The role of learners' memory in app-based language instruction: the case of Duolingo

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Abstract. The current study investigated the role of visual short-term memory, working memory, and declarative memory as individual differences in the earliest stages of vocabulary and syntactic learning in *Duolingo*-based language instruction. Thirty-eight L1-Greek adults completed memory tasks and engaged in learning Navajo on *Duolingo*. Subsequently, vocabulary and syntax were assessed respectively via a word recognition, a word translation, and a grammaticality judgement task. Multiple regression analyses revealed an advantage for distributed practice both in vocabulary and syntax, after controlling for amount of practice. Further, declarative memory played a significant role in learning syntax and vocabulary, when measured in a word translation task. Extending the analysis for the first time to app-based environments, the results of the present study confirm the importance of declarative memory and distributed practice in adult acquisition of L2 vocabulary and syntax.

Keywords: mobile-assisted language learning, Duolingo, individual differences, memory functions.

1. Introduction

Ubiquitous availability of mobile-assisted language learning technology has led to the development of commercial tools, with studies relating their use to significant linguistic gains in second language (L2) vocabulary and grammar (Loewen et al., 2019). Mobile apps offer benefits including access to less commonly taught languages (Reinders & Benson, 2017) as well as features designed to increase learners' motivation (Rachel & Rockinson-Szapkiw, 2018), such as *experience points* (Duolingo). Additionally, some apps (including Duolingo) provide

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approachable bite-sized lessons offering adaptability to individual study habits (Rosell-Aguilar, 2018) and thus allowing a more distributed learning, a type of schedule for which advantages have been independently reported in the SLA literature (e.g. Bird, 2010).

Next to learning schedule, many studies in the SLA literature have evidenced the role of cognitive individual differences including short-term and working memory (e.g. Dussias & Piñar, 2010). Additionally, experimental studies have reported that declarative long-term memory generally predicts L2 vocabulary learning and L2 grammar learning in the early stages of acquisition (e.g. Morgan-Short et al., 2014). Although previous research has investigated the role of memory in computer-assisted environments, little research is available on the role of cognitive individual differences in more ecologically valid environments, such as commercial language learning applications.

Considering the extensive use and success of *Duolingo*, our aim was to investigate the role of cognitive abilities in learning a new language through this application. The study's main research question was formulated as follows:

> RQ: To what extent do working memory, visual short-term memory, and declarative memory predict vocabulary and syntactic learning in the early stages of Duolingo-based instruction?

2. Methods

2.1. Participants

Thirty-eight L1-Greek adults (18 to 54 years of age) with no significant previous exposure to verb-final languages, including Navajo, agreed to learn the language on Duolingo for a period of five days. Greek was not available as a medium of instruction on Duolingo. However, participants' proficiency (B1 to C1 CEFR; based on self-reports) was considered sufficient for English to be used.

2.2. Cognitive tests

In Phase 1, participants completed three computer-administered cognitive tasks. Declarative long-term memory was assessed through a verbal paired-associates task, visual short-term memory was measured via a visual forward digit span task, and working memory was measured via a backward digit span task.

2.3. Language learning on Duolingo

In Phase 2, participants engaged in learning Navajo on Duolingo. The tracking feature *Duolingo for Schools* allowed researchers to assign participants the same set of lessons and review their practice schedules unobtrusively.

Participants were assigned a total of nine lessons starting from the lowest level of difficulty from four thematic units (introduction, family, food, and animals), known as ‘bubbles’. The lessons included 46 lexical items (conversational expressions, nouns) and 16 sentences with four different verbs. Participants received no explicit rules but received correct/incorrect feedback and in some cases, the correct answer was presented after trial. The participants were free to distribute learning across the instruction period (one to five days).

2.4. Linguistic assessment

In Phase 3, one to two days after language instruction was completed, participants were given computer-administered tests to assess learning of Navajo vocabulary and syntax. For vocabulary learning, participants completed a word recognition and a word translation task. In the word recognition task, participants were asked to judge whether 16 presented words were Navajo words. In the word translation task, participants judged the correctness of 16 Navajo items paired with an English translation. For syntactic learning (word order learning), participants were assessed in a grammaticality judgement task, where they were asked to judge the word order grammaticality of 40 sentences. Grammatical sentences (20 items) followed the patterns typical of Navajo (SOV, Location-V) whereas ungrammatical sentences violated Navajo’s word order (*VSO, *SVO, *V-Location).

3. Results and discussion

Multiple regression models were calculated with accuracy in each assessment task as the dependent variable, and outcomes in the three memory functions as well as three co-variates as independent variables. The co-variates were: age at testing, number of days of Duolingo study (as a measure of distribution of practice), and L2 exposure (number of years of formal English instruction and residency in

English-speaking countries). A summary of the descriptive statistics can be found in supplementary materials S1.

3.1. Vocabulary learning

The first model analysed word recognition accuracy (Table 1) and revealed that no memory function predicted accuracy in word recognition. The only statistically significant (p=.001) predictor was the days of Duolingo study with a β value of .56. It is possible that the word recognition task required a relatively low cognitive load and thus differences in cognitive ability did not emerge as a significant factor.

Table 1. Multiple regression model for word recognition accuracy

Model	**Predictors**	***B***	***SE***	**β**	***p***	R^2	***Adjusted*** R^2
1						.361	.224
	STM	.06	.17	.07	.626		
	WM	-.07	.19	-.08	.699		
	DLTM	.12	.11	.18	.295		
	AaT	.01	.04	.04	.821		
	L2 Exposure	-.07	.31	-.04	.054		
	Nr. Days	.77	.21	.56	.001		

However, memory functions held a predictive role in word translation accuracy (Table 2).

Table 2. Multiple regression model for word translation accuracy

Model	**Predictors**	***B***	***SE***	**β**	***p***	R^2	***Adjusted*** R^2
2						.433	.323
	STM	.33	.18	.33	.038		
	WM	-.25	.19	-.26	.196		
	DLTM	.31	.12	.46	.012		
	AaT	.00	.04	.00	.979		
	L2 Exposure	-.10	.32	-.05	.772		
	Nr. Days	.55	.22	.36	.019		

Here declarative long-term memory was a statistically significant predictor (p=.010) with a correlation coefficient value of .46, and short-term memory was a significant predictor (p=.038) with a value of β=.33. These results are in line with the hypothesis of a key role of declarative memory in learning of vocabulary, a relationship which might have also been strengthened by the pair-associative learning characteristics of the translation task. No significant relationship between working memory and word translation accuracy emerged. Once more, the days of Duolingo study was a significant predictor (p=.019) with a β value of .36.

3.2. Syntactic learning

The multiple regression model for syntactic accuracy (Table 3) revealed that declarative long-term memory was a significant predictor of accuracy (p=.007), with a β value of .53.

Table 3. Multiple regression model for syntactic accuracy

Model	**Predictors**	***B***	***SE***	**β**	***p***	***R*²**	***Adjusted R*²**
3						.590	.564
	STM	-.36	.45	-.12	.439		
	WM	.45	.49	.15	.367		
	DLTM	.85	.29	.53	.007		
	AaT	-.21	.09	-.31	.032		
	L2 Exposure	-1.7	.83	-.30	.074		
	Nr. Days	.62	.56	.49	.008		

This finding is consistent with experimental studies that reported a role of declarative memory in grammatical accuracy in the early stages of adult L2 acquisition (Morgan-Short et al., 2014). Contrary to previous findings (Dussias & Piñar, 2010), working memory was not a significant predictor of participants' sensitivity to Navajo sentence grammaticality (p>.05). Perhaps the role of working memory was not prominent as participants judged word order in sentences without complex structures which might have required less attentional resources.

The days of Duolingo study was also a significant predictor (p=.008) with a coefficient of β=0.49. This finding shows that more distributed practice predicted higher syntactic accuracy scores, corroborating the findings of previous studies on syntactic acquisition (Bird, 2010). Age at the time of testing was also a significant predictor (p=.032) with a negative coefficient β=*-0.31*, meaning that the older participants were, the more limited was their ability to distinguish grammatical and ungrammatical sentences in Navajo, possibly due to age-related cognitive decline (Salthouse, 2004).

4. Conclusions

Overall, the findings of the present study suggest that declarative memory and visual short-term memory play an important role in lexical learning as measured in a word translation task. Declarative memory was also a significant predictor of syntactic learning. Moreover, the study reported a distributed study effect in both lexical and syntactic learning. This means that, when matched for the amount of instruction, the more days participants spent on the application, the better they performed in both vocabulary and grammar tasks.

5. Supplementary materials

https://research-publishing.box.com/s/z25f55ew3wor8ekettiywc5ni3j7uvij

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