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INDIVIDUAL DIFFERENCES IN WORKING MEMORY AND ITS INFLUENCE ON TOEFL PERFORMANCE

Second language acquisition (SLA) research, the study of how people learn to communicate in a language other than their native language, encompasses a broad range of questions from a wide variety of perspectives. One of the questions which has attracted the attention of many researchers is why some learners struggle to acquire a second language (L2) while others are quite successful in the same instructional context. Numerous studies have indicated that one of the factors which can explain some variability among learners is working memory (WM). WM is a cognitive construct which is involved in the simultaneous processing and short-term storage of incoming stimuli, including language stimuli. An increasing interest in WM issues has triggered an ample body of research in SLA concerning the role that WM plays in L2 acquisition. In an overview of research on WM, Juffs and Harrington [2011] pointed out that differences in working memory capacity (WMC) can partially explain some variability in success at learning a second language. Also, researchers have investigated the role of WM in different L2 processes: reading comprehension [Harrington, 1992; Walter, 2004], speech production [Mota, 2003], writing [Adams & Guillot, 2008], vocabulary learning [Service, 1992], and grammar development [French & O'Brien, 2008]. WM has been identified as an essential component in L2 aptitude [Safar & Kormos, 2008], as an important factor in the noticing of interactional feedback [Individual differences in 2002] Moreover, WM was found to interact with overall language proficiency as assessed by word translations and self-reports [van den Noort, Bosch, & Hugdahl, 2006].

In spite of an abundance of available research, the vast majority of the studies have focused on different aspects of L2 proficiency rather than L2 proficiency in general as measured by, for example, the Test of English as a Foreign Language (TOEFL). The TOEFL provides a standardized estimate of a person's overall proficiency by gauging four inextricably intertwined but distinct aspects of language: reading, writing, speaking, and listening [Powers, 2010]. In light of the importance ascribed to the TOEFL test, which is considered to be a valid criterion for an international student's admission decision in English medium universities in more than 130 countries [Enright & Tyson, 2008], it appears necessary to explore the non-linguistic factors, such as WM that may contribute to students' TOEFL scores.

In this study, we would like to shed light on the following questions:

1. Does working memory capacity as measured by the LI, L2 Digit Spans and Operation Span correlate with learners' TOEFL scores? Which working memory test correlates with the TOEFL scores the best?
2. Which component of the TOEFL test (reading, listening, grammar or composition) has the strongest correlation with working memory capacity?
3. Does the level of working memory capacity predict how much TOEFL scores are going to improve?
4. How do the following factors influence TOEFL scores: time of living in the US, the number of years a person has been studying English, age when the learner began studying, and working memory?

METHOD

Participants

Participants are native speakers of Chinese enrolled in the Ohio Program of Intensive English (OPIE) at Ohio University. To be included, participants had to have recent TOEFL scores including the scores of TOEFL components (reading, listening, grammar, and composition) within the past 6 months. Participants' TOEFL scores ranged from elementary to advanced levels. The participants had different education backgrounds, different lengths of residence in the US (from 1 month to 5 years), different lengths of English instruction (from 1 to 22 years).

Materials

In order to determine WM level, the following tests were administered: *Participant Questionnaire:* Each participant completed a brief questionnaire which asked students about their gender, age, TOEFL scores (including reading, listening, grammar, and composition), academic major, current education level, length of time in the US, length of time studying English, age when English study began, how many languages the participant knows and what they are.

The next tasks were *the LI and L2 Digit span tasks* which measure the ability of an individual to reproduce immediately, after one presentation, a series of discrete numerical stimuli in their original order. The digit span task is a common measure of short term memory via the phonological loop, which is a component of WM**.** The sequences of numbers are presented to the research participant auditorily.

Phonological Loop (LI) Digit Span: The participants listened to sets of numbers in Chinese and tried to recall these numbers aloud upon set completion. The research participants were presented with digits at levels that increased the sequence of digits by one digit after a level had been presented three times. The task consisted of 24 trials which had increasing levels of difficulty from 4 to 11 digits per level.

Phonological Loop (L2) Digit Span: The participants listened to sets of numbers in English which they were required to repeat aloud when each set was completed. The stimuli for this task consisted of sequences of digits ranging from 4 to 9, 3 trials per level, 18 trials total.

The operation task was modeled on Trude and Tokowicz's [2011] adaptation of Turner and Engle's 1989 task. The operation span task is a complex cognitive task which requires participants to continuously shift between immediate task performance and retrieval processes. The operation span task measures the central executive, which is a component of WM. The central executive «controls the selective attention needed to maintain focus and inhibit information that might distract from or interfere with successful task execution)) [Juffs & Harrington, 2011, p. .40].

In the operation task the participants were shown a mathematical operation and solution on the computer screen and asked to judge the correctness of the solution by saying «right» or «wrong» to the experimenter, who pressed the appropriate key on the keyboard. Then the participants viewed a letter on the screen and said it aloud. At the end of each trial set, the participants were asked to say aloud as many letters presented as they remembered. Each trial consisted of two to six mathematical problems and letters. Three trials of each set size were presented, with gradually increasing set sizes.

All tasks mentioned above were programmed with the help of a free, open-source software application called Psyscope and piloted with several students to identify problems.

RESULTS

Statistical analysis revealed that TOEFL scores significantly correlated with WM as measured by L2 digit span, but not with other tasks. This might mean that language proficiency in English can affect performance on an L2 digit span task. Also, the importance of WM might change with the level of proficiency because the TOEFL scores of advanced students correlated better with WM as measured by the operation span while the TOEFL scores of lower level students correlated better with WM storage capacity measures. Overall, beginner level students appear to rely more heavily on WM in comparison with the advanced level students.

As far as the second research question is concerned, the analysis showed that the TOEFL components weakly correlate with different measures of WM, but there is a significant positive correlation between WM and grammar and a significant negative correlation with composition scores. Harrington and Sawyer [1992] also investigated the relationship between the grammar and reading subsections of TOEFL and WM as measured by a reading span test, random digit strings, and random word strings in L2. The analysis showed a weak correlation between the L2 digit span and the reading and grammar components of TOEFL. These findings are in line with our research. Nevertheless, in a regression analysis Harrington and Sawyer [1992] found a small effect for WM on reading and grammar.

As for writing, several studies [Adams & Guillot, 2008; Bergsleithner, 2010] have found a correlation between writing and WM. For example, Bergsleithner [2010] found a statistically significant relationship between WM as measured by the operation span task and L2 writing performance in 32 Brazilian learners of English with advanced proficiency. The differences in the findings between Bergsleithner's [2010] study and the present study might be due to different criteria used for scoring the writing performance.

The findings of the present research further indicate that WMC in L1 predicts how fast language learners can improve their TOEFL scores and proficiency associated with them. This result is in line with the study by Alloway and Alloway [2010], which demonstrated evidence for the relationship between WM and academic attainment. The findings indicate that children's WM skills at 5 years of age were the best predictor of literacy and numeracy 6 years later. The researchers believe that WM at the start of formal education is a more powerful predictor of subsequent academic success than IQ.

Finally, the analysis revealed that L2 WM contributes to the number of factors influencing TOEFL scores. The model which includes the number of years studying English and L2 WM accounts for 29,1 % of the TOEFL score variance in our data.

To summarize, this study has offered insights into the complex relationship between WM capacity and TOEFL. The study demonstrated that the storage and processing capacities of WM play a different role at different stages of language proficiency. Regarding the effects of WM, the findings indicate that LI digit span performance (i.e., storage capacity in the native language) is a fairly good predictor of how quickly the learners acquire English and consequently improve their TOEFL scores, whereas L2 digit span level (i.e. storage in the second language) contributes to successful performance on the TOEFL test. Additionally, higher processing efficiency as measured by the operation span task is a better predictor of students' levels of ultimate attainment. The overall outcome of the study is that WM influences the speed of second language acquisition and contributes to the performance on the TOEFL test.

IMPLICATIONS

In the light of the current research demonstrating the important role WM appears to play in TOEFL performance, an interesting practical question arises: Can WM capacity be enhanced in order to improve TOEFL scores?

Recently some studies have presented evidence mat WM can be improved by training. Jaeggi, BuschkuehL Jonides, and Perrig-s [2008] research undermines the earlier assumption that although performance on trained tasks can increase dramatically, transfer of this learning to other tasks remains poor. They present evidence that WM greatly increases with training. Moreover, Jaeggi and colleagues show that an increase in WM transfers to measures of fluid intelligence, which is the ability to reason and to solve new problems independently of previously acquired knowledge. This transfer results even though the trained task is entirely different from the intelligence test itself.

Another study conducted by Olesen, Westerberg, and Klingberg [2004] reported changes in brain activity that were induced by 5 weeks of WM training. At the end of the training period, functional magnetic resonance imaging (fMRI) showed that brain activity increased in the middle frontal gyrus as well as the superior and inferior parietal cortices. Olesen et al. concluded that «the changes in cortical activity could be evidence of training-induced plasticity in the neural systems that underlie WM» [p. 75]. Similar results were also obtained by Westerberg and Klingberg [2007] who pointed out that «practice on the WM tasks gradually improved performance and this effect lasted several months. The effect of practice also generalized to improve performance on a non-trained WM task and a reasoning task» [p. 186].

The idea of being able to train WM can have a wide application in classroom pedagogy because WM is an explanatory variable of greater language proficiency. The current study showed that number of years studying English and WM in L2 explain 29 % of the variance and that WM capacity determines how quickly language learners can increase their TOEFL scores. So international students will be able to increase their probability of receiving a high score on TOEFL not only by practicing test-taking strategies and techniques but also by training their WM. Of course, an experiment needs to be conducted to test if WM training can increase performance on the TOEFL test, but this should be the topic of a separate study. This experiment can make use of the WM training tasks developed by Jaeggi et al. [2008].

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