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Research Article

Take a Load off: How Cognitive Load Relates to Phonological Fluency of Novel Sounds in EFL Learners

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ABSTRACT

Learning a foreign language is a complex process that requires not only requires the acquisition of a new set of phonological and lexical items, but also developing the ability to put them to use. In order to use these newly-acquired tokens, foreign language learners must first recognize words as significant, store them in working memory (WM) long enough to encode them into long-term memory (LTM), and then reverse this process while simultaneously employing both their sensory and motor cortexes for language production. Thus, retrieval of words with novel phonemes creates a heavy cognitive load on the working memory (WM) of English as a foreign language (EFL) learners. Our study investigated phonemic fluency and WM capacity in EFL learners. Participants were 64 native Arabic speakers enrolled in an English-medium university. Phonological fluency was tested using a phoneme found in both English and Arabic as the control condition (/f/), whereas a phoneme found in English but not Arabic was used as the test condition (/p/). Results showed significant relationships between phonological fluency of the novel consonant /p/ and measures of WM capacity, suggesting that greater cognitive load may be associated with the retrieval of words beginning with a novel phoneme. Thus, EFL learners may benefit from instruction targeting phonological awareness of novel phonemes to reduce the cognitive load in foreign language processing.

Keywords: Cognitive Load, English as a Foreign Language, Phonology, Working Memory, Phonemic Fluency

INTRODUCTION

Attaining proficiency in a foreign language is a complex process requiring active learning through the interplay of a multitude of cortical areas spanning both hemispheres of the brain. These cortical areas must work in conjunction with one another to perform the numerous cognitive skills required for the language learning process [1,2,3]. Chief among these cognitive processes is working memory (WM), the device by which information is (1) obtained from the environment and encoded into long-term memory (LTM), (2) items are retrieved from LTM, and (3) items are manipulated to be put to use [4]. WM itself is comprised of three primary subcomponents: The phonological loop (verbal WM), the visuo-spatial sketchpad (visuo-spatial WM), and the central executive (manipulation and use of items stored in WM). Baddeley's 2000 [5] model also includes a component known as the episodic buffer, a temporary storage system that modulates and integrates information in WM within a restricted period of time. Among its many functions, the WM system is deeply interconnected with LTM, linguistic areas of the brain, and the auditory, visual, and sensorimotor cortices [6].

Among the key features of WM is the fact that it is limited in capacity to a range of five to nine items, with an average of 7 items. It can only maintain and manipulate said items for a limited period of approximately 20 seconds. If during this time items are not either dispersed to LTM storage and/or put into practical use, they will degrade from WM and become lost [5].

Participating in activities that require multiple forms of engagement can increase the extent to which demand is placed on the limited capacity of WM. The degree of such demand is known as cognitive load (CL) [7]. Differing types

of CL are required for the process of developing proficiency in a foreign language. One such type is intrinsic CL, which refers to the degree to which new information aligns with existing knowledge. For English as a foreign language (EFL) learners, this indicates that there will be reduced CL when learning or using aspects of English that align with their native language as compared to when learning or using novel linguistic concepts. Another necessary type of CL is germane CL, which refers to the mental effort involved in using WM to integrate new information into existing schemas. This form of CL increases or decreases proportionally to intrinsic CL [8].

With regards to learning the phonological structure of English (the system of linguistically meaningful units of sound and the ways in which they can be combined for use), features that are similar to those of an EFL learner's native language will likely require lower CL for encoding, retrieval, and use than those that differ from an individual's native language [8]. An example of a language with a phonological structure that differs from English is Arabic. One difference between these two languages is the fact that the English-language phonemes (linguistically meaningful units of sound) /p/ (e.g. "play") and /b/ (e.g. "boy") exist as allophones of the phoneme /b/. An allophone is a variation of one phoneme that is not consciously perceived as a unique sound by native speakers of a language. Although the allophone [p] is used in Arabic in certain phonological environments, it is consciously processed by native speakers of Arabic as /b/. That is, /p/ is not perceived as a linguistically meaningful unit of sound [9].

As such, native speakers of Arabic often substitute /b/ for /p/ in both oral and written English-language production. This may reflect incorrect encoding into LTM when words containing /p/ are learned by native speakers of Arabic, due to the fact that it is difficult to perceive what are allophones of a phoneme in one's native language as independent phonemes during the EFL learning process. However, many EFL learners who are native speakers of Arabic are aware of the existence of the phoneme /p/ in English, despite facing difficulty in differentiating this sound from /b/ when encountered in speech [10]. To circumvent the possibility of an erroneous substitution, such EFL learners may engage in avoidance, a process by which speakers find alternative words or use circumlocution, descriptive methods that employ multiple words to express the meaning of a single unknown or unwanted word, to evade using a novel phoneme [11, 12, 13].

However, to improve the ease of word retrieval from LTM into WM for use, EFL learners must attempt to use novel words frequently. Increasing the frequency of use will lead the brain to adapt such that it is able to more easily retrieve novel words over time [14, 15,16]. Conversely, avoidance likely leads to more difficulty in the retrieval of novel lexical items as these cognitive adaptations do not form. As such, when native speakers of Arabic engage in avoidance, there may be greater CL when they are required to produce words containing novel phonemes in either their spoken or written form [17]. To reduce CL, greater WM resources, such as larger capacity and improved ability to employ executive function, may aid in retrieving words containing novel phonemes [18].

The ability to retrieve and use words containing a specified phoneme is known as phonological fluency. This skill differs from phonological awareness as it requires one to use a phoneme present in a real word rather than simply exhibit awareness of the existence of said phoneme [10]. It has been shown that greater WM capacity is associated with improved phonological fluency in one's native language. It is hypothesized that this is due to the fact that to produce more words containing a specified phoneme, it is necessary to be able to more quickly retrieve and hold items in WM while they are manipulated for use by the sensorimotor cortex and the related vocal production system. However, although this has been found to be true in one's native language, the relationship between WM capacity and phonological fluency has yet to be examined in foreign language use [19].

In the current study, we examined the relationship between phonological fluency and WM capacity in a group of EFL learners whose native language is Arabic. Participants were female students studying at an English-medium university located in Saudi Arabia that follows a United States-based curriculum. All participants had been deemed to be moderate to competent users of English as measured by standardized testing.

The phonological fluency of two phonemes were examined. The first of these was a control phoneme that is found in both Arabic and English. This phoneme was /f/ (e.g., "fish"). The second phoneme used was a novel phoneme that exists in English but not Arabic. This phoneme was /p/. This phoneme was treated as a test measure of phonological fluency. Forward and backward digit span tasks were used to measure WM capacity under their respectively lower and higher conditions of CL.

There were two hypotheses for this study:

H1: It was hypothesized that a significant difference would be found between the number of both correct and incorrect responses when prompted with the control phoneme as compared to when prompted by the test phoneme. Participants were hypothesized to provide a greater number of correct responses in the control phoneme condition as compared to the test phoneme condition. It was further hypothesized that fewer erroneous responses would be produced in the control phoneme condition as compared to the test phoneme condition. Such a difference would indicate that familiarity with a phoneme from one's native language shows a positive transfer effect with regards to phonological fluency when learning a foreign language. This type of transfer effect may assist in reducing both the intrinsic and germaine CL required for both encoding lexical items containing familiar phonemes into LTM and retrieving them into WM for future use.

H2: It was hypothesized that a significant positive correlation would be found between phonological fluency of the test phoneme and both low and high conditions of CL as measured by the forward and backward digit span WM capacity assessment tasks. It was further hypothesized that this relationship would not be found for the control phoneme. Such a relationship between the test phoneme and measures of WM capacity would indicate that increased WM capacity reduces the CL required to put words containing this novel phoneme into use.

1.1 Motivation and Contribution

The phonological loop of WM is in many ways the gateway for all cognitive processes related to both language learning and its use. It serves the function of collecting linguistic information from the environment, transferring this information to LTM for later use, and both retrieving and manipulating this information when needed to produce or comprehend written or oral communication [20]. Without the initial retrieval of information into WM, there is no linguistic knowledge to be encoded and synthesized by the numerous cognitive processes necessary for linguistic use. Although the extant literature contains extensive research pertaining to the relationship between WM in EFL learners and the four language competencies (listening, speaking, reading, and writing) [21, 22, 23, 24, 25, 26], the relationship between WM and phonological awareness remains an understudied concept. Yet, without phonological awareness, it is not possible to build linguistic skills to the level where EFL learners are able to recognize lexical items in the ambient environment. Phonological awareness is also essential for vocabulary learning in explicit educational environments and is an essential precursor to the development of phonological fluency [27].

Additionally, when examining the extant literature, it becomes clear that EFL learners who are moderate to competent users of English are an understudied population. Much of the extant literature has examined only introductory and beginning-level EFL learners [28, 29, 30]. The current study focuses on a unique population of native speakers of Arabic who have been assessed by standardized testing as sufficiently proficient in the English language to study at an English-medium university following a United States-based curriculum.

By examining the relationship between WM capacity in this unique population of EFL learners and phonological fluency of both a phoneme that exists in English as well as their native language and an English-language phoneme that exists only as an allophone of an independent phoneme in their native language, we may attain a deeper understanding of the role of CL on challenges faced by such students. In doing so, we may then work to develop methods by which to decrease the CL faced by this population in both their academic careers and later professional lives.

1.2 Objectives

The objectives of this study are as follows:

A. Determine whether there is a difference in CL for EFL learners when using a phoneme found in participants' native language, Arabic, and a novel phoneme that is found in English but not Arabic

B. Determine the extent to which CL impairs the use of phonemes found in both participants' native language and English as compared to impairment in the use of phonemes that are found only in English but not Arabic

C. Identify possible interventions that can be implemented to assist in reducing CL when using novel phonemes, should greater CL in this condition be found

METHODS AND METHODOLOGY

1.1 Participants

Participants included 64 native speakers of Arabic between the ages of 18 and 25 years. They were comprised of a convenience sample of female undergraduate students at a university in Saudi Arabia that follows a United States curriculum with a student-centered pedagogy. Participants represented all levels of the university's undergraduate program (freshman, sophomore, junior, and senior) and were considered modest to competent English-language users as measured by the International English Testing System (ILETS) exam. Enrollment in a bachelor's program at this university requires a minimum overall score of 6.0 and a writing score of 5.5 (score range: 0-9). As such, the participants of this study are unique as compared to the introductory/beginning English-language level students who are more typically featured in EFL research [28, 29, 30].

1.2 Procedure

All testing took place in a sound-attenuating room in the Cognitive Science Research Center of Prince Mohammed Bin Fahd University, located in Saudi Arabia. Debriefing was offered at the end of each session. After providing informed consent, students participated in two tasks. The first of these was a variation of the FAS Test, a linguistic production task used to test phonemic fluency. Phonemic fluency in the current study can be defined as the ability to rapidly retrieve English-language words from LTM into WM and produce these words orally in response to a phonemic prompt [31]. This task has been used to test the phonemic fluency of native speakers of English by using the prompts /f/ (e.g. "fish"), /æ/ (e.g., "at"), and /s/ (e.g., "sit"). As in the original FAS test, after participants were provided a phonemic prompt, they were given one minute to produce as many English-language words as possible beginning with the given sound. Prior to testing, the phoneme /d/ (e.g., "dog") was used to familiarize participants with this task. This phoneme was chosen as it is present in both English and Arabic. As such, it was presumed that it would be readily recognized by participants and serve as a clear example of task requirements. Testing began with the control phoneme, /f/, which, like /d/, is also found in both English and Arabic. Participants were then assessed using the test phoneme, /p/. Both correct and incorrect responses to each phonemic prompt were recorded.

Following this task, participants completed the Multi-Ethnic Study of Atherosclerosis (MESA) Digit Span Test [32]. This task was selected because it does not require complex vocabulary knowledge and, as such, has been deemed appropriate for use with non-native speakers of English [33]. It consists of two separate portions, both of which are designed to test different, though related, aspects of WM capacity and related levels of CL. The first of these was a forward digit span task. In this task, participants were auditorily presented with a sequence of pre-recorded numbers which they were then required to reproduce orally in the order in which they had been presented. As this is a single processing task, it is associated with lower CL. The first trial in this task consisted of two numbers to be repeated. The number of items increased by one with each trial. Each trial consisted of two numerical series of the same length. The task ended when a participant failed to correctly reproduce both items within a trial. The second portion of this task was the backward digit span. As in the forward task, participants were presented with sets of pre-recorded numerical items in trials of increasing length. However, in this task, participants were not only required to hold sequential items in WM, but were also required to manipulate these items by orally producing them in the reverse order from which they had been presented. As this is a dual processing task, it is associated with higher CL.

RESULTS

Phonological fluency was measured by the number of both correct and incorrect responses produced following either the control or test phonemic prompt. As shown in Table 1, a 2x2 Repeated Measures ANOVA found significant differences between the number of both correct and incorrect responses to the control phoneme (/f/) and the test phoneme (/p/).

Table 1. Outcomes of a 2X2 Repeated Measures ANOVA Showing the Differences between Responses to the Prompts /f/ and /p/

	Mean Square	F	Significance
Correct Responses	3284.723	174.848	≤0.000
Incorrect Responses	14.535	4.655	0.035
Correct Responses*Incorrect Responses	30.941	6.954	0.011

To determine whether a relationship exists between forward and backward WM capacity and the above measures of phonological fluency, Pearson Correlational Coefficients were calculated. As shown in Table 2, the number of correct responses produced in the test phoneme condition is positively correlated with measures of both forward and backward WM capacity. The number of incorrect responses in the control phoneme condition was negatively correlated with measures of both forward and backward WM capacity. No significant correlations were found between measures of WM capacity and the number of correct responses to the control phoneme, /f/, or the number of incorrect responses to the test phoneme, /p/.

Table 2. Outcomes of Pearson Correlational Calculations between Responses to both /f/ and /p/ and both Forward and Backward WM span.

Significant correlations have been marked in bold with an asterisk.

	Forward WM Capacity	Backwards WM Capacity
Number of Correct Responses to /f/	0.223	0.164
Number of Incorrect Responses to /f/	**-0.319***	**-0.316***
Number of Correct Responses to /p/	**0.265***	**0.293***
Number of Incorrect Responses to /p/	-0.135	-0.197

DISCUSSION

This study examined the phonological fluency of a familiar and novel phoneme in EFL learners whose native language is Arabic. The relationship between outcomes of phonological fluency measures and measures of both forward and backward WM capacity were also examined. This allowed us to study both the differences between the phonological fluency of the two types of phonemes tested as well as the differences between CL when retrieving and using lexical items containing familiar as compared to novel phonemes. As the forward digit span task does not require manipulation, it was used as a measure of lower CL. Because the backward digit span is a dual processing task, it was used as a measure of higher CL.

Two hypotheses were examined in this study. The first of these concerned whether a significant difference exists between the phonological fluency of EFL learners for a control phoneme, found in both participants' native language and English, and a test phoneme that exists in English, but not in their native language of Arabic. The results of a 2x2 Repeated Measures ANOVA indicate that significantly more correct responses were produced when prompted by the control phoneme, /f/, than were produced in response to the test phoneme, /p/. This suggests that participants were more readily able to produce words beginning with a phoneme that was already familiar to them prior to exposure to the English language. These findings imply that both intrinsic and germane CL are lower for EFL learners when retrieving words beginning with a familiar phoneme.

Although notably fewer errors were made in both conditions, as is indicated by the difference between both the mean square and F values of the two conditions of correct and incorrect responses, a significant difference in errors produced in response to these phonemic prompts was also found. This may in part be due to the fact that the test phoneme, /p/, exists in Arabic as an allophone of the phoneme, /b/, unlike the independent phoneme, /f/. As such, participants may have been more likely to produce erroneous responses to this prompt in which lexical items retrieved began with the phoneme /b/ rather than the target English-language phoneme, /p/ [9]. Thus, H1 is supported by these findings.

The second hypothesis examined in this study predicted that a significant positive correlation would be found between phonological fluency of the novel phoneme and both high and low CL as measured by the WM capacity assessment tasks. This was found to be partially true. Outcomes of both the forward and backward digit span tasks were found to negatively correlate with the number of errors produced in response to the control phoneme, /f/, indicating that with lower WM capacity, the greater the number of errors produced in response to this prompt. In future studies, the reliability of this finding may be further investigated by measuring task engagement as such errors may have occurred as a result of a lack of focus during the testing process [33].

Of greater note is the fact that both forward and backward WM capacity were found to positively correlate with the number of correct responses produced for the novel phonemic prompt. This finding supports H2 and indicates that

the ability to store a greater number of items in WM is related to the ability to retrieve and use a greater number of words beginning with a novel phoneme for the population tested. This finding further indicates that increased WM capacity reduces both the intrinsic and germane CL required to retrieve and use words containing novel phonemes for the population tested.

However, no notable difference was found in the percentage of variance accounted for by either the forward or backward digit span tasks. This indicates that the ability to complete a dual processing task (higher CL) was not a greater predictor of phonological fluency of a novel phoneme than the ability to complete a single processing task (lower CL) in the population tested.

As such, H2 is partially supported in that, as predicted, positive correlations were found with both measures of WM capacity in the test condition, yet unexpectedly, errors in the control phoneme condition were also found to be negatively correlated with both measures of WM capacity.

CONCLUSION

From the results of this study, it can be discerned that moderate to competent EFL learners who are native speakers of Arabic exhibit lower phonological fluency with regards to novel phonemes in English that are not found in their native language as compared to that of phonemes which are found in both English and their native language. A significant relationship between the number of correct responses to a non-native phonological prompt and measures of CL was also found.

These findings have potential pedagogical implications for EFL instruction. Prior to beginning their role, it may be beneficial to explicitly educate EFL instructors on the phonological differences between English and the native language of their future student population. Instruction that particularly stresses allophonic as opposed to phonetic differences between the two languages may allow EFL instructors to better identify and understand both oral and written errors made by their students. It may also allow EFL instructors to implement targeted phonological interventions in the classroom in order to increase students' familiarity and comfort with novel phonemes found in English but not in their native language [4]. Such targeted interventions may reduce the issue of avoidance, and thus the CL necessary for the retention, retrieval, and use of words containing non-native phonemes.

The findings of this study lead to future potential research opportunities. One potential confound of the current study is students' engagement level in the tasks [34]. This issue is indicated by the negative correlation found between errors in the control phonological awareness task and measures of WM capacity. Future studies may include a measure of engagement to assess the reliability of participants' results. Another potential confound may be the extent to which participants are prone to engaging in avoidance of vocabulary items containing novel phonemes. As increased use of such lexical items leads to greater ease of retrieval from LTM into WM, an additional assessment regarding participants' likelihood to engage in avoidance may lead to a more comprehensive understanding as to why greater CL is needed for the retrieval and use of words containing novel phonemes by EFL learners. By assessing these factors, a more robust conclusion regarding the role of CL on phonological fluency in EFL learners may be discovered. Thus, further interventions to assist EFL learners may be implemented to promote the development of their English language skills.

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Data Availability

Data is available upon request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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