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Brief Multisensory Training Enhances Second Language Vocabulary Acquisition in Both High and Low Performers

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Abstract. Research in the field of vocabulary acquisition has demonstrated that enriching novel words with sensorimotor information enhances memory outcome compared to reading. However, it has been asserted that enrichment might exceed the cognitive load of low performers and therefore be detrimental to them. Here, in a brief training, thirty-two subjects learned thirty novel items of a foreign language according to three conditions: (1) reading, (2) reading and listening, (3) reading and listening and watching an actress performing a gesture semantically related to the words. Conditions (2) and (3) enriched the baseline (1) with multisensory information. Memory performance was assessed through written tests immediately after learning. Results indicate that both high and low performers benefit from sensorimotor learning. The significant interaction between group and method in one of the tests shows that low performers learn better through enrichment than by only reading the words. Implications for education are discussed.

Keywords: vocabulary acquisition, high and low performance, second language learning, enrichment, memory, multisensory training, gesture, cognitive load.

1. Introduction

Wittgenstein once wrote "The limits of my language are the limits of my universe" (Wittgenstein & Russell, 1922). In many countries, multilingualism is the key to education and to professional life. However, learning a second language (L2), particularly learning vocabulary is time consuming and takes dedication. Usually, vocabulary acquisition happens incidentally through reading activities (Krashen, 2013) and by repetition of odd bilingual word lists. It has been known for a long time that learning in lists compared to other strategies does not lead to vocabulary size or to general language proficiency (Gu & Johnson, 1996). However, lists are still used (Choo, Lin, & Pandian, 2012) and people with good memory are at an advantage in this task (Papagno & Vallar, 1995). Those who are not put a great effort into learning but achieve poor results. Hence, for obvious reasons, methods that help low performers (LP) to overcome difficulties in memorizing are welcome and necessary in education.

Behavioral studies have demonstrated that enriching verbal information with multisensory stimuli enhances retention (Shams & Seitz, 2008). Paivio's Theory of Dual Encoding paved the way for enrichment. It suggests that verbal and visual information belong to two different systems (Paivio & Csapo, 1969). By engaging both systems while learning, memory is supported because the limited processing capacity of the verbal system can be compensated by the visual (Clark & Paivio, 1991). Alan Baddeley's Model (1974) proposed working memory as a modular system with different subcomponents including the phonological loop and the visual sketchpad. Together they contribute to memory formation. In their Levels of Processing Framework, Craik and Tulving (1975) claimed that retention of verbal information is dependent on the richness with which it is presented. Engelkamp and Zimmer (1994) also described explicit memory as a multimodal system consisting of sub-systems, i.e. the verbal and other non-verbal systems (visual, sensorimotor, etc.). Hence, according to the above theoretical views, engagement of more subcomponents in the process of learning words has an impact on word retention (Macedonia, 2015). In other words, the view that verbal memory can be enhanced if enriched with visual and sensorimotor components has long been known in memory research.

Vocabulary learning still occurs with bilingual lists but also with enrichment. Pictures illustrating the words' semantics are successfully employed (Bisson et al., 2014). Less known in practice is that gestures accompanying the words also have an impact on memory. This approach is particularly effective compared to reading and reading and listening to words in L2, in the long and short term (for a review, see Macedonia, 2014). In a recent behavioral study by Mayer et al. (2015), gestures were proven to be superior to pictures in supporting memory. In the brain imaging section of the study, the authors found different neural cortices depending on the modality of stimulus processed, i.e. visual or sensorimotor. Thereafter, enrichment engages "more" brain in word learning than unimodal learning such as reading of words from lists. From an evolutionary point of view, it is argued that our brain is optimized for multisensory stimulation because of the multisensory environments in which we grow up and live (Shams et al., 2011). Accordingly, learning words by reading bilingual lists does not exploit the capacities of the brain. Instead, learning in lists deprives learners of modalities that support acquisition.

Considering that LP may fail to acquire an L2 at a proficient level, education needs to make use of strategies that are particularly supportive to them. However, the issue of whether enrichment is a benefit to both high performers (HP) and LP is still discussed. In this regard, it has been proposed that multi-sensorial information might disadvantage LP because it increases the perceptional and cognitive load, i.e. the amount of mental effort employed to store information (Harp & Mayer, 1998; Mayer, Heiser, & Lonn, 2001). Accordingly, enrichment should not be beneficial to LP. On the other hand, the contrary has also been asserted, i.e. that multisensory learning reduces cognitive load because it breaks up information into the different modalities and makes retention easier (Bagui, 1998; Cherry et al., 2008).

In L2 word learning, there are only a few studies addressing this issue. Perlmutter and Myers (1975) found that enrichment by pictures help low performers to memorize words better than only hearing the words. Call and Switzky (1975) achieved similar results in training and testing elderly. Enrichment by means of iconic gestures has been investigated in a study by Macedonia et al. (2010). There, low performers who learned vocabulary items by self-performing iconic gestures took more advantage of enrichment than HP. However, that study documented learning outcome after intense training, i.e. three hours daily for five days.

Here, contrarily to other studies, we are interested in the initial phase of learning, i.e. when learners perceive and encode a word in a foreign language for the first few times. Our aim is to discern whether LP at this stage of learning can benefit from enrichment and we hypothesize that LP also benefit from enrichment at the initial phase of learning.

2. Method

2.1. Participants

Thirty-two native German-speaking subjects (mean age M = 24.45 ys, SD = 3.15, 20 females, 12 males) took part in the experiment. They were recruited from the database of the University of Graz (Austria) and had no reported history of language, psychiatric or neurological disorders. Participants gave written consent to participate and received 10€ as a compensation. The study was approved by the Ethics Committee of the University of Graz (Austria).

2.2. Pre-testing

Prior to the experiment, we interviewed participants regarding their experience with L2 learning, i.e. their learning habits and the number of languages they had acquired. Also, we administered a Wechsler verbal intelligence test (Tewes, 1998) with verbal paired associations in German, the subjects' L1. Additionally, participants accomplished a forward and a backward digit span test (Schroeder, Twumasi-Ankrah, Baade, & Marshall, 2012). Both tests assessed the participants' working memory as predictors of language learning ability.

2.3. Training materials

Thirty novel words of Vimmi, an artificial corpus, were created for experimental purposes (Macedonia, Müller, & Friederici, 2011), every word being three-syllabic and conforming to Italian phonotactic rules (Table 1). The words were arbitrarily assigned a translation into German. The German words were controlled for their familiarity according to the Wortschatzportal of the University of Leipzig (http://wortschatz.uni-leipzig.de/). For each word, stimulus material consisted of the written word in Vimmi and its translation into German. Additionally audio files of the words (1s), as well as video clips (4.7s) were recorded with a German female speaker. In the clips, an actress performed a gesture semantically related to the word. The 30 words in Vimmi were randomly subdivided into three blocks and assigned to three different training conditions. In the visual condition (V), participants only read the written words; in the audiovisual test, participants additionally heard the words in L2 (AV); in the sensorimotor condition, besides reading the words and listening to them, participants saw videos of the actress performing an iconic gesture related to the word's semantics (SM).

Cond. 1 Visual (V)			
	Vimmi	*German*	*English*
1	nelosi	Reissverschluss	zip
2	gelori	Ohrring	earring
3	miruwe	Pfeffermühle	pepper mill
4	gepesa	Besen	broom
5	mebeti	Becher	cup
6	atesi	Treppe	stairs
7	lofisu	Foen	hair dryer
8	serawo	Giesskanne	watering can
9	siroba	Seife	soap
10	botufe	Taschentuch	handkerchief
Cond. 2 Audiovisual (AV)			
11	suneri	Geige	violin
12	wugezi	Regal	shelf
13	mewima	Stempel	stamp
14	guriwe	Faden	thread
15	sigule	Tempel	temple
16	lifawo	Stuhl	chair
17	bekoni	Kaffee	coffee
18	dafipo	Huegel	hill
19	pirumo	Erde	earth
20	giketa	Blume	flower
Cond. 3: Sensorimotor (SM)			
21	magosa	Shampoo	shampoo
22	uladi	Pullover	pullover
23	dirube	Zettel	sheet of paper
24	ganuma	Messer	knife
25	nabita	Welle	wave

26	mesako	Telefon	telephone
27	midaro	Spiegel	mirror
28	raone	Fernbedienung	remote control
29	motila	Banane	banana
30	nukile	Poster	poster

Table 1: Vimmi Words used during training, their translation into German for the participants, and into English for the readers.

2.4. Training procedure

In a larger experimental setup, our aim was to investigate the first stage of learning, i.e. the encoding of novel words with different modalities and the neural substrate exploiting this function (Macedonia, Repetto, & Ischebeck, under revision). Therefore, we opted having our participants learn in a functional Magnet Resonance (fMRI) scanner. For the present study, we used the behavioral data acquired during the scanning procedure. Lying supine in the scanner, subjects were instructed to memorize as many words as they could in Vimmi and German that were presented to them via headphones (Earplug, NordicNeuroLab AS, Norway) and via a back-projection screen mounted at the participant's feet. Participants could view the contents of the screen over a mirror mounted on top of the head coil. The thirty items were subdivided into three blocks, 10 items for each learning condition. In the scanner, during each trial which lasted approx. 7s, the written word in Vimmi and its translation into German underneath were presented (V). Additionally, in the AV-condition, the audio-file was played. Finally, in the SM-condition, the video of the iconic gesture was shown. Every block of words was shown three times. Within the block, items were randomized giving a total number of 90 repetitions and a training duration of approximately 25 minutes.

2.5. Testing

After the training, participants were given a five-minute break in a room adjacent to the scanner. Thereafter, in the same room, they completed the written tests.

In the German free recall, participants were instructed to write as many items as they could remember on an empty sheet of paper, only in German, their L1. Similarly, participants were asked to do the same for the free recall in Vimmi. In the paired free recall in German and Vimmi, participants had to write down pairs of words. In the cued recall German, participants were given a randomized list of the 30 Vimmi items and instructed to translate them into German. In the cued recall Vimmi, participants translated the German words into Vimmi. We alternated the order of the translation from one participant to the other. Each test lasted 5 minutes.

2.6. Statistical Analyses

For each participant we computed a performance index for each memory task under each experimental condition; it was calculated as the percentage of correctly recalled items over the total number of items. Thereafter, we summarized the individual performance by calculating a global performance index, obtained as the mean value of each participant's performances in all the memory tasks. On this basis, we split the sample in two groups based on the global performance index, by using the Median value (34.7) as the cut-off between groups: those who obtained scores below the cut-off belonged to the LP group, and those who obtained scores above the cut-off belonged to the HP group. Table 2 summarizes the descriptive statistics of the above mentioned indexes.

		Group			
		LP		HP	
Task	**Condition**	**Mean %**	**SD**	**Mean %**	**SD**
Free German	V	31.25	19.28	57.50	15.71
	AV	42.50	12.38	58.13	15.15
	SM	65.00	18.26	74.38	11.53
Free Vimmi	V	8.33	9.51	28.13	13.55
	AV	10.00	9.03	27.29	17.77
	SM	8.96	7.86	37.92	17.76
Paired recall	V	6.46	7.84	29.58	13.05
	AV	11.46	11.67	27.29	18.47
	SM	7.50	6.15	38.54	20.26
Cued recall German to Vimmi	V	18.33	15.96	58.13	25.12
	AV	19.79	15.37	46.25	27.48
	SM	11.04	10.02	55.63	19.35
Cued recall Vimmi to German	V	36.88	23.01	77.50	19.83
	AV	34.38	20.65	74.38	17.11
	SM	31.25	20.62	75.00	21.29
Global performance		22.88	8.36	51.04	13.53

Table 2: Memory performance for the HP and LP (descriptive statistics)

In order to test the impact of the different learning conditions on the memory tasks, we conducted Repeated Measures ANOVAs, using each task performance index as a dependent variable, the Learning Condition as within subject factor with three levels (Visual- V; Audiovisual – AV; Sensorimotor – SM), and the Group as between subjects factor with two levels (LP vs HP). Single effects analyses and contrasts were performed when the interaction between the Learning Condition and Group was significant.

In order to assess if the pre-test memory assessment (Wechsler paired recall, Digit Forward and Digit Backward) was able to predict the global performance, and thus for the HP vs LP groups, we calculated correlation indexes (Pearson's r) between the global performance index and each pre-test. Thereafter, we conducted a logistic regression using the Group as dependent variable and the pre-test(s) significantly correlated with the global performance score as predictor(s).

2. Results

For the free recall test in German, we found a main effect of the Learning Condition, [F (2.60) = 31.68, $p < 0.001$, $\eta^2 = 0.51$]. Sensorimotor encoding proved to be significantly superior [F(1.31)= 38.84, $p < 0.001$] to the other learning conditions. The interaction between Learning Condition and Group was also significant [F(2.60)= 3.29, $p = 0.04$; $\eta^2 = 0.1$]. Single effects analyses indicated that the HP performed better with SM learning than with the other two modalities [SM vs AV and V F(1.15)= 14.4 $p = 0.02$]. However, LP, gradually improved their performance if learning was enriched across the conditions [AV vs V: F(1.15)= 5.65 $p = 0.03$; SM vs AV: F(1.15)= 37.1 $p < 0.001$].

In the free recall task in Vimmi and in the paired recall task, data underlined that on the whole the Learning Condition did not impact performance, i.e. the main effect was absent for the whole group. However, the learning condition affected performance differently depending on the group [Learning Condition X Group – Free Vimmi: F(2.60)= 3.51, p = 0.04; $\eta^2 = 0.11$; Paired recall: F(2.60)= 6, p = 0.04; $\eta^2 = 0.17$]. In both tasks, only the HP took advantage from the SM learning condition against V and AV conditions [Free Vimmi: SM vs AV and V F(1.15)= 6.63 p = 0.02; Paired recall: SM vs AV and V F(1.15)= 11.8 p < 0.004].

In the cued recall from German to Vimmi, the main effect was not significant, but the interaction between Group and Learning condition was significant [F(2.60)= 3.38, p = 0.04; $\eta^2 = 0.10$]; within subjects comparisons underlined that in the learning conditions AV vs. SM, HP still take a greater advantage from SM enrichment, whereas for LP the contrary is the case F(1.30)= 5.93, p = 0.02; $\eta^2 =$ 0.16].
In the cued recall from Vimmi to German, the data underlined that neither the main effect nor the interaction were significant.

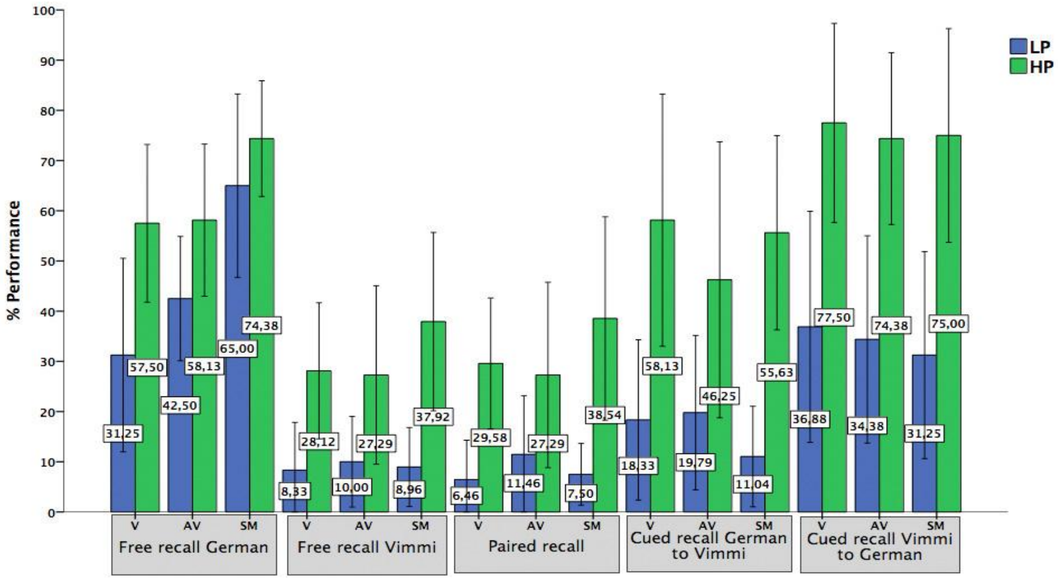

Figure 1: Memory performance for the HP and LP (descriptive statistics)

2.1. Pretests and correlations

We conducted correlation tests between the scores obtained in the memory pre-tests and the global performance index. We found a significant correlation with the Wechsler Paired recall test (r=0.63; $p<0.001$). As a consequence, the binomial logistic regression model including the Wechsler paired recall test as predictor also resulted statistical significance ($\chi2=7.6$; $p<0.01$). The model could explain 28.0% (Nagelkerke R2) of the variance in Group and correctly classified 65.6% of the cases. The sensitivity and specificity were 75% and 56.3% respectively. Hence, as shown in Table 3, an increase in score in the Wechsler paired recall is likely to be associated with the HP.

	B	E.S.	Wald	df	*p*	Exp(B)
Paired-word	0.244	0.115	4.484	1	0.034	1.276
Constant	-12.296	5.902	4.340	1	0.037	0.000

Table 3: Logistic regression parameters

3. Discussion and Conclusion

The above results appear to indicate that three repetitions of 30 novel words lead to poor results in memorization (Figure 1). This applies to both the LP and HP groups. Considering the single tests, free recall in German scored best. It is possible that participants first store the concept. Once it is memorized, retrieving the concept label, the word in L1, is “easy”. Instead, L2, phonematics makes the task more demanding. Hence, results are poorer compared to free recall in L1.

Consequently, the results of paired recall are also affected because the word in L2 is missing. Cued recall tests showed poor performance altogether and learning conditions did not significantly differ from each other. Hence, these data suggest that three repetitions of 30 novel items do not lead to good retention for the population taking part in the experiment.

However, even if general performance was poor, the results show that enrichment of the written words in L2 enhances their memory. In detail, high performers significantly benefit from SM-enrichment in free recall in German, Vimmi and in the paired free recall. Low performers take advantage of SM encoding only in the easiest measure, i.e. the free recall in German. There, we also found a significant interaction between the group and the learning condition. This interaction indicates that both audio-visual enrichment impacts their memory and sensorimotor learning, hence enrichment altogether. Considering this interaction, it stands to reason that enrichment does not burden LP's cognitive load. Instead, enrichment may engage more cognitive resources in word learning and therefore might facilitate retention also for LP, as asserted in a number of scientific papers (Paivio, 2006; Shams & Seitz, 2008; Shams et al., 2011).

In the cued-recall test from German to Vimmi, results indicate an inverse trend in the conditions AV and SM for both groups of participants. Whereas HP still take advantage of enrichment, LP benefit from less enriched input. Being cued recall a demanding task, as it creates a bottle neck by the matching of the words, we speculate the two groups of participants might have adopted different cognitive strategies when retrieving the words. In fact, retrieval strategies may vary depending on the task, the capacities of learners and their age (Danielsson et al. 2015; Touron, 2015).

The positive correlation between HP' memory scores in the retention tests and the Wechsler Paired recall test show that HP have a superior working memory (Baddeley, 2003) for lists and strings of letters. This might have to do with their faculty to process phonologically unfamiliar sounds (Kaushanskaya, Yoo, & Van Hecke, 2013) but bilingualism could also contribute to this capacity (Kaushanskaya & Marian, 2009). From a brain perspective, the ability to better learn language has been attributed to several factors including anatomy (Xiang et al., 2012) and differences in brain function (Golestani, 2014). Specifically, a study addressing high performance in multisensory learning of L2 words has found that HP show higher activity in multisensory integration areas of the brain as the angular gyrus (Macedonia et al., 2010). This ability to put the different pieces of sensory information in a more efficient way together (Macedonia et al., 2010; Seghier, 2012) could explain why HP show superior results independent of the method(s) used during learning.

Taken together, our results indicate that both HP and LP take advantage of enrichment when learning novel words in L2. In other words, additional information related to a word is basic to its retention (Hulstijn, 2001). Furthermore, considering also the behavioral results in a study by Macedonia et.

al. (2010), LP take advantage of sensorimotor enrichment at a lower number of repetitions if the task is not demanding. With a higher number of repetitions, LP can take advantage in more difficult tasks.

From an educational point of view, these findings lead to the consideration that HP having a strong working memory, master memorization easily, and take advantage of sensorimotor enrichment. LP compensate for a weak working memory through enrichment.

In this context, the Wechsler paired test could help to detect low performance. Accordingly, educationalists could select appropriate activities with enrichment and a high number of repetitions in order to support LP. Hence, multisensory learning could possibly help to restrict the performance gap between HP and LP but would certainly allow LP to achieve better results in L2 education and professional development.

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