). *Assessing reading*. New York: Cambridge University Press.

Arthur, W., & Day, D. V. (1994). Development of a short form for the Raven Advanced Progressive Matrices test. *Educational and Psychological Measurement, 54*, 394-403.

Aryadoust, V., & Baghaei, P. (2016). Does EFL readers' lexical and grammatical knowledge predict their reading ability? Insights from a Perceptron Artificial Neural Network study. *Educational Assessment*, *21*, 135-156.

Baghaei, P. (2009). *Understanding the Rasch model*. Mashhad: Mashhad Islamic Azad University Press.

Baghaei, P., & Tabatabaee-Yazdi, M. (2016). The logic of latent variable analysis as validity evidence in psychological measurement. *The Open Psychology Journal*, *9*, 168-175.

Baghaei, P., & Tabatabaee, M. (2015). The C-Test: An integrative measure of crystallized intelligence. *Journal of Intelligence, 3*, 46-58.

Baghaei, P., Yanagida, T., & Heene, M. (2017a). Development of a descriptive fit statistic for the Rasch model. *North American Journal of Psychology*, *19*, 155-168.

Baghaei, P., Yanagida, T., & Heene, M. (2017b). A new fit statistic for the dichotomous Rasch model: Modified cut-off values. *Rasch Measurement Transactions, 31, 1621-1624*.

Benson, N. (2008). Cattell–Horn–Carroll Cognitive Abilities and Reading Achievement. *Journal of Psychoeducational Assessment*, 27-41.

Bond, T.G., & Fox, C.M. (2007). *Applying the Rasch model: Fundamental measurement in the human sciences* (2nd ed.). Mahwah, NJ: Erlbaum.

Borsboom, D. (2008). Latent variable theory. *Measurement, 6*, 25-53.

Cornoldi, C., De Beni, R., & Pazzaglia, F. (1996). Profiles of reading comprehension difficulties: An analysis of single cases. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Process and intervention* (pp. 113–136). Mahwah, NJ: Lawrence Erlbaum.

Carroll, J. B., & Sapon, S. (1959). The Modern Languages Aptitude Test. San Antonio, TX: Psychological Corporation.

Dörnyei, Z. (2005). *The Psychology of the Language Learner Individual Differences in Second Language Acquisition*. Mahwah, New Jersey: Lawrence Erlbaum.

Elliot, C. D., Smith, P., & McColloch, K. (1996). *British ability scales*. (2nd ed.). Windsor: National Foundation for Educational Research.

Flanagan, D. P. (2000). Wechsler-based CHC Cross-Battery assessment and reading achievement: Strengthening the validity of interpretations drawn from Wechsler test scores. *School Psychology Quarterly*, *15*, 295–329.

Floyd, R., Bergeron, R., & Alfonso, V. C. (2006). Cattell–Horn–Carroll cognitive ability profiles of poor comprehenders. *Reading and Writing*, *19*, 427–456.

Kuncel, N. R., Hezlett, S. A., & Ones, D. S. (2004). Academic performance, career potential, creativity, and job performance: Can one construct predict them all? *Journal of Personality and Social Psychology, 86,* 148 –161.

López-Escribano, C., Juan, M. R. E. d., Gómez-Veiga, I., & García-Madruga, J. A. (2013). A predictive study of reading comprehension in third-grade Spanish students. *psicothema, 25*(2), 199-205.

McGrew, K. S. (1993). The relationship between the WJ-R Gf-Gc cognitive clusters and reading achievement across the life-span. *Journal of Psychoeducational Assessment, Monograph Series WJ-R*, 39-53.

Nation, K., Clarke, P., & Snowling, M. J. (2002). General cognitive ability in children with reading comprehension difficulties. *British Journal of Educational Psychology, 72*, 549–560.

Rasch, G. (1960/1980). *Probabilistic models for some intelligence and attainment tests* (Copenhagen: Danish Institute for Educational Research, 1960. ed.). Expanded edition, Chicago: The university of Chicago Press, 1980.

Reynolds, C. R., Vannest, K. J., & Fletcher-Janzen, E. (Eds.) (2013). *Encyclopedia of Special Education*. Boston: John Wiley & Sons, Inc.

Robinson, P. (2001). Individual differences, cognitive abilities, aptitude complexes and learning conditions in second language acquisition. *Second Language Research, 17*, 368-392.

Schipolowski, S., Wilhelm, O., & Schroeders, U. (2014). On the nature of crystallized intelligence: The relationship between verbal ability and factual knowledge. *Intelligence*, *46*, 156–168.

Schneider, W.J., & McGrew, K.S. (2012). The Cattell-Horn-Carroll model of intelligence. In D. Flanagan, & P. Harrison, (Eds.), *Contemporary Intellectual Assessment: Theories, Tests, and Issues*, (3rd ed.) (pp. 99–144). New York: Guilford.

Stothard, S. E., & Hulme, C. (1995). A comparison of phonological skills in children with reading comprehension difficulties and children with decoding difficulties. *Journal of Child and Adolescent Psychiatry, 36*, 399–408.

Stothard, S. E., & Hulme, C. (1996). A comparison of reading comprehension and decoding difficulties in children. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Process and intervention* (pp. 93–112). Mahwah, NJ: Lawrence Erlbaum.

van der Elst, W., van Boxtel, M, P. J., van Breukelen, G, J. P., & Jolles, J. (2006). The Letter Digit Substitution Test: Normative data for 1,858 healthy participants aged 24–8 from the Maastricht Aging Study (MAAS): Influence of age, education, and sex. *Journal of Clinical and Experimental Neuropsychology, 28*, 998–1009.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). Woodcock–Johnson III . Itasca, IL: Riverside.