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Effects of proficiency and age of language acquisition on working memory performance in bilinguals

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This study examined language proficiency and age of language acquisition influences on working memory performance in bilinguals. Bilingual subjects were administered reading span task in parallel versions for their first and second language. In Experiment 1, language proficiency effect was tested by examination of low and highly proficient second language speakers. In Experiment 2, age of language acquisition was examined by comparing the performance of proficient second language speakers who acquired second language either early or later in their lives. Both proficiency and age of language acquisition were found to affect bilingual working memory performance, and the proficiency effect was observed even at very high levels of language competence. The results support the notion of working memory as a domain that is influenced both by a general pool of resources and certain domain specific factors.

Key words: *working memory, bilingualism, language proficiency, age of acquisition, reading span.*

Bilingualism today is more of a rule than an exception, since at least half of the world's population is bilingual (Grosjean, 1989). Consequently, the research of bilingual cognitive functioning had been receiving increasing attention in past twenty years. The majority of the studies in the field tackled the questions of long-term memory organization, lexical storing, access and retrieval, bilingual language production, etc. (cf. Costa, La Heij, & Navarrete, 2006, French & Jacquet, 2004; Schwartz, & Kroll, 2007). Although the idea of connections between immediate memory capacities and bilingualism is not a new one (cf. Kolers, 1963; Weinreich, 1953), the number of studies addressing this subject is considerably smaller.

Working memory – more specifically its verbal component, phonological loop – is seen as a system of critical importance in the process of language

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acquisition (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Pickering, 2000). In this view, the role of phonological loop in recollection of familiar phonological material (known words or numbers) is regarded as a byproduct of the development of a system whose primary function is the acquisition of new phonological material (i.e. new language). Though the previous statement renders the significance of working memory for people acquiring the second language (future bilinguals) evident, connections between bilingualism and working memory go beyond the language acquisition processes. There are a vast number of studies showing that long-term knowledge affects immediate memory performance (for an overview, see Thorn, Frankish & Gathercole, 2008). These influences are argued to be both phonological (e.g. Conrad & Hull, 1964; Gathercole, Frankish, Pickering, & Peaker, 1999) and lexical/semantic (e.g. Hulme, Maughan, & Brown, 1991; Hulme et al., 1997; Poirier & Saint Aubin, 1995) in nature. Since bilinguals typically differ in linguistic knowledge of the first (L1) and second language (L2) it is important to investigate the effect these differences on the working memory performance in two languages. The question of concern here is whether a person acquired the first and then the second language (using the phonological loop system), exhibits different working memory performance in the two languages, and what factors might possibly drive those differences. Another potentially interesting question, both for actual models of working memory (e.g. Baddeley, 2003) and bilingual educational practice, is whether the acquisition of L2 might have backward effect on working memory functioning in L1. In other words, could the functioning of verbal working memory, or perhaps even working memory in general, be improved by the L2 acquisition? Current notions of working memory do not predict such an outcome, and they would need to be revised in case of positive effect of L2 acquisition on working memory.

Present study had two specific goals. The first one was to examine the influence of language proficiency on verbal working memory performance in bilinguals' L2. Language proficiency in L2 is known to affect L2 processing from the levels as low as the individual word recognition. For example, Favreau and Segalowitz (1983) showed that highly proficient bilinguals exhibited greater semantic priming than less proficient bilinguals, especially at short stimulus onset asynchrony intervals. Whether, and to which extent, the proficiency effect is present in the verbal working memory operation is still unclear, as the previous findings have not been unanimous. In an early study of Harrington and Sawyer (1992) native (L1) Japanese speakers with upper-intermediate to advanced proficiency in L2 English were tested on a version of reading span task of Daneman and Carpenter (1980). The subjects exhibited no differences in working memory span in L1 and L2. However, significant correlation between L2 proficiency and working memory span in L2 was observed in the same study, suggesting that the issue required further inquiry. Moreover, the same study reported of moderate correlations between L1 and L2 working memory spans (higher correlations were found in Osaka and Osaka, 1992 and Miyake and Friedman, 1998). These findings were compatible with the capacity theory of comprehension (Just & Carpenter, 1992). More recently, Service, Simola, Metsaenheimo and Maury (2002) examined two groups of Finnish-English bilinguals. The task in this study was to memorize the last words of the auditively presented sentences while judging their correspondence with the pictures that were shown. No difference between L1 and L2 working memory spans was found in a group of highly proficient L2 speakers. However, significantly lower working memory spans in L2, as compared to L1 spans, were registered in a group of less proficient L2 speakers. These results suggested that proficiency effect does exist, but that it can only be observed at lower levels of L2 proficiency. Investigating the same issue, Van den Noort, Bosch and Hugdahl (2006) conducted a study that examined working memory functioning of trilinguals. Their subjects were native (L1) Dutch speakers who spoke fluent German (L2)[1] and less-fluent Norwegian language (L3). These subjects performed better on the L1 reading span task, as compared to the L2 task, and their performance in L2 was better than in L3. Accordingly, the study confirmed the language proficiency affects working memory performance. However, the study of Van den Noort et al. showed that the effect might not be exclusive feature of insufficiently proficient language processing. Contrary to the findings of Service et al. (2002), the study suggested that the effect of language proficiency might be a more comprehensive one, and that it could be registered in fluent speakers of foreign language, too. In the same vein, an fMRI study by Chee, Soon, Lee and Pallier (2004) reported proficiency effect in patterns of brain activation during auditory n-back task. Recent studies, thus, generally support the view of some kind of dependence of verbal working memory performance on language proficiency. Whether this dependence is only present in less proficient L2 speakers, meaning that there is some proficiency threshold beyond which the effect is not observed, is still unclear. Alternatively, it might be the case that the proficiency is influencing verbal working memory performance even in highly competent L2 speakers. This dilemma is addressed in our Experiment 1.

The second goal of our study was to examine the age of language acquisition effects on verbal working memory performance. Relevance of age of acquisition factor was extensively explored and documented in different areas of psycholinguistics, especially after the influential study of Morrison and Ellis (1995) which showed that early-acquired words are processed faster than the later acquired ones, even after controlling for the frequency effect. Effects of age of acquisition on the word level language processing were shown in different experimental paradigms: naming (e.g. Brysbaert & Ghyselinck, 2006), lexical decision (Morrison & Ellis, 2000), semantic categorization task

1 Proficiency level in L2 German of these subjects was comparable to the proficiency level in L2 English of the highly proficient group from the study of Service et al (2002).

(Brysbaert, Van Wijendaele & De Deyne, 2000), etc. Several reported studies explored the effects of age of acquisition in the second language, as well. Mainly motivated by the pursuit of the critical period for language acquisition, these showed clear differences in processing of L2 words in function of their age of acquisition. For example, Silverberg and Samuel (2004) found effects of L2 semantic priming in early, but not in late bilinguals. Their results suggested that early bilinguals might have unitary conceptual system, whereas late bilinguals use separate conceptual systems for each of their languages. Abundant research on age of acquisition in past two decades demonstrated this factor affects various aspects of language processing, yet thus far no study investigated whether the age of acquisition of a particular language might be a factor relevant for the working memory processing in that language. On the other hand, bilingual working memory research, as commented, focused principally on the examination of the language proficiency effect. In our Experiment 2, we made the first exploratory step in examining the possibility of independent influence of the age of language acquisition on verbal working memory performance.

EXPERIMENT 1

The goal of Experiment 1 was an elaborate examination of the effect of second language proficiency on working memory performance in bilinguals.

Method

Participants: Thirty-one first year students of psychology at the University of Novi Sad took part in this experiment. Out of all first year psychology students, those with the lowest and the highest scores on the placement test of English language (Quick Paper and Pen Test, 2001) were chosen for the experiment[2]. Selected students formed the less proficient (LP) and the high proficient (HP) experimental groups. All subjects spoke Serbian as their native language (L1), and English as their second language (L2). Groups were of the similar age ($M_{LP} = 20$; $M_{HP} = 20.5$; $t(29) = 0.877$, $p > 0.05$), did not differ in age at which they began L2 acquisition ($M_{LP} = 10.6$; $M_{HP} = 9.6$; $t(27.394) = 1.466$, $p > 0.05$), nor duration of L2 learning ($M_{LP} = 9.87$; $M_{HP} = 10.69$; $t(21.731) = -0.852$, $p > 0.05$).[3] All 15 subjects from the LP group attended the lowest offered level of the English course (pre-intermediate), while the HP subjects attended the most advanced level of English course offered (upper-intermediate) or were exempt from the course due to very high English competence. Mean English test scores were 27.2 and 45.94 (out of 60) for the LP and the HP group, respectively. Difference between them was significant ($t(29) = -18.224$, $p < 0.01$).

2 The placement test is regularly administered to all first year students in order to assign them to study groups with similar English competence level for their English language course. The test is comprised of 60 multiple-choice questions that examine the knowledge of English grammar, vocabulary and comprehension and is valid criterion for the English language competence selection (Radić-Bojanić, 2008).

3 Reported language background information was obtained through subjects' self-reports.

Tasks: Subjects were administered the reading span task of working memory (Daneman & Carpenter, 1980) in two parallel language variants: the Serbian and the English. The reading span task was chosen as it is the most commonly used procedure for the verbal working memory capacity assessment. The English task procedure resembled the procedures used in Waters and Caplan (1996) and Engle, Tuholski, Laughlin and Conway (1999) and was based on the findings of the study of methodological and technical aspects of the reading span task (Lalović & Vejnović, 2008).

Stimuli (task elements) were presented on the computer screen one at a time. Task element consisted of a sentence, followed by the question-mark, followed by the uppercase target-word (for example: "*Nigel can't swim as fast as his younger window and his friends can. ? FLOWER*"). Subjects were asked to read out loud each sentence the moment it appears on the screen, say "yes" if the sentence made sense or "no" if it did not[4], and read and memorize following target-word. When this was done presentation of the next element was activated by the experimenter. After the presentation of several elements, three question-marks would appear on the screen notifying the subject to pass to the reproduction phase in which he was instructed to write all the target-words from the previous trial in the response sheet. Reproduction phase was then succeeded by the presentation of next trial, and the presentation and reproduction phases would alternate until the end of experiment.

The experiment consisted of twelve trials (sequences of elements between two reproduction phases), and trial size (2–5) was calculated as the number of elements in a given trial. Total number of elements in the experiment was 42, so that trials of each size were administered three times within the experiment. The order of the presentation of trials was randomized so the subject could not know the timing of the next recollection phase. The Serbian version of the task was exactly the same as the described English in all aspects save for the language employed.

Stimuli: Eleven to fifteen word long sentences, followed by target-words (nouns), were used as stimuli. They were presented on 17" computer screen, in 20pt Arial white font on dark background. In order to make the two language versions of the task parallel, the stimuli were matched for several relevant characteristics: sentence length, syntactic and vocabulary complexity[5], target-word frequency and target-word length (as measured by the number of phonemes). Mean sentence length was 12.36 for Serbian, and 12.43 for English task; with two language variants not differing significantly ($t(82) = –0,365$, $p > 0.05$). Frequencies of the Serbian target-words were extracted from the Serbian Language Corpus (Kostić, 1999) and the English from the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Mean target-word frequency was 266.29 occurrences per million words for Serbian, and 194.43 occurrences per million words for English target-words. This difference was not significant either ($t(82) = 1.139$, $p > 0.05$). Average number of phonemes was 4.69 in Serbian target-words and 4.38 in English target-words, and their difference was statistically insignificant ($t(82) = 1.319$, $p > 0.05$).

Design: Main analysis of Experiment 1 included L2 working memory span as a dependent variable, L2 proficiency as a categorical predictor, and L1 working memory span as a

4 Half of the sentences were made semantically implausible by substituting animate subject for inanimate. Semantic verification of the sentences was introduced in order to make sure the sentences were read for comprehension.

5 In the pilot examination it was ensured that syntactic complexity and vocabulary of the selected sentences were appropriate for the low-proficiency level of L2. Half of the sentences were then kept for the English version of the task, and the other half was translated for the use in the L1 (Serbian) version of the task.

continuous covariate predictor. Additionally, ANOVA and hierarchical regression models were performed (see the results section) and within-group comparison of the L1 and L2 working memory span was made for each of the groups.

Working memory spans were operationalized as an average proportion of correctly reproduced elements of all trials. For each trial, an index representing the number of correctly reproduced elements divided by trial size was calculated. Final score was obtained as the sum of all the indices, divided by total number of trials in the experiment (12), and the reading span index took the values between 0 and 1.

Procedure: Two language versions of the task were administered individually in one session. The order of administration was balanced and had no effect on results. The DMDX software v.3.2.5.4 (Forster & Forster, 2003) was used for the presentation of the stimuli. Average duration of the session was around 25 minutes.

Results

Correlations between the English test scores and the reading span measures in two languages were calculated together for subjects from the two groups. The span scores in two language versions of the task were highly and positively correlated ($r(29) = 0.647$, $p < 0.01$)[6]. The English test scores were significantly correlated with working memory span in English task ($r(29) = 0.432$, $p < 0.05$), but not with the span in the Serbian version of the task ($r(29) = 0.199$, $p > 0.05$).

Mean working memory spans and standard deviations for two groups of subjects are shown in Table 1.

Table 1: Means and standard deviations of L1 and L2 spans for two groups of subjects.

Group	Span	M	SD
Less proficient	L1	0.596	0.104
	L2	0.461	0.078
Highly proficient	L1	0.639	0.112
	L2	0.543	0.102

Proficiency effect on L2 span was examined by linear modeling (ANCOVA design). Significant main effect of proficiency level on L2 reading span task performance was registered ($F(1, 28) = 5.022$, $p < 0.05$) even after controlling for the covariate L1 span effect ($F(1, 28) = 18.760$, $p < 0.01$). Additional test showed that unique contribution of proficiency level was significant ($R^2 = 0.12$, $F(1, 29) = 4.955$, $p < 0.05$), after L1 span effect was accounted for. At the same time, effect of proficiency on L1 span was not significant ($F(1, 29) = 1.21$, $p > 0.05$).

6 When computed separately for each group, the correlations were: $r(15) = 0.538$, $p < 0.05$ (LP group) and $r(16) = 0.701$, $p < 0.01$ (HP group).

In order to further inspect the proficiency effect, the reading span task performance in L1 and L2 was compared for each group of subjects. Both groups had significantly higher spans when they performed the task in their native, as compared to their second language ($t(14) = 5.809$, $p < 0.01$, for the LP group; and $t(15) = 4.633$, $p < 0.01$, for the HP group).

Discussion

Results showed that the reading span scores in L1 an L2 were highly correlated. Subjects' reading span in L2 (English) was moderately correlated with their English knowledge test scores, while, expectedly, English knowledge test scores did not correlate with L1 working memory spans. The pattern of these correlation coefficient magnitudes is similar to the one reported in Osamu (2006). It suggests that performance on the reading span task in L2 depends both on 1) a common pool of resources that is involved in verbal working memory processing independently of the task characteristics, and, at least to some extent, on 2) the mastering of L2.

Subjects from the highly proficient L2 group performed substantially better on the L2 task than their less proficient matches, while the two groups' performance in L1 was comparable. Importantly, the effect of proficiency level on L2 performance remained significant even after the L1 performance influences were statistically partialled out, and its unique contribution improved the model significantly. Thus, Experiment 1 showed that language proficiency influences working memory performance in L2.

Additionally, Experiment 1 also showed that both experimental groups were more successful when faced with the reading span task in L1 (Serbian) than when performing the same task in L2 (English). Better L1 performance of the less proficient group can easily be attributed to their higher proficiency in L1, as compared to proficiency in L2. Yet more importantly, similar claim could be made for the highly proficient L2 subjects, too, for their L1 proficiency is arguably superior to their L2 proficiency, as well. Consequently, it could be concluded that the proficiency effect is not exclusive feature of the non-proficient language processing. Our results showed that it can be spotted even in highly proficient L2 speakers.

However, there is an alternative explanation for the subjects' superior L1 performance (that is particularly relevant for the highly proficient group). As described, our subjects started acquiring L2 (English) at the age of nine or ten – at the time they already were reasonably competent L1 (Serbian) speakers. Therefore, it perhaps might be the case that the difference in the performance in two languages that was observed in highly proficient subjects was not (only) due to their superior proficiency in L1, but (at least partly) due to the difference in the age at which they had acquired those languages. This issue was addressed in our Experiment 2.

EXPERIMENT 2

The main goal of Experiment 2 was to examine effect of age of language acquisition on verbal working memory performance in bilinguals.

Method

Participants: A group of 15 subjects, students of psychology or Serbian language for ethnic minorities, participated in Experiment 2. Their native language was Hungarian and they all spoke fluent Serbian, as a language of the community they live in. The results of this group (*the early acquired – EA group*) were contrasted with the data obtained from the highly proficient L2 speakers of Experiment 1 (*the later acquired – LA group)*. Both of the groups, thus, were comprised of proficient L2 speakers. Importantly, the groups matched in L2 proficiency self-assessments on a ten-point Likert scale ($M_{LA} = 7.31$; $M_{EA} = 8$; $t(29) = 1.92$; $p > 0.05$) and crucially differed in the age at which they had started L2 acquisition ($M_{LA} = 9$; $M_{EA} = 4$, $t(29) = 6.680$, $p < 0.01$).

Tasks: Two language versions of the reading span task were administered: the Hungarian and the Serbian. The Serbian version was the same as in Experiment 1. The Hungarian was constructed for the purpose of this experiment and matched the Serbian in all relevant aspects (see below).

Stimuli: Two language versions of the reading span task were matched for the sentence length, syntactic and vocabulary complexity, frequency and the length of target-word. Average sentence length was 12.36 words in both versions of the task. Hungarian target-word frequencies were extracted from the Hungarian National Corpus (Magyar Nemeti Szövegtár, 2003), their mean was 205.43 occurrences per million, and it matched mean Serbian target-word frequency ($t(82) = 1.026$, $p > 0.05$). Mean number of phonemes in target-words was 4.45 and 4.69 for the Hungarian and Serbian version of the task, respectively, with the two versions not differing in this respect either ($t(82) = 0.962$, $p > 0.05$).

Design: The main analysis of Experiment 2 included L2 working memory span as a dependent variable, with age of L2 acquisition as a between-group categorical predictor and L1 working memory span as a continuous covariate predictor. Within-group comparison of L1 and L2 spans of the EA group was performed for further examination of proficiency effect. Working memory spans were calculated in the same fashion as in Experiment 1.

Procedure: Administration of the task was individual. Participants were administered two parallel language variants of the reading span task (Hungarian and Serbian) in one session. The order of task administration was balanced and had no effect on the results. Technical aspects of the presentation of the stimuli were identical to those in Experiment 1.

Results

Descriptive statistics of the subjects tested in Experiment 2 (the EA group), together with the highly proficient subjects from Experiment 1 to whom they were compared to are displayed in Table 2. Due to lower variability in language proficiency of the EA subjects, their L1 and L2 spans were even more highly correlated ($r(29) = 0.84$, $p < 0.01$) than those of the groups tested in Experiment 1.

Table 2: Means and standard deviations of L1 and L2 spans for the groups of early and later acquired L2 subjects.

Group	Span	M	SD
Early acquired	L1	.627	.111
	L2	.590	.111
Later acquired	L1	.639	.112
	L2	.543	.102

Linear model (ANCOVA) was performed in order to examine the effect of the group membership on L2 span. Significant main effect of group was registered ($F(1, 28) = 5.064$, $p < 0.05$), even after controlling for the covariate L1 span effect ($F(1, 28) = 41.405$, $p < 0.01$). Conversely, group effect on L1 span was not significant ($F(1, 29) < 1$). While compared groups equaled in their L1 performance, the EA group performed significantly better in L2. Furthermore, subjects from the EA group had larger spans in L1 than in L2 ($t(14) = 2.342$, $p < 0.05$).

Discussion

As in Experiment 1, high correlation between working memory spans in L1 and L2 was found. This correlation was even higher than the correlation registered in HP group of the Experiment 1.

Unlike in Experiment 1, subjects from both groups considered in Experiment 2 analyses were proficient speakers of both L1 and L2. They matched in self-assessment of L2 proficiency, with the critical difference between the groups being the age of L2 acquisition. Subjects from the EA group started L2 acquisition at the age of four, while those of the LA group did so at the age of nine. This difference is both statistically significant and substantial. Furthermore, the EA group subjects acquired L2 within the critical period that is often claimed to be the maturational constraint for fully successful language acquisition (cf. Johnson & Newport, 1989; Newport, 1990), whereas the age of first exposure to L2 for the LA group goes well beyond the critical age of seven, with their L2 acquisition continuing during puberty period.

Experiment 2 showed that the two groups had similar working memory spans in their L1. The EA group, however, performed significantly better in the L2 task than the LA group. Accordingly, the experiment showed that the verbal working memory performance is affected by the age of language acquisition.

Results of Experiment 2 also showed that the L1 span was larger than the L2 span even in subjects who acquired L2 early in their lives and have very good command of it. This finding gives an additional support to the results of Experiment 1. More specifically, it shows that language proficiency effect on verbal working memory is not only characteristic of lower level L2 mastering, but that it is present even in very highly skilled speakers.

GENERAL DISCUSSION

This study examined factors that influence bilingual verbal working memory performance. The nature of previously reported proficiency effect was under particular scrutiny in our experiments, while the age of language acquisition effect was examined for the first time. The answer to the first principal question of the study – is verbal working memory performance affected by language proficiency? – is clearly affirmative. Several findings support this claim. Most importantly, critical comparison of two experimental groups in Experiment 1 showed that proficient L2 speakers had larger L2 working memory spans than the group characterized by lower L2 proficiency, even after the influence of L1 performance was statistically controlled for. At the same time, two groups did not show significant differences in their L1 performance. Moreover, subjects' scores on L2 knowledge test were correlated with their L2 spans, and not with their L1 spans. Registered proficiency effect confirmed previous findings of Service et al. (2002) and Van den Noort et al. (2006), in spite of notable methodological differences in three studies. In particular, Service et al.'s experimental task was considerably different from ours: their subjects were shown pictures while the sentences were presented auditively. The task was to verify the correspondence between the two, while at the same time memorizing the last words of the presented sentences. Languages used were Finnish and English, and there were several procedural particularities in this study. In the Van den Noort's study standard reading span task was administered in three Germanic languages (Dutch, German and Norwegian), while the same task and different scoring procedure was applied in our study. The languages we used (Serbian, Hungarian and English) origin from different and quite distant language groups. Thus, the concurrence of the results from the three studies proves that the proficiency effect is robust enough to be registered by the application of different experimental procedures and in very different languages. Additional support for this finding comes from the neurological study of Chee et al. (2004) where different brain activation at different L2 proficiency levels in working memory (n-back) task was reported. On the basis of the presented results, we concur with the view of Service and colleagues, and argue that language proficiency affects verbal working memory performance. It is our view that this happens in the following way: higher language proficiency in a given language leads to greater automatization of its processing, which leads to smaller processing costs in comprehension of the verbal material. This in turn causes that larger portion of available resources can be employed in the retainment of the information in working memory, which can ultimately be observed in superior working memory spans in proficient language processing.

Furthermore, results of the study allow for a more precise specification of registered proficiency effect. In Experiment 1, the effect was shown at lower levels of language proficiency (L1 span > L2 span). But more importantly, the same result was obtained in highly proficient L2 speakers, too, for even highly proficient L2 subjects performed better when they were administered the task in L1 (in which they were more proficient), than in L2 (which they mastered fairly well, but not as good as L1). Finally, larger L1 span was found even in the group of early acquired L2 subjects (Experiment 2). Clearly, these results conflict with the threshold hypothesis that predicts the effect is to be observed at lower levels of language proficiency only. Presence of the effect at all examined proficiency levels contrasts with the findings reported in the study of Service et al. (2002), and concurs with the results of the Van den Noort's et al. (2006). We suspect that the divergent findings of Service et al. are likely to have emerged due to application of considerably different procedure than the one used in other two studies. Our results suggest that even highly proficient L2 speakers do not reach the level of automatization of L2 processing that is characteristic of their L1 processing. Consequently, when comprehending L2 material they need to engage more of available resources than in L1 processing, and this in turn results in less information retained in their working memory.

However, there is one objection that can be made with respect to previous discussion. It can correctly be noted that superior L1 working memory performance of the Experiment 1 subjects may not necessarily have been caused by their superior L1 proficiency, since there also was a substantial difference in the age at which these subjects had acquired two languages. Having in mind the critical period hypothesis of language acquisition (cf. Johnson & Newport, 1989; Newport, 1990), one could wonder whether the L1 working memory superiority was (at least partly) caused by this other difference. The outcome of Experiment 2, however, does not support this skepticism, as similar superiority of L1 performance was found in subjects that had started with L2 acquisition very early (at the age of four), well before L1 acquisition was anywhere close to completion, and certainly well before the end of the critical period.

Relevance of the age of language acquisition on verbal working memory performance was examined in Experiment 2 where two highly proficient L2 groups were tested. Critical comparison showed that the group that acquired L2 at the early age had larger L2 working memory span than the group that started with the L2 acquisition later (the groups equaling in L1 performance). This showed that, in addition to language proficiency, age of language acquisition presents another domain specific variable that affects bilingual verbal working memory performance. Given that we have shown that proficiency affects working memory performance, potential objection regarding previous conclusion concerns the question of whether the subjects of the two highly proficient groups were exactly equal in their L2 competence, i.e. whether L2 proficiency of the later-acquired group was as high as that of the early-acquired group. In response to this, we firstly note that an effort was made to select the best later-acquired L2 speakers available. Their L2 proficiency was judged as high both by experts and by the objective L2 test scores. These L2 (English) test scores could not have been compared with objective L2 (Serbian) test scores of the early-acquired group, since matching standardized test of Serbian as the second language is not available. However, we asked our subjects to assess their L2 proficiency, and these self-assessments did not show between-group difference. Also, subjects from the two groups were similar in declaring preference of the use of L1. Based on all this, we conclude that there was no evidence indicating between-group difference in L2 proficiency, and suggest that the observed results were likely to be the consequence of the differences in the age of L2 acquisition. This first establishment of the age of language acquisition effect is to be reconfirmed in subsequent experimentation.

Besides two principal outcomes of the study, two other results are also worth noting. Firstly, high positive correlation of performance in reading span tasks in different languages is found in both experiments. These correlations are comparable in size to the ones reported in Osaka & Osaka (1992) and Van den Noort et al. (2006). Differences among three languages used in our study additionally strengthen this finding. Viewed in the light of domain generality discussion, this result supports the notion of working memory as a cognitive capacity that is largely domain general, or at least language independent. However, registered interlingual correlation was far from perfect, indicating some specific language factors (e.g. language proficiency and age of language acquisition) also contribute to the working memory performance. Secondly, an effect of L2 proficiency or age of L2 acquisition on L1 working memory performance was not shown in either of the experiments. Learning of L2, even in an early period, does not seem to have backward beneficial effect on general working memory functioning. As discussed, this comes as no surprise, since current notions of working memory do not predict such an effect.

In conclusion, results of the study support the notion of a general pool of resources that are engaged in every working memory processing. This general ability, by large, determines working memory performance in verbal domain irrespectively of the language employed. However, the research unambiguously showed that some specific characteristics of language also have effect of verbal working memory performance. These are, namely, language proficiency and age of language acquisition. Age of acquisition effect was shown for the first time, and language proficiency was proved to affect working memory performance even in very high levels of language mastering.

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