Working memory hinders learning semantic noun classes but aids in learning phonological ones

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Working memory and verbal short-term memory are important cognitive factors in second language learning, but research has focused largely on their involvement in learning L2 vocabulary and syntactic constructions. Research on language categorization devices such as noun classes remains largely unexplored even though they can reveal much on how human language categorizes the natural world. Therefore, the aim of this exploratory study was to determine the role of working memory and verbal short-term memory in learning semantic noun class categories and phonological noun class categories. 21 Japanese native speakers participated in two counterbalanced semi-artificial language learning experiments. In experiment one, the determiner-noun agreement pattern was based on a noun`s semantic characteristics (animate, small objects, large objects), and, in experiment two,  the copula-noun agreement pattern was based on the phonological form of a noun`s second mora (-he, -u, -sa). A spearman's correlation revealed a moderate negative correlation between working memory as measured by reading span and the semantic noun class generalization scores. For the phonological noun class learning experiment, a moderate positive correlation between working memory and generalization scores was found. No significant correlations between verbal short-term memory and the generalization tests in experiment one and experiment two were found. The results demonstrate that higher working memory capacity plays an inhibitory role in learning semantic noun class categories while it plays a significant role in learning phonological noun class categories.

Key words: working memory, verbal short-term memory, noun class learning

Introduction

When it comes to learning a second language, most adults differ in their success and overall attainment. Working memory is an important factor in explaining these individual differences (Wen, 2015). There is now growing evidence supporting a relation between working memory and second language acquisition (Juffs & Harrington, 2011; Wen, 2015). One growing area of this literature is investigating working memory's contribution in learning the language categorization device noun classes. Noun classes are grammaticalized agreement systems that categorize all nouns according to semantic or formal characteristics (Aikhenvald, 2000). There are two types of formal noun classes one which relies on the phonological properties of the noun and the other relying on morphological properties in order to categorize. On the other hand, semantic noun classes categorize nouns based on the shared characteristics of the nouns themselves.

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Of these different types of noun classes, the most extensively studied have been morphological noun classes. Williams and Lovatt (2003) investigated the relationship between verbal short-term memory and learning morphological noun classes. Their results showed that verbal short-term memory had a significant positive correlation with learning morphological noun classes which they concluded was due to the nature of retaining morphological representations in short-term memory and applying them to novel words. Kempe and Brooks (2008) extended Williams and Lovatt's study by investigating the relationship between working memory and learning morphological noun classes by looking at the Russian case system. The Russian case system marks many grammatical features such as gender, number, and case and provides language learners with many problems. The aim of their study was to investigate if grammatical categories require reliable morpho-phonological cues or if they can be learned purely by morphological means. The authors found that working memory was important in maintaining memorized information when it came to learning morphological noun classes and concluded that learning morphological noun classes is possible with higher working memory capacity. Kempe, Brooks, and Kharkhurin (2010) replicated the Kempe and Brooks 2008 study confirming that working memory is important in learning morphological noun class categories since in order to learn and produce the correct form, a good memory is required.

The previous studies reveal much about the nature of learning morphological noun classes, but, as mentioned earlier, it remains unclear whether the results of morphological noun class learning generalize to phonological and semantic noun classes. Since previous studies focused only on learning morphological noun classes, the aim of the present study is to investigate the role of working memory and verbal short-term memory in learning semantic noun class categories and phonological noun class categories. The study will also focus on working memory and verbal short-term memory because previous studies have found that both working memory and verbal short-term memory make independent contributions in learning morphological noun class categories. Therefore, it is possible these components may be involved in learning semantic and, particularly, phonological noun class categories. Thus, there are four research questions this study aims to answer:

1. Is working memory involved in learning semantic noun class categories?
2. Is verbal short-term memory involved in learning semantic noun class categories?
3. Is working memory involved in learning phonological noun class categories?
4. Is verbal short-term memory involved in learning phonological noun class categories?

Methods

Participants

The participants in this experiment were 21 Japanese native speakers ($M = 23.14$, $SD = 4.07$). Two participants` data was discarded because of equipment failure during the

experimental session. During the recruitment period, participants with more than one-month experience living abroad, language certifications or majoring in Linguistics and/or related field were also excluded from this study. The languages participants studied were English (21), French (6), Spanish (4), German (4), Chinese (2), and Korean (1). All participants signed the consent form. The consent form was written in Japanese. Participants could drop out of the study at any time. They were paid for their participation. The study was approved by the Institutional Review Board at the Department of International Cultural Studies, Tohoku University.

Instruments

Questionnaire

In this study, participants completed a questionnaire. The questionnaire contained questions about participants' age, education level, languages studied, and total years of foreign language study. Information from the questionnaire was created with the following variables: age, education background, noun class language background, and total language study background.

In the questionnaire, participants were allotted one point for each year of education and one point for each year of language study. They received .5 point for less than one year of education or language study. In the case of education, if a student was a first-year Master`s student, they would receive .5 point because the participant is still in the first year. In the case of language study, if a participant studied Chinese for 7 months, that participant would receive .5 point. This scoring method follows Martin and Ellis (2012). Extra points were given for participants who studied a noun class language such as Spanish since the to be learned languages are noun class languages. Participants received one point for one year of study and half a point for less than one year (Williams & Lovatt, 2003). If a person studied English for one year and Spanish for one year, their total score for language study would be 2, and their noun class language score would be 1 since they studied the noun class language Spanish.

Reading Span

In order to assess working memory, a reading span task was used. The reading span task is a valid and reliable measure of working memory, and it has been used in several studies investigating the relationship between working memory and language learning (Juffs & Harrington, 2011). The stimuli for the Japanese version of the reading span task used in this study were created according to Osaka and Osaka (1994). The reading span task was also administered to participants according to Osaka and Osaka (1994).

The author administered the test with each participant in a quiet room. The test was administered on a computer using PowerPoint. The participants gave permission to have their voices recorded in order to score the reading span task offline. Furthermore, participants read N sentences out loud and at their normal reading pace. Each sentence contained an underlined

word. After reading N sentences, participants had to recall the underlined word from each sentence in the correct order. The participants completed two practice trials before moving onto the actual test. The reading span task was scored as partial-credit units as described by Conway et al. (2005).

Nonword Repetition Task

Participants completed a nonword repetition task. The nonword repetition task was used to assess participants' verbal short-term memory capacity. The nonword repetition task is a reliable and valid measure of verbal short-term memory and has been used in a variety of psychological and clinical research (Archibald & Gathercole, 2006; Kormos & Safar, 2008). A Japanese nonword repetition task using Japanese nonsense words was used. The Japanese nonsense words were taken from Sakano and Ito (2015).

Administration of the test with each participant was conducted in a quiet room. The nonword repetition task was presented audially on the computer with nonsense words pre-recorded by a Japanese female native speaker. The nonsense words ranged from four mora to seven morae. The nonsense words were spoken at approximately one mora per second as done in Martin and Ellis (2012). Participants heard an N-mora nonsense word and repeated each mora out loud and in the correct serial order to the best of their ability. Participants completed two practice trials before moving onto the actual test. Participants gave permission to have their voices recorded in order to score the nonword repetition task offline. The nonword repetition task consisted of two practice trials and four real trials. One trial consisted of five sets. The nonword repetition task was scored according to Kane et al. (2004).

General Procedure

Participants attended two experimental sessions, and all tasks were conducted in a quiet room individually. Participants were selected at random to begin experiment 1 or experiment 2. Participants completed the reading span task, questionnaire and experiment 1 together in one session and completed the nonword repetition task and experiment 2 in another session. After completing one of the individual difference measures, participants proceeded to the language learning experiment. Both experiments were identical in the amount of vocabulary and the procedure. The only difference between them was the artificial language and the target grammar. The experiments were counterbalanced so that half of the participants completed the experiment 1 session first while the other half completed experiment 2 session first. Participants were randomly assigned to which experiment they would start. Participants completed their final session 5-8 days after their first session. One session lasted approximately 1.5 hours. In both language learning experiments, stimuli were presented electronically using the E.Prime 3.0 (Psychology Software Tools, Pittsburgh, PA).

Experiment 1

Experiment 1 aimed at determining the role of working and verbal short-term memory in semantic noun class learning. The experiment used a semi-artificial language consisting of three noun classes based on the semantic properties of animate, small in-animate, and large in-animate. This experiment focused solely on ultimate learning rather than learning over time.

The Semi-Artificial Language / Target Grammar

The language stimuli consisted of 30 two-mora words. All words were concrete nouns. This semi-artificial language consisted of actual noun class structures found in natural language rather than artificial classes created by the experimenter. It is important that the stimuli imitate natural languages, so a clearer picture of the cognitive processes involved in language learning reflect reality.

The target grammar was noun class agreement between the noun and the demonstrative *this*. Each noun class took a unique demonstrative based on the noun's respective class. There were three noun classes divided semantically: animate, small in-animates, and large in-animates. Nouns in the animate class took the demonstrative *ha,* nouns in the small in-animates class took the demonstrative *di,* and nouns in the large in-animates class took the demonstrative *ro*. All three demonstratives (*ha*, *di*, and *ro*) translated as *this*. The semantic divisions used in this experiment are common for noun classes typologically and are found in Luganda (Aikhenvald, 2000; Hurskainen, 1999).

There were 10 nouns for each noun class. There were eight regular nouns and two irregular nouns in each class. A regular noun refers to a noun that contains the characteristics reflective of the class it is in. For example, for the small in-animate class, the noun *tennis ball* is a regular noun because it is small and in-animate. An irregular noun refers to a noun that consists of characteristics not reflective of the class it is assigned. For example, in the context of this experiment, the noun *train* should be assigned to the large in-animate class but, instead, it is assigned to the animate class. This makes it an irregular noun. Irregular words are commonly found in noun class languages around the world, and they were included in this experiment in order to stay consistent with the semi-artificial language reflecting natural language.

Procedure

Vocabulary Learning Phase

Participants in this experiment learned all the vocabulary words used in the learning phases prior to the session. They were given a list of the 30 stimuli words along with each word's Japanese translation. The list of vocabulary words was inserted in a random list generator and the output list was generated. This was done to randomize the word list to prevent any cues to the target grammar. The stimuli word list did not contain any of the three demonstratives. Participants were never exposed to the demonstratives until the learning

phases.

Prior to beginning the learning experiment, participants were tested on the vocabulary. They were asked to translate the words from Japanese into the foreign language and vice versa. Participants proceeded to the learning phase after achieving a 100% score on the vocabulary test. The 100% score was essential in order to control for the relationship between vocabulary learning and verbal short-term memory and ensure that any correlations between grammar learning and verbal short-term memory were not mediated by vocabulary. Prior to the beginning of the learning phase, participants were trained on the vocabulary again but this time with the corresponding pictures that would be used in the learning phases. They were also told they would be learning a unique grammar rule with more than one word to say *this*. They were instructed to find the rule to the best of their ability.

Grammar Learning Phase

There were three learning phases where the participants heard the learned vocabulary with their agreement patterns. Stimuli was presented aurally twice and at random for each learning phase. Participants were asked to repeat what they heard one time. For each word, a corresponding picture was presented on the screen. Pictures consisted of real-world objects.

The first learning phase consisted of eight words (two regular words for each noun class and two exception words). The last two learning phases, 11 words (three regular words for each noun class and two exception words). The reason for the differences between the number of words in learning phase one and learning phases two and three were to ensure that each word that corresponded semantically with its noun class (regular word) was equally distributed in each learning phase.

Test Phase

In the test phase, participants were presented the written form of the word and its corresponding picture on the screen. Participants had to produce the word with the correct agreement form. The test phase words were taken from the learning phase that followed.

Table 1.   Descriptive data for variables of interest for experiment 1 and experiment 2.

Variables	*M*	*SD*	95% CI	Min	Max
Age	23.14	4.07	[21.28, 24.99]	18.00	30.00
Education	14.95	1.50	[14.22, 15.67]	12.00	18.00
Language Background	8.95	.74	[8.61, 9.28]	6.00	10.00
Noun Class Background	0.95	0.49	[0.72, 1.17]	0	2.00
Nonword Repetition Task	0.87	0.06	[0.84, 0.89]	0.76	0.95
Reading Span	0.75	0.09	[0.71, 0.80]	0.51	0.93
Semantic Generalization Test	14.19	5.43	[11.71, 16.66]	5.00	21.00
Phonological Generalization Test	13.90	6.54	[10.92, 16.88]	4.00	21.00

Note. CI = confidence intervals

Participants answers were recorded and scored offline. Participants received one point for correctly producing the word and its agreeing demonstrative. No points were awarded for producing words that sounded similar to the demonstrative such as *shi* for *di* or only producing the demonstrative by itself because they were explicitly instructed to produce both the word and its determiner.

Generalization Test

The generalization test consisted of 21 novel, concrete, two-mora words with seven words for each noun class. No irregular words were presented. Prior to taking the generalization test, participants were shown the 21 words and their Japanese meaning with their corresponding picture at random on a computer using PowerPoint. Participants did not need to memorize the 21 words. The generalization test phases proceeded, and they were scored exactly as the test phase portions of the experiment. After the test, participants were asked to describe in writing the rules of the language, and what strategies they used to support their reasonings. No additional points were allocated for participants who described the rules correctly.

Table 2.   Correlations between the measured variables for experiment 1.

Variables	1	2	3	4	5	6	7
1. Age	-						
2. Education	.581**	-					
3. Language Background	-.291	.109	-				
4. Noun Class Background	-.096	-.317	.531*	-			
5. Nonword Repetition Task	-.376	-.181	.184	-.125	-		
6. Reading Span	-.169	.057	.215	-.059	.656**	-	
7. Semantic Generalization Test	.384	.244	-.494*	-.296	-.319	-.468*	-

*p < .05, two-tailed. **p < .01, two-tailed

Results / Discussion

All statistics for both experiments were calculated in SPSS version 25 (IBM Corp., 2017). Descriptive statistics for all variables in experiment one are provided in Table 1. The correlation coefficients for all variables of interest in experiment one are provided in Table 2.

The aim of experiment 1 was to investigate the role of working memory and verbal short-term memory in semantic noun class learning. Some variables did not pass normality so the non-parametric Spearman's correlation method was used. A Spearman's rho correlation examined the relationship between the generalization test scores and reading span. There was a negative, moderate, correlation between working memory as measured by reading span and the generalization test scores, r_s = -.46, n = 21, p < .05. This negative correlation reveals that participants with lower working memory were better at generalizing the rules than those with

higher working memory. This result suggests that learning semantic noun classes is different from learning morphological noun classes. Research on learning morphological noun classes showed a positive correlation between working memory and rule learning while experiment one showed working memory can interfere with learning semantic noun classes (Kempe & Brooks, 2008; Kempe et al., 2010). This result suggests the learning semantic noun classes may require a different type of learning process that possibly interferes with working memory as seen in information-integration learning (Ashby & Valentin, 2017).   There was no significant correlation between verbal short-term memory as measured by the nonword repetition task and generalization test scores, r_s = -.31, n = 21, p > .05. This result is not surprising since experiment one dealt specifically with semantics and little with phonological grammar structures which verbal short-term memory is usually associated with (Williams, 2012). This result is consistent with previous research which has shown that once vocabulary is controlled, as in this experiment, verbal short-term memory had no direct influence on grammar learning (Andrade & Baddeley, 2010).

There was also a negative, moderate correlation between language background and generalization test scores r_s = -.49, n = 21, p < .05. This finding is inconsistent since previous research has reported a positive correlation between language background and language learning especially when learning noun classes (Brooks, et al., 2010; Williams & Lovatt, 2003). This result suggests that studying languages for a longer time inhibits participants ability to learn semantic noun classes. However, an alternative and more plausible explanation is that these results are a statistical anomaly. The participants with the lowest working memory capacity were also less likely to attend university. Since some of these participants did not attend university, they also did not take any extra language classes. Tohoku University requires two years of English education, and since the participants either did not attend any university or attended only Tohoku University, the total language score would favor those who attended Tohoku University i.e. the participants in the current study. Since lower working memory capacity participants did better learning semantic noun classes and were also likely have less education and language learning experience, this explains the negative correlation between the successful learning of semantic noun classes and language background. Therefore, this result is likely to be more mirage than real.

Experiment 2

The goal of experiment 2 was to investigate working and verbal short-term memory's role in phonological noun class learning. This experiment used a semi-artificial language with phonological based noun classes.

Participants

The participants from experiment 1 all took part in experiment 2.

The Language Stimuli / Target Grammar

The language stimuli consisted of 30 two-mora words. As in experiment 1, all vocabulary words consisted of concrete nouns. This semi-artificial language also consisted of actual noun class structures found in natural languages rather than artificial classes created by the experimenter.

The target grammar of this experiment was noun class agreement between the noun and the copula. Each noun class took a unique copula based on the phonological cues of a noun's respective class. This type of noun class agreement was based on Yimas (Foley, 1991). There were three noun classes divided via phonology with little semantic correlation: class 1 (words with second mora ending in *-he*), class 2 (words with the second mora ending in the vowel *-u*), and class 3 (words with the second mora ending in *-sa*). Class 1 nouns took the copula *te*, class 2 nouns took the copula *ke*, and class 3 nouns took the copula *pe*.

There were 10 nouns for each noun class. There were eight regular nouns and two irregular nouns in each class. In this case, any noun with the second mora ending in anything other than the three noun class endings were categorized semantically. For this experiment, class 1 corresponded to masculine kinship, class 2 to feminine kinship, and class 3 as a residue class. These types of irregulars are found in natural languages since no noun class system is completely devoid of semantic classification even if it is minimal (Aikhenvald, 2000).

Table 3. Correlations between the measured variables for experiment 2.

Variables	1	2	3	4	5	6	7
1. Age	-						
2. Education	**.581**[**]	-					
3. Language Background	-.291	.109	-				
4. Noun Class Background	-.096	-.317	**.531**[*]	-			
5. Nonword Repetition Task	-.376	-.181	.184	-.125	-		
6. Reading Span	-.169	.057	.215	-.059	**.656**[**]	-	
7. Phonological Generalization Test	-.114	-.117	.224	.008	.171	**.530**[*]	-

*p < .05, two-tailed. **p < .01, two-tailed

Procedure

The procedure for experiment 2 was conducted exactly as the procedure for experiment 1.

Results / Discussion

Descriptive statistics for all variables in experiment 2 are provided in Table 1. The correlation coefficients for all variables in experiment two are provided in Table 3. Data analysis was conducted exactly as experiment 1.

The purpose of experiment 2 was to investigate the role of working memory and verbal short-term memory in phonological noun class learning. Some variables did not pass the

normality so the non-parametric Spearman's correlation method was used. A Spearman's rho correlation examined the relationship between the generalization test scores and reading span. There was a positive, moderate, correlation between working memory as measured by reading span and the generalization test scores, $r_s = .53$, n = 21, $p < .05$. The positive correlation demonstrates that participants with higher working memory were better at generalizing the rules than those with lower working memory. This result suggests that learning phonological noun classes is different from learning semantic noun classes. Also, this result is consistent with previous research on learning morphological noun classes and other grammatical structures suggesting that learning phonological noun classes is similar to learning morphological noun classes with both relying on working memory to abstract patterns (Kempe & Brooks, 2008; Kempe et al., 2010; Martin & Ellis, 2012).

There was no significant correlation between verbal short-term memory as measured by the nonword repetition task and generalization test scores, $r_s = .17$, n = 21, $p > .05$. This is somewhat surprising since phonological noun classes rely on phonological associations, and verbal short-term memory is related to learning those types of morpho-phonological structures (Verhagen & Leseman, 2016; Williams, 2012). However, learning phonological noun classes may be more cognitively demanding, and therefore require working memory rather than verbal short-term memory which accounts for the lack of a significant correlation between the generalization test scores and verbal short-term memory.

Also, unlike experiment 1, there was no correlation between language background and generalization test scores $r_s = .22$, n = 21, $p > .05$. This lack of correlation contradicts previous research which has shown a positive correlation between language background and language learning especially noun classes (Kempe & Brooks, 2008; Williams & Lovatt, 2003). An explanation could be that participants were Japanese and are not as heavily exposed to phonological noun class languages as in Europe and the United States. Europe and the United States are places where noun class languages are spoken, and participants in these areas often report studying them. However, in Japan, English is the only foreign language that Japanese are required to study in the public-school system. Therefore, their influence on learning in experiment 2 would be minimal.

General Discussion

This study explored the role of working memory and verbal short-term memory in the learning of semantic and phonological noun classes. Experiment 1 set out to answer the first two research questions about working and verbal short-term memory's involvement in learning semantic noun classes while experiment 2 aimed to answer the last two research questions concerning working and verbal short-term memory's involvement in learning phonological noun classes.

The results of experiment 1 show that working memory may play an inhibitory role in learning semantic noun classes. Although seemingly unintuitive, it is not uncommon. Negative

correlations between working memory capacity and successful learning of implicit, complex or intuitive problems or categories have been reported (Ashby & Valentin, 2017; DeCaro, M.S., Thomas, R.D., & Beilock, S.L., 2008; DeCaro, Van Stockholm, Jr., & Weith, 2015). A possible reason for this finding is that the combination of the nature of semantic categories and the irregulars could have hindered the learning process for higher working memory capacity participants. Due to the diverse nature of semantic noun classes, categorization according to precise rules may have been difficult for participants. Semantic categories may have contained too many dimensions to quantify a specific rule. Support for this interpretation comes from the participants when asked to verbalize the rules. Though participants scored high, the rules varied quite substantially between individual participants with near ceiling scores. For example, instead of the correct classification of animate, large, and small, some participants classified the stimuli as *things with moving parts, immovable objects,* or *graspable objects.* These same participants also reported difficulty in verbalizing the rules. This evidence supports the idea that semantic noun class categories can be learned and categorized in a similar way to information-integration category learning. A hallmark of information-integration learning is the difficulty of verbalizing rules and their difficulty in categorization like what was reported by participants in this experiment (Ashby & Valentin, 2017). Previous studies have shown that working memory capacity hinders learning information-integration categories due to the complexity and difficulty of discovering a precise rule since many rules and its reliance on other cognitive systems such as long-term memory and implicit learning (Ashby & Valentin, 2017; DeCaro & Beilock, 2008).

In addition, the irregulars included alongside exemplars could have forced higher working memory capacity participants to use more complex, but task-irrelevant strategies that did not work. High working memory capacity people have been shown to fixate too long on needless information preventing them from discovering more efficient methods of learning and problem-solving (DeCaro, Van Stockholm, Jr., & Weith, 2015; Storm & Angello, 2010). In this case, higher working memory participants fixated too much on the irregulars, which played no role in helping learn the semantic noun class categories, rather than suppressing them, which would have helped them learn the semantic noun class categories. This focus on the irregulars probably caused higher working memory participants to create more elaborate rules to account for all the data. On the other hand, the lower working memory participants were more likely to focus less on the irregulars so the irregulars would not affect them as much as higher working memory participants. In addition, lower working memory people are prone to re-using words or hypotheses during tasks involved in learning or retrieval (Engle, 2018; Rosen & Engle, 1997). In this experiment, it is likely that that once a "hypothesis" about the rule was tested by higher working memory participants, it was then abandoned in favor of another and never returned to again. Conversely, lower working memory participants may have continuously come back to the same "hypothesis." This recycling of the same hypothesis is a big advantage for the lower working memory participants in this learning experiment. For example, participants would encounter a certain demonstrative with people and animals and

hypothesize that this determiner goes with animate concepts. However, they would also then encounter this same demonstrative used with people and animals with the irregulars *train* and *wallet*. Train and wallet are not animate. Higher working memory participants would likely abandon the hypothesis that animate things agree with the demonstrative completely and continue to find another rule. Lower working memory participants, on the other hand, would most likely return to the hypothesis that the demonstrative agrees with animate things. In the case of this experiment, this is much more useful than completely abandoning the hypothesis. In the end, the combination of irregulars and the inherent nature of semantic noun categories give the "disadvantages" of lower working memory participants the edge in learning semantic noun class categories over the higher working memory participants. Further research can investigate whether the semantic noun class categories or the irregulars or both together are hindering the learning process for higher working memory capacity participants in two separate experiments.

Experiment 1 also revealed that verbal short-term memory is not involved in learning semantic noun classes. This is not entirely surprising since learning semantic noun classes requires semantic knowledge to generalize the agreement pattern. However, in the case of this experiment, the agreement pattern was simple so it is not clear if verbal short-term memory would be important in learning semantic noun class categories with complex agreement patterns. Further research should investigate this possibility.

In contrast to working memory's role in learning semantic noun classes, experiment 2 demonstrated that working memory aids in learning phonological ones. The reason for this contrast could lie in the fact that because the rules relied on phonology, not semantics, the rules were just cognitively demanding enough for working memory to influence the discovery of the agreement patterns i.e. the nature of learning phonological noun classes is more rule-based. Support for this comes from the rules reported by the participants. There was no variation in the rules among participants who successfully learned the phonological noun classes which was the opposite of the semantic noun class experiment. In addition, the participants also reported the rule was easy to verbalize. Easy to verbalize, optimal and clear-cut rules are the hallmarks of rule-based learning, and higher working memory people outperform lower working memory people in this type of learning (Ashby & Ell, 2001; Ashby & Valentin, 2017). Due to the more verbalizable and explicit nature of the rules in phonological noun classes, it may have been easier to update information regardless of the irregulars in comparison with the semantic noun class experiment. Since updating is closely tied to working memory especially when measured with span tasks as in this study, it is reasonable that higher working memory participants outperformed lower working memory participants (Shipstead, Harrison, & Engle, 2016). In addition, L2 processing studies in phonological noun class languages such as Spanish have shown working memory to be a significant factor in processing phonological noun class agreement since working memory aids in gaining sensitivity to these agreement patterns (Sagarra & Herschensohn, 2010; Sagarra & Herschensohn, 2013). This lends further credibility that working memory facilitates the learning and abstracting of

predictable, phonological rules that can be applied to novel items as in the case of experiment 2. Due to working memory's involvement, future research should measure other aspects related to working memory such inhibition and updating abilities in order to see if they are involved in learning phonological noun classes as done in Kapa and Colombo (2010). They investigated the correlation of various executive functions such as inhibition and updating in learning word order structures for adults and children. They found that different executive functions predicted second language learning for adults than children. Research approached in the same way as Kapa and Colombo's (2010) can help narrow the components of working memory involved in learning phonological noun classes.

Like experiment 1, there was no correlation between verbal short-term memory and learning phonological noun classes. This result is a little surprising considering that phonological noun classes rely on sound-based agreement patterns. This finding, however, does provide support for the claim that verbal short-term memory has only an indirect role in grammar learning via vocabulary. Since vocabulary was controlled in this study, the null correlation with learning phonological noun classes is consistent with previous studies showing that verbal short-term memory plays no direct role in grammar learning once vocabulary is controlled (Andrade & Baddeley, 2010; Engel de Abreu & Gathercole, 2012). However, these results do not settle the controversy if verbal short-term memory contributes directly to grammar learning since other studies have found that verbal short-term memory is directly involved in grammar learning (Martin & Ellis, 2012; Verhagen & Leseman, 2016; Williams & Lovatt, 2003). Also, as with experiment 1, the pattern agreement in experiment 2 was simple so it is not clear if verbal short-term memory is directly involved in learning more complex agreement patterns. Further research is needed to disentangle the grammatical constructions that rely on verbal short-term memory.

Though this study has revealed the different roles of working memory and verbal short-term memory's contribution to learning semantic and phonological noun classes, there are some limitations in this study. One limitation was that this study only investigated working memory and verbal short-term memory in learning noun class categories. Although working memory and verbal short-term memory are important cognitive factors that explain individual differences in learning semantic and phonological noun classes, other cognitive factors such as intelligence or implicit learning may contribute as well. Without measuring other cognitive abilities, it is difficult to know what exactly is happening during the learning process. In addition, the sample size in this experiment was only 21 participants. In order to find more robust results, a large sample size is needed to confirm the findings in this study. Also, as with any experiment, replication studies are needed in order to validate the findings in this study. Since this study appears to be the first study investigating working memory and verbal short-term memory in learning semantic and phonological noun class categories, the results should be taken with caution. The results in this study await further confirmation.

Conclusion

The current study was an exploratory one aimed at investigating four research questions concerning working memory and verbal short-term memory's role in learning semantic noun classes and phonological noun classes. In order to accomplish this task, two learning experiments using semi-artificial languages based on semantic noun classes and phonological noun classes were conducted. The results indicated that working memory plays two different roles in learning semantic noun class categories and phonological noun class categories. In learning semantic noun class categories, working memory plays an inhibitory role preventing high working memory from correctly learning the rules for categorization. On the other hand, working memory is important in learning the rules for phonological categorization. Finally, verbal short-term memory showed no significant role in learning either semantic or phonological noun classes. The results are important not only for extending research on the cognitive factors involved in learning noun classes but also in understanding the different roles of working memory in learning language specific categories.

Acknowledgement

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