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Learning and Individual Differences 14 (2004) 137–151

Learning and
Individual Differences

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Working memory performance of Italian students with foreign language learning difficulties

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Received 28 April 2003; received in revised form 10 November 2003; accepted 22 January 2004

Abstract

It has been suggested that the ability to learn a foreign language is related to working memory. However, there is no clear evidence about which component of working memory may be involved.

Two experiments investigated working memory problems in groups of seventh and eighth grade Italian children with difficulties in learning English as a second language. They were compared with control groups of children matched for age, education, school, and intelligence who differed for foreign language learning ability.

Experiment 1 focused on clarifying how modality-specific the memory problem of children with a foreign language learning difficulty (FLLD) is. Verbal working memory tasks (forward and backward digit span) were proposed together with visuospatial working memory (VSWM) tasks. Groups showed a significant difference only in the more passive verbal working memory task, that is, the forward digit span.

Experiment 2 focused on clarifying how central the verbal working memory problem of students with an FLLD is. A nonword repetition task and an Italian version of the listening span test were proposed. Groups differed significantly in both tasks. However, differences in the listening span test disappeared when nonword repetition performance was partialled out. It was concluded that a difficulty in learning a foreign language is mainly related to the more passive aspects of verbal working memory, typically associated with the articulatory loop.

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Keywords: Working memory performance; FLLD; Foreign language

1. Introduction

Research on learning problems has recently focused on foreign language learning difficulties (FLLD), a student's specific trouble in learning a second language (Ganschow & Sparks, 1995; Ganschow,

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Sparks, & Javorsky, 1998; Palladino, 2003). Students with FLLD have been described as having an average or above-average level of intelligence and adequate scholastic achievement but a specific impairment in foreign language learning (FLL). Pimsleur, Stockwell, and Comrey (1962), Diklage (1971), and Ganschow and Sparks (1986) documented cases of students who performed less well in FL than in other courses, or even failed. However, compared with a control group, they did not differ in intelligence (Ganschow & Sparks, 1995).

Although different disability profiles can be identified in young children with FLLD (Sparks & Ganschow, 1993), they typically seem to have problems with native-language learning. However, although FLLD often appears to be associated with specific language disorders, it can also emerge as a more specific and selective problem, especially with older children or adolescents. In fact, older children with FLLD may show only slight difficulties in language and reading tasks. Furthermore, the pattern of difficulties of FLLD children may be rather complex. In one study (Sparks, Ganschow, Javorsky, Pohlman, & Patton, 1992), low-risk postsecondary FL learners exhibited significantly higher phonological/orthographic and syntactic skills than did high-risk FL learners, but did not differ in semantic processing. Recently, Meschyan and Hernandez (2002) found that native-language decoding skill predicted second-language proficiency in college-aged adults. The relationship was mediated by the participants' second-language word decoding ability.

Furthermore, Hulstijn and Bossers (1992) showed that individual differences in foreign language proficiency are related to native language proficiency, especially at higher levels of foreign language acquisition. In bilingual children, a close interdependence between native and foreign languages was consistently found in several studies (Cummins, 1991). Carroll (1962, 1981) explored individual differences in foreign language learning and focused on the predictive variables of foreign language learning. On the basis of the results, he devised a powerful test to measure aptitude to second-language learning, the Modern Language Aptitude Test (MLAT, Carroll & Sapon, 1959), which also evaluates first-language grammar and phonological sensitivity as well as associative learning. In conclusion, a widely accepted view assumes that native language skills play a critical role in the acquisition of FL learning and, therefore, in FLLD (linguistic coding differences hypothesis, LCDH; Ganschow et al., 1998).

Significant parallel research contributions to the study of second-language learning come from investigations into the relationship between memory and first/second-language (L1–L2) vocabulary knowledge. According to the working memory model of Baddeley (1986, 1990), the verbal short-term memory subsystem (the so-called articulatory loop) has a phonological store in which phonological traces are constantly refreshed by an articulatory rehearsal. The possibility that a new word, just heard, could become a new long-term lexical knowledge depending on the efficiency of the articulatory loop. In particular, nonsense word repetition could be considered a pure measure of phonological memory, as nonwords are new phonological combinations, which are not likely to have been encoded previously. Therefore, nonword repetition is, in principle, a phonological memory measure independent of vocabulary knowledge. However, it is predictive of vocabulary acquisition in first and second languages.

Several empirical studies have demonstrated the parallel and independent role of phonological memory, measured with a nonword repetition task, and previous vocabulary knowledge to vocabulary learning (Baddeley, Gathercole, & Papagno, 1998; Baddeley & Wilson, 1993; Gathercole & Baddeley, 1989; Papagno, Valentine, & Baddeley, 1991; Thorn & Gathercole, 1999). Further researches have tried to extend the relationship between phonological memory and word learning to foreign language learning. Service (1992) demonstrated that a phonological memory measure, requiring the repetition

of nonwords that sound like foreign language (English) words, was a good predictor of learning English as a second language in Finnish children. English learning was not tested directly by researchers but was obtained from a scholastic proficiency evaluation. When English has been tested independently by researchers, a significant correlation between phonological memory (nonwords repetition) and foreign language learning was still found (Service & Kohonen, 1995; Service, Simola, Metsaenheimo & Maury, 2002). Cheung (1996) also found that phonological memory, measured with a task similar with the one used by Service, is significantly related to foreign language learning. However, the size of participants' English vocabulary appeared as an additional important factor in foreign language learning.

Evidence concerning the phonological memory deficit in children with FLLD can be better understood within a theoretical analysis of working memory. In the working memory model of Baddeley (1986), working memory is divided into three main components, that is, a central executive supervising the system and two components involved in processing modality-specific information, either visuospatial or phonological, that is, the visuospatial sketchpad and the articulatory loop, respectively. The articulatory loop includes storage (the phonological store) and maintenance functions (rehearsal loop), which operates on maintaining phonological traces. According to Baddeley's working memory model, the specific phonological memory problem of children with FLLD could be referred to a specific impairment of the articulatory loop, but should not involve the central executive component nor the visuospatial sketch pad.

Similar, but not identical, predictions can be formulated according to different working memory models. In particular, Cornoldi and Vecchi (2000, 2003) developed a modified model of working memory in which two continua expand according to active versus passive process dichotomy and verbal versus visuospatial modality dichotomy. The model can explain empirical evidence obtained from developmental research on learning disabilities (Cornoldi, Carretti & De Beni, 2001; Swanson & Siegel, 2001) and evidence from individual differences in working memory, avoiding constraints due to the division of working memory into independent systems. According to the model of Cornoldi and Vecchi, the specific phonological memory problem of children with FLLD could also involve more active and controlled working memory processes, to a decreasing extent. In fact, it is assumed that it is possible to distinguish more passive versus more active verbal working memory tasks within the different measures of verbal working memory. Verbal repetition tasks, such as the forward digit span and the nonword repetition tasks, are considered as quite passive working memory tasks, as they simply require the repetition in sequential order of speech strings just heard without any transformation of the items. A slight transformation is required with the backward digit span test, which can be classified as more active than the forward digit span test. A more active measure of verbal working memory is a quite complex reading/listening span task like the one originally proposed by Daneman and Carpenter (1980) and is widely used in the field of language difficulties. The task requires the participant to process a series of sentences and then to recall only the last word of each sentence in the series. In the 'listening' version, the material is presented auditorily, whereas in the 'reading' version, it must be read. Dissociations between passive and active verbal tasks have been observed, for example, with poor comprehenders who perform lower in the reading or listening span test compared with a control group, but perform similarly in digit or word span tasks (Cornoldi & Oakhill, 1996; Oakhill, Yuill, & Parkin, 1986). De Beni, Palladino, Pazzaglia, and Cornoldi (1998) obtained similar results by comparing good and poor comprehenders with an Italian version of the listening and digit span tests. Poor comprehenders' lower performance in the active verbal working memory task was associated with a higher number of intrusion errors, which the authors argued were due to inhibitory difficulties. In fact, the listening span task

requires controlling not only the activation of relevant information, but also the suppression of no longer relevant information. However, poor comprehenders do not seem to have similar problems in the control of working memory when visuospatial material is presented (Cornoldi & Oakhill, 1996).

Only a few studies have investigated the relationship between active working memory measures and foreign language learning. Harrington and Sawyer (1992) showed a strong relationship between working memory performance in a foreign language reading span test and the foreign language proficiency of Japanese adults. Similar results were obtained by Geva and Ryan (1993) who showed that the relationship between a foreign language reading span test and foreign language reading comprehension was still significant even after the common variance shared with vocabulary and grammatical knowledge was removed. This relationship was still significant when the variance shared with intelligence and age was removed in children in Grades 5–7 (Geva & Ryan, 1993). However, this line of research does not clearly separate second-language learning, measured as grammar and vocabulary knowledge, from reading comprehension ability. Furthermore, these studies have the methodological limitations typical of correlational designs that Miyake and Friedman (1998) tried to overcome when testing a path model. They proposed listening span tests, in both the native and foreign language, and a syntactic comprehension task. They tested a model that obtained a good fit index (CFI=.96), in which native language working memory influences foreign language working memory that, in turn, influences syntactic comprehension. These results are methodologically stronger than the correlational results, but a main confounding emerged. In fact, Miyake and Friedman measured working memory with the typical listening span procedure (Daneman & Carpenter, 1980), which requires understanding sentences and recalling their final words. Unfortunately, in the syntactic comprehension task, the request was again to understand sentences (although probably syntactically more complex), and this may have affected the results.

In general, the relationship between foreign language learning and working memory has been examined from various perspectives. However, the different results obtained do not fit coherently as various memory measures have been presented and working memory was not systematically investigated to exclude/include the involvement of specific components. Recent models of working memory should help in establishing the nature of the working memory deficit in children with FLLD. In particular, on the basis of the model of Baddeley (1986), evidence has been collected to show that a deficit should involve the articulatory loop, whereas no evidence is available for the visuospatial sketch pad. Evidence regarding the central executive is unclear, and the issue has many facets. In fact, the above-quoted studies (e.g., Geva & Ryan, 1993; Miyake & Friedman, 1998) have shown working memory impairments by using tasks which involve central executive components, according to Baddeley (1990), a view which is questioned by Cornoldi et al. (2001) and Cornoldi and Vecchi (2003). These authors assume, on the one hand, that the tasks involve components in the vertical working memory continuum, which are still modality specific, as they are an intermediate between the most passive phonological components and the most central and active amodal components. On the other hand, they assume that the disabilities associated with the phonological treatment of information should present decreasing impairments moving from the passive to the active components of verbal working memory.

The present study was aimed at investigating FLLD children further by examining their working memory performances. The main goal was to systematically investigate working memory with tasks that differed for modality processing and the amount of active processing request, that is, by administering tasks which measure not only verbal passive memory but also visuospatial and active

working memory. In testing phonological memory, different from previous studies using nonwords that sound like a foreign language, we decided to use words (Experiment 1) and nonwords (Experiment 2) belonging to, or sounding like, the first language. In fact, the literature on clinical profiles of students with FLLD seems to suggest main problems in the first language, which appear to induce foreign language problems (Sparks & Ganschow, 1993). Therefore, if learning a foreign language or, more specifically, learning foreign vocabulary, is mainly related to first-language problems, and phonological memory is responsible for first-language learning, the memory performance of students with FLLD should also be impaired when tested with nonwords sounding like their first language words.

In this study, to have a group with an important and specific difficulty in foreign language learning, we only selected children who met some precise criteria (a difficulty in foreign language learning associated with a high performance in an intelligence test). This had the implication that the selected groups we studied were rather small but specific, thus offering information on a particular subtype of learning disability, rarely studied by the literature. Experiment 1 was intended to test the hypothesis that children with FLLD have problems in passive verbal working memory but not in visuospatial working memory (VSWM). For this purpose, children with FLLD and controls were administered passive and more active verbal and visuospatial tasks. Verbal working memory was tested not with specific phonological nonsense material but with standard digit span tasks, in the most passive version (forward digit span) and in a more controlled version (backwards digit span), to examine the generality of the verbal working memory deficit of children with FLLD. VSWM was tested with three tasks that have been shown to describe well the control continuum along the visuospatial modality (Cornoldi & Vecchi, 2003), that is, the most passive Corsi Block Task requiring the repetition of a sequence of spatial locations, in the slightly more controlled backwards version and in a more active selective task. Experiment 2 tested the extent to which a more active verbal working memory is impaired in children with FLLD. Children identified with FLLD were administered a low-control verbal working memory task, the nonword repetition task, and an active verbal working memory task, the listening span test.

2. Experiment 1

2.1. Participants

A group of 18 seventh and eighth grade Italian students (13 males and 5 females) with FLLD participated in this experiment. They had good intelligence but a specific problem in foreign language learning (English). For some children, there were records of earlier language and reading difficulties, but at the time of testing, these difficulties appeared less critical than foreign language difficulties. Children with FLLD were compared with a control group of 24 Italian students (12 males and 12 females) with good foreign language learning, and similar age, education, and general intelligence. The groups were selected from a population of 380 students, 177 (98 females and 79 males) seventh graders (mean age 12.39) and 203 (93 females and 110 males) eighth graders (mean age 13.38). At the initial screening, all 380 children were proposed an English Learning Task (ELT) collectively (Ungaro, 1999), including an English dictation and 19 multiple-choice questions on English grammar and syntactic rules based on expected school achievement according to their grade. To check general intelligence, the children were

also proposed with two subtests, the spatial and reasoning tests, from the Primary Mental Aptitude Battery (Thurstone & Thurstone, 1963). The criteria of selection were as follows:

FLLD group: a score lower than the 20th percentile in the ELT, but a score equal to or higher than the 50th percentile in the PMA spatial and reasoning tests;

Control Group: a score equal to or higher than the 50th percentile in the ELT and the PMA spatial and reasoning tests.

Foreign language teachers completed a questionnaire to obtain their personal evaluation of each student's foreign language proficiency on a scale from 1 (*no difficulty*) to 4 (*great difficulty*). Groups differed significantly in their teachers' evaluation, $t(1,40)=4.90$, $P<.001$ (FLLD group: $M=2.72$ S.D. = 0.96, control group: $M=1.50$ S.D. = 0.66).

The mean scores and mean age of the groups are shown in Table 1.

2.2. Material and procedure

The following memory tasks were administered individually to each child:

Forward and backward digit span tests (Wechsler, 1987). A forward and a backward digit span test were administered individually in a quiet room. The materials and procedures adopted were from the Wechsler Intelligence Scale for Children (1987). Each participant was required to repeat a series of digits immediately after the presentation in sequence, and in forward (forward digit span) or reverse (backward digit span) order. After two consecutive errors, the task was interrupted. The child's span was defined by the highest number of digits correctly repeated.

Corsi Block Tests (Corsi, 1972; Milner, 1971). The participants were presented a small board on which some cubes were placed. The cubes were numbered on the examiner's side (who could therefore present the sequence of locations in the required order and check the correctness of the response). During the presentation phase, the examiner progressively indicated positions and then asked the participant to repeat the sequence. The various positions were presented as a sequence, an ideal pathway. The backwards version of the Corsi test was also proposed. Participants were asked to indicate the positions starting from the last, going back to the first.

Selective VSWM test (Cornoldi & Mammarella, 2003). This task is a recent attempt to provide a visuospatial sibling of the listening span task of Daneman and Carpenter (1980). (This task was administered in the context of another study that involved the children of this study as well as other children). The participants were presented successively with two or three or four sequences of three positions on a 4×4 matrix of cubes on a small board. They were required to both decide whether each

Table 1

Mean ages and mean scores (and standard deviations) in the English learning tasks and PMA subtests for the FLLD and control groups

	FLLD group	Control group
Age (in months)	154.33 (6.57)	153.62 (6.96)
English learning tasks (total score)	30.66 (4.33)	45.99 (3.04)
Spatial test (PMA)	25.66 (8.23)	25.00 (7.51)
Reasoning test (PMA)	14.72 (2.08)	15.21 (3.12)

sequence of three positions is aligned and, after having completed the task for the whole sequences, to indicate on the matrix the last position of each sequence in the order of presentation.

Performance was defined by the number of final positions of each matrix (out of a maximum of 54) correctly recalled in the original order. Errors were also computed: sequential (incorrect order of target locations), intrusion (recall of locations which were pointed to in the same series of matrices, but were not target ones), and inventions (recall of positions which were not indicated).

2.3. Results

The means and standard deviations of memory performance for the two groups are displayed in Table 2.

A MANOVA was conducted on the memory scores as dependent variables and the group (FLLD vs. control) as the independent variable. The multivariate main effect of group approached significance, $F(8,33) = 2.20$, $P = .054$, $\eta^2 = .35$. However, from Table 2, it can be seen that groups had similar scores in most of the indices. In fact, from the analysis, it emerged that the groups significantly differed only in the forward digit span test, in which the FLLD group showed a poorer performance, $F(1,40) = 5.01$, $P < .05$, $\eta^2 = .11$, and in the number of sequential errors at the VSWM test, $F(1,40) = 6.48$, $P < .05$, $\eta^2 = .14$, in which, surprisingly, the FLLD group had fewer sequential errors than the control group had. In the Corsi Block Task, groups recalled a similar number of correct final positions, $F(1,40) < 1$. In the VSWM task, the groups recalled a similar number of correct final positions, $F(1,40) < 1$, and made a low and comparable number of intrusion and invention errors, $F(1,40) < 1$. The complete list of statistical indices is reported in Table 2.

2.4. Discussion

In agreement with our hypotheses, students with FLLD appeared to have a specific problem in working memory related to the nature of the material and processes, rather than a general difficulty and a broad memory problem. In fact, groups performed similarly in the more passive visuospatial memory tasks (Corsi tasks) requiring them to remember positions in sequential or reversed order. Furthermore, the groups were not different when a higher control was required in VSWM, as their performance with selective tasks on a matrix were substantially similar for recall profile and errors. However, students with FLLD showed a working memory problem with a memory task using first language items (digits). This evidence shows the relationship between native and foreign language, thus supporting the hypothesis

Table 2

Mean scores (and standard deviations) in the memory tasks of the FLLD and control groups

	FLLD group	Control group	<i>F</i> value	η^2
Forward digit span test	5.50 (1.29)	6.29 (0.99)	5.01	.11
Backward digit span test	4.00 (1.50)	4.50 (1.25)	1.39	.03
Corsi block forward	5.78 (1.17)	6.08 (0.93)	0.89	.02
Corsi block backward	5.44 (1.15)	5.21 (0.93)	0.54	.01
VSWM, correct recall	45.94 (5.38)	46.88 (3.97)	0.42	.01
VSWM, inventions	5.33 (4.93)	4.79 (3.23)	0.19	.01
VSWM, intrusions	2.72 (2.70)	2.50 (2.64)	0.07	.00
VSWM, sequential errors	1.28 (1.18)	2.79 (2.30)	6.48	.14

that tasks involving first-language materials play a critical role in the acquisition of FL and, therefore, in FLLD (LCDH, Ganschow et al., 1998). In particular, this result specifies the previously mentioned hypothesis suggesting that native-language verbal working memory is significantly related to foreign-language learning.

These results suggest that the memory problems of students with FLLD are circumscribed to the verbal modality passive processes. In fact, the only significant difference between the groups concerned the forward digit span. The fact that we found a smaller nonsignificant difference between groups in the backward digit span test seems to suggest that the verbal working memory deficit of children with FLLD involves active verbal working memory only marginally. In fact, the backward digit span task requires reversing the order of presentation and is considered a more controlled, hence, less passive, working memory measure. This result is in contrast with studies that have also shown an impairment in the active verbal working memory of children with FLLD. To clarify this issue, a second study was run.

3. Experiment 2

Two groups, a FLLD and a control group, were selected and compared in two verbal working memory tasks. Memory tasks were administered to clarify whether the memory problems of the children with FLLD are related to phonological storage only, or also emerge when storage and processing are required simultaneously. In this research, the children's school only allowed us to carry out a short session involving two tasks. The tasks were distinguished according to the nature of the memory request, a more passive maintenance task and a more active working memory task. To have a purer measure of the phonological store capacity than the digit span, a nonword repetition task was proposed, independent of long-term lexical knowledge but able to offer information about the influence on the child's memory of the likeness between the nonword and the real native language words (Gathercole & Baddeley, 1989). To measure active verbal working memory, the Italian version of the Daneman and Carpenter (1980) listening span test, widely used and considered as a measure of active verbal working memory, was proposed.

3.1. Participants

A group of 13 Italian students (9 males and 4 females) with FLLD, with normal intelligence but a specific problem in foreign language learning (English), participated in this experiment. They were compared with a control group of 17 Italian students (8 males and 9 females) with good foreign language learning and similar age, education, and level of general intelligence. They were selected from a population of 177 students, 89 (51 females and 38 males) seventh graders (mean age 12.38) and 88 (45 females and 43 males) eighth graders (mean age 14.42). They were administered the previously described ELT, collectively, and a visuospatial subtest from the Primary Mental Aptitude Battery (Thurstone & Thurstone, 1963). The criteria of selection were similar with that adopted in Experiment 1 (with slightly more lenient criteria for the group with FLLD than in the preceding Experiment due to the smaller size of the original sample):

FLLD group: a score lower than the 25th percentile of the total score for the ELT but a score equal to or higher than the 50th percentile for the PMA visuospatial task;

Control group: a score equal to or higher than the 50th percentile for the ELT and the PMA visuospatial task.

The groups' mean scores and mean ages are shown in [Table 3](#).

3.2. Material and procedure

Two memory tasks were proposed individually:

Nonword repetition task (Ciccarelli, 1998). The test comprised 32 nonwords, 8 for each of the following lengths: 3, 4, 5, and 6 syllables. For each length, 4 nonwords were very similar with Italian words [high word-likeness, (WL)] and 4 were only slightly similar (low WL). Inasmuch as the stimuli were presented orally, similarity was evaluated on a phonological basis, the number of words obtained substituting a single phoneme without changing its position in the string. Due to the typical features of Italian words, where it is easier for short words than for longer words to obtain new words from the substitution of a letter, the criteria for high and low WL slightly varied depending on nonword length:

3-syllable nonwords: Low WL, number of words ≤ 1 ; High WL, number of words ≥ 2

4-syllable nonwords: Low WL, number of words = 0; High WL, number of words ≥ 1

5-syllable nonwords: Low WL, number of words = 0; High WL, number of words = 1

6-syllable nonwords: Low WL, number of words = 0; High WL, number of words = 1

The grouping of vowels and consonants was counterbalanced between different-length words. For all words, the stress was placed on the penultimate syllable according to the most frequent Italian stressing (Dollagher, Biber, & Campbell, 1993). Nonwords were orally presented at a rate of one item per second in pairs of the same length and WL in two lists. Each list started with the shortest series and gradually increased in length. The participants were instructed to repeat aloud each sequence of two nonwords in sequential order immediately after its presentation. Their performance was recorded and a score of 1 was assigned to each nonword correctly repeated.

Listening span test (De Beni et al., 1998). An Italian version of the listening span task of Daneman and Carpenter (1980) was presented. The test required the participants to semantically analyse a sequence of sentences presented orally to judge their truth and, at the same time, to memorize the last word in each sentence. Eighty sentences were presented in four different sequences of 2, 3, 4, 5, or 6 sentences each.

Table 3

Mean ages and mean scores (and standard deviations) in the English tasks and PMA subtests for the FLLD and control groups (Experiment 2)

	FLLD group	Control group
Age (in months)	154.33 (6.57)	153.62 (6.96)
English learning tasks (total score)	22.26 (4.42)	41.12 (4.08)
Spatial test (PMA)	22.38 (9.61)	25.41 (16.43)

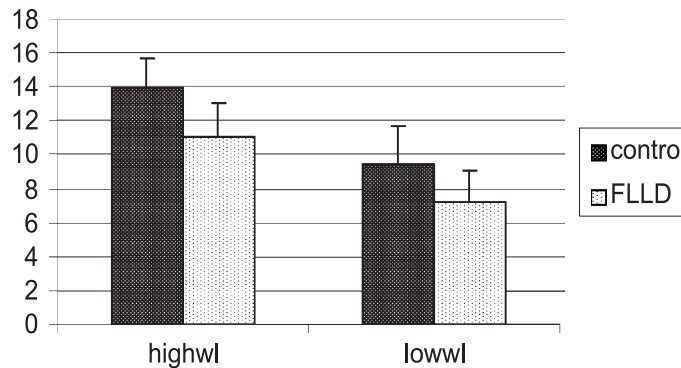


Fig. 1. Mean scores in nonword repetition tasks with high and low WL stimuli for the FLLD and control groups.

In scoring this test, we considered the following indices (see De Beni et al., 1998):

1. *decision errors*—the total number of errors in a semantic analysis of sentences;
2. *number of recalled words*—the total number of final words recalled during the whole test;
3. *intrusions errors*—the total number of words incorrectly recalled, but which appeared in the sentences presented; and
4. *sequential errors*—the total number of target words recalled in an incorrect order.

3.3. Results

The means and standard deviations for the nonword repetition task are shown in Fig. 1. A 2×2 ANOVA was conducted on correct repetition scores, with group as a between-subject factor with two levels (FLLD vs. control group) and WL as a within-subject factor with two levels (high vs. low). A main effect of WL was found, $F(1,28) = 115.89$, $MSE = 2.27$, $P < .001$, $\eta^2 = .81$, as high WL advantaged nonword repetition. Furthermore, a main effect of group was found, $F(1,28) = 18.03$, $MSE = 5.36$, $P < .001$, $\eta^2 = .39$, due to a lower performance by the FLLD group. No interaction was found between group and WL factors, $F < 1$. As can be seen in Fig. 1, FLLD participants were able to correctly repeat a mean number of nonwords lower than the control group did, independently of WL.

The means and standard deviations for the listening span test indices are reported in Table 4. The participants were able to follow instructions and shift from the task of judging sentence truth to the recall task. In fact, errors in sentence judgement were very low although, significantly

Table 4

Mean scores (and standard deviations) in the listening span test for the FLLD and control groups (Experiment 2)

	FLLD group	Control group	<i>F</i> value	η^2
Words recalled	50.54 (8.46)	58.82 (8.85)	5.08	.16
Intrusion errors	1.31 (1.49)	.56 (1.09)	2.41	.08
Sequential errors	1.69 (1.70)	1.06 (1.09)	1.43	.05

different between groups, $t(1,28)=4.29$, $P<.01$ (FLLD group: $M=1.23$, $S.D.=.73$; control group: $M=0.29$, $S.D.=.47$). Concerning the listening span test, a MANOVA was performed with the three memory indices as dependent variables and groups as the independent variable. The multivariate analysis showed that the main effect of group was not significant, $F(3,25)=2.48$, $P=.09$, $\eta^2=.23$, but that the groups differed significantly in final recall, $F(1,27)=5.08$, $P<.05$, $\eta^2=.16$. As can be seen in Table 4, the FLLD group had a poorer memory performance. However, although FLLD participants performed generally lower in the task, they did not show a significantly higher number of errors than the control participants did, either for intrusions or sequential errors that are typical of populations with low working memory performance (De Beni et al., 1998). The complete list of statistical indices is reported in Table 4. The same outcome emerged with the use of separate Student's t test comparisons between groups for each memory index, as the groups significantly differed only in final recall, $t(1,28)=2.58$, $P<.01$.

To test the hypothesis that the FLLD participants' lower working memory performance in the listening span test could be simply a side effect of a poor phonological maintenance in working memory, an analysis of covariance was conducted comparing the groups for working memory recall, with their nonword repetition overall score as a covariate. Results showed that the significant difference between groups disappears if a measure of phonological maintenance is covariated, $F(1,27)<.1$ $MSE=56.51$, $P=n.s$, η^2 = close to zero.

3.4. Discussion

The results of the second experiment confirm previous evidence of a relationship between FLLD and verbal working memory. Furthermore, a distinction between a less and a more controlled verbal working memory task was made by presenting two different tasks: a passive nonword repetition task and the listening span test, a complex double task. FLLD participants performed worse in both tasks. They recalled, on average, about five nonwords less than the control group did, and about eight final words less. WL affected the performance of both groups to a similar extent, suggesting that FLLD children's difficulty with the task is independent of the linguistic properties of the material. A similar effect was obtained by Service and Tujulin (2002) comparing dyslexic and control children on a list-recall task.

The fact that the FLLD group had difficulty in both tasks could be interpreted as evidence of a verbal working memory problem involving both the phonological-articulatory loop and the component measured by the listening span test, that is, the central executive, according to the model of Baddeley (1990), and the active components of verbal memory, according to the model of Cornoldi and Vecchi (2003). However, this result should be in contrast with the results of the preceding Experiment showing that both active verbal working memory, measured by the backwards digit span, and the more controlled VSWM processes, measured by the selective VSWM task, are not impaired in the FLLD group. The covariance analysis partially changed the picture and suggested that the FLLD group's difficulty with the listening span test could be due, at least in part, to working memory phonological problems. This result supports the evidence obtained in Experiment 1 with forward digit span test, as nonword repetition could be considered as a measure of the phonological store capacity, though purer than the digit span, (Gathercole & Baddeley, 1989). Furthermore, these results are coherent with evidence obtained by Gathercole and Baddeley (1989) with native-language learning, and by Service (1992), Cheung (1996) and Service et al. (2002) with second-language learning.

4. General discussion

The aim of the present study was to investigate the relationship between foreign language learning and working memory. Several studies have addressed this topic but with different, and not always converging, research paradigms and measures. The approach adopted in the present study is based on a design often applied in individual difference research, in which matched groups, who differ in a critical learning variable, are compared. In the present study, the FLLD group was selected with a composite test that mirrors scholastic learning requirements in Italian schools, measuring different, but interrelated, aspects of their knowledge of English, such as phonics, vocabulary, and grammar. This selection largely overlaps that used in clinical–educational studies (see, e.g., Ganschow & Sparks, 1986, 1995) and appears to be the best choice for this preliminary phase in the study of FLLD. However, it obviously requires further controls based either on more specific (e.g., only vocabulary) or more general (e.g., with a greater focus on semantic aspects and associated learning disabilities) selection criteria.

The results of the present study show that verbal working memory is specifically poor in the FLLD group, as measured with both a forward digit span (Experiment 1) and a nonword repetition task (Experiment 2). These results are coherent with evidence showing a relationship between foreign language vocabulary knowledge and phonological working memory, with results for first-language learning difficulty in foreign learning disability. Furthermore, the results of the present study extend previous results in two principal ways. First, they show that foreign language learning is related not only to foreign language phonological working memory problems (Cheung, 1996; Service, 1992) but also to native-language phonological working memory problems. Second, they integrate the evidence for native-language phonological problems, with results showing that students with a foreign language difficulty have related problems in their native language (see, e.g., Ganschow et al., 1998). The fact that two different groups of FLLD children failed in two different measures of phonological working memory offers evidence of the generality and consistency of the effect. However, as the phonological working memory involves different processes and can be tested with various types of measures (Swanson & Siegel, 2001), future, more systematic research is needed, which administers to groups of FLLD children large batteries of working memory tasks.

Until now, no study has examined whether a working memory difficulty in FLLD children is specific, or whether it involves all aspects of working memory, including VSWM. Our results clearly show that children with specific FLLD do not have specific problems in VSWM. The two groups were not significantly different in any of the VSWM measures, except one (order errors), where the FLLD group was even better. The result concerning spatial order errors not only strongly supports the assumption that FLLD do not have VSWM problems, but it also shows that linguistic difficulties do not necessarily imply general problems in processing sequential information. It must also be noted that our selection criteria, which includes children with specific problems in FL but matched for general cognitive competencies, contributed to producing such clear-cut results.

A further aim of the present study was to examine to what extent more controlled verbal working memory processes are involved. Therefore, in Experiment 2, two measures were proposed: a less controlled phonological working memory test (nonword repetition task) and a more controlled working memory test (listening span test). It must be noted that previous studies (Geva & Ryan, 1993; Harrington & Sawyer, 1992; Miyake & Friedman, 1998) found a relationship between controlled verbal memory and

foreign language learning. According to the working memory model proposed by Baddeley (1990), the listening span test should be a measure of the central executive; therefore, children with FLLD should also have an impairment in the central executive. This prediction conflicts with our results with the verbal working memory tasks and with the observation that our children with FLLD do not have any problem in the selective VSWM, which requires a type of control similar with that required by the listening span task. We think that our results are more compatible with the continuum model of working memory (Cornoldi & Vecchi, 2000, 2003), which assumes that the working memory measures should be distinguished according to the type of content (verbal vs. visuospatial) and should be located at different points along the continuum of control activity. According to the latter continuum concerning the verbal areas of working memory, the listening span test and the backward digit span test are closer, and the nonword repetition and the forward digit span test are farther from the extreme pole of highly controlled memory processes. The continuity between points also makes it possible to anticipate results that do not necessarily reflect an all-or-nothing effect. On the basis of a hypothesis of a specific failure of FLLD children in tasks concerning the low control pole of the verbal continuum (phonological memory and forwards digit span), the continuum model predicts a decreased impairment in correspondence with increases along the verbal continuum. This prediction is substantially coherent with our results showing a significant difference between the groups in the two low-control passive verbal working memory tasks and some less evident effects for the more controlled tasks. In fact, we found a slight, but not significant, difference in the backwards digit span and an ambiguous effect in the other active verbal task, as the difference in the listening span test disappeared when the phonological working memory scores were partialled out. These results are not so easily explained by the model of Baddeley, which suggests a fractionation between a peripheral phonological loop and a central executive component, unless it is assumed that both components (and not only the central executive) are involved in the listening span task.

In conclusion, the present research offers further evidence of an impairment of the passive components of verbal working memory in FLLD children, typically associated with the phonological subsystem of working memory. Furthermore, it is clearly shown that VSWM is not involved. Finally, evidence concerning the active components of verbal working memory is less clear, suggesting that some impairment could be present, but less severe than for passive components. Altogether, these data show the importance of using articulated models of working memory for examining working memory deficits in specific populations.

Acknowledgements

We sincerely thank Chiara Braga, Patrizia Caricato and Stefania Ungaro for their assistance in preparing material, testing children and scoring test performances. We also wish to thank Elisabet Service for her useful comments on a preliminary version of the manuscript.

References

- Baddeley, A. D. (1986). *Working memory*. New York: Oxford University Press.
- Baddeley, A. D. (1990). *Human memory, theory and practice*. Hove, UK: Lawrence Erlbaum Associates, Publishers.
- Baddeley, A. D., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review*, 105, 158–173.

- Baddeley, A. D., & Wilson, B. A. (1993). A developmental deficit in short-term phonological memory: Implications for language and reading. *Memory*, *1*, 65–78.
- Carroll, J. B. (1962). The prediction of success in intensive foreign language training. In R. Glaser (Ed.), *Training research and education* (pp. 87–136). Pittsburgh, PA: University of Pittsburgh Press.
- Carroll, J. B. (1981). Twenty-five years of research on foreign language aptitude. In K. C. Diller (Ed.), *Individual differences and universals in language learning aptitude* (pp. 83–117). Rowley, MA: Newbury House.
- Carroll, J. B., & Sapon, S. M. (1959). *Modern language aptitude test: MLAT*. New York: The Psychological.
- Cheung, H. (1996). Nonword span as a unique predictor of second-language vocabulary learning. *Developmental Psychology*, *5*, 867–873.
- Ciccarelli, L. (1998). *Comprensione del linguaggio, processi di elaborazione e memoria di lavoro: Uno studio in eta prescolare (Language comprehension, processing and working memory: A study with preschoolers)*. Unpublished dissertation thesis. University of Padova, Italy.
- Cornoldi, C., Carreti, B., & De Beni, R. (2001). How the pattern of deficits in groups of learning-disabled individuals helps to understand the organization of working memory. *Issues in Education*, *7*, 71–78.
- Cornoldi, C., & Mammarella, N. (2003). *Visuo-spatial working memory and interference*. Manuscript submitted for publication.
- Cornoldi, C., & Oakhill, J. (Eds.) (1996). *Reading comprehension difficulties: Processes and intervention* (pp. 113–136). Mahwah, NJ: Erlbaum.
- Cornoldi, C., & Vecchi, T. E. (2000). Mental imagery in blind people: The role of passive and active visuospatial processes. In M. A. Heller (Ed.), *Touch, representation, and blindness* (pp. 143–181). Oxford, UK: Oxford University Press.
- Cornoldi, C., & Vecchi, T. E. (2003). *Visuo-spatial working memory and individual differences*. Hove, UK: Psychology Press.
- Corsi, P.M. (1972). *Human memory and the medial temporal region of the brain*. Unpublished doctoral dissertation, McGill University, Montreal.
- Cummins, J. (1991). Interdependence of first- and second-language proficiency in bilingual children. In E. Bialystok (Ed.), *Language processing in bilingual children* (pp. 70–89). New York: Cambridge University Press.
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450–466.
- De Beni, R., Palladino, P., Pazzaglia, F., & Cornoldi, C. (1998). Increases in intrusion errors and working memory deficit of poor comprehenders. *The Quarterly Journal of Experimental Psychology*, *51A*, 305–320.
- Diklage, K. (1971). Inability to learn a foreign language. In G. Blaine, & C. McArthur (Eds.), *Emotional problems of the student* (pp. 185–206). New York: Appleton-Century-Crofts.
- Dollaghan, C., Biber, M., & Campbell, T. (1993). Constituent syllable effects in a nonsense-word repetition task. *Journal of Speech and Hearing Research*, *36*, 1051–1054.
- Ganschow, L., & Sparks, R. L. (1986). Learning disabilities and foreign language difficulties: Deficit in listening skills? *Journal of Reading, Writing, and Learning Disabilities International*, *2*, 305–319.
- Ganschow, L., & Sparks, R. L. (1995). Effects of direct instruction in Spanish phonology on the native language skill and foreign language aptitude of at-risk foreign language learners. *Journal of Learning Disabilities*, *28*, 107–120.
- Ganschow, L., Sparks, R. L., & Javorsky, J. (1998). Foreign language learning difficulties: An historical perspective. *Journal of Learning Disabilities*, *31*, 248–258.
- Gathercole, S. E., & Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. *Journal of Memory and Language*, *28*, 200–213.
- Geva, E., & Ryan, E. B. (1993). Linguistic and cognitive correlates of academic skills in first and second languages. *Language Learning*, *43*, 5–42.
- Harrington, M., & Sawyer, M. (1992). L2 working memory capacity and L2 reading skill. *Studies in Second Language Acquisition*, *14*, 25–38.
- Hulstijn, J. H., & Bossers, B. (1992). Individual differences in L2 proficiency as a function of L1 proficiency. *European Journal of Cognitive Psychology*, *4*, 341–353.
- Meschyan, G., & Hernandez, A. (2002). Is native-language decoding skill related to second-language learning? *Journal of Educational Psychology*, *94*, 14–22.
- Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin*, *27*, 272–277.
- Miyake, A., & Friedman, N. P. (1998). Individual differences in second language proficiency: Working memory as language

- aptitude. In A. F. Healy, & L. E. Bourne (Eds.), *Foreign language learning* (pp. 339–364). London: Lawrence Erlbaum Associates.
- Oakhill, J. V., Yuill, N. M., & Parkin, A. (1986). On the nature of the difference between skilled and less skilled comprehenders. *Journal of Research in Reading*, 9, 80–91.
- Palladino, P. (2003). Le difficoltà di apprendimento della lingua straniera. (Foreign language learning disabilities). *Psicologia Clinica Dello Sviluppo*, 7, 161–184.
- Papagno, C., Valentine, T., & Baddeley, A. D. (1991). Phonological short-term memory and foreign-language vocabulary learning. *Journal of Memory and Language*, 30(3), 331–347.
- Pimsleur, P., Stockwell, R. P., & Comrey, A. L. (1962). Foreign language learning ability. *Journal of Educational Psychology*, 1, 15–26.
- Service, E. (1992). Phonology, working memory, and foreign language learning. *Quarterly Journal of Experimental Psychology*, 45(1), 21–50.
- Service, E., & Kohonen, V. (1995). Is the relation between phonological memory and foreign language learning accounted for by vocabulary acquisition? *Applied Psycholinguistics*, 16, 155–172.
- Service, E., Simola, M., Metsaenheimo, O., & Maury, S. (2002). Bilingual working memory span is affected by language skill. *European Journal of Cognitive Psychology*, 14, 383–407.
- Service, E., & Tujulin, A. M. (2002). Recall of morphologically complex forms is affected by memory task but not dyslexia. *Brain and Language*, 81, 42–54.
- Sparks, R. L., & Ganschow, L. (1993). The impact of native language learning problems on foreign language learning: Case study illustrations of the linguistic coding deficit hypothesis. *Modern Language Journal*, 77, 58–74.
- Sparks, R. L., Ganschow, L., Javorsky, J., Pohlman, J., & Patton, J. (1992). Test comparisons among students identified as high-risk, low-risk, and learning disabled in high school foreign language courses. *Modern Language Journal*, 76, 142–159.
- Swanson, H. L., & Siegel, L. (2001). Learning disabilities as a working memory deficit. *Issues in Education*, 7, 1–48.
- Thorn, A. S. C., & Gathercole, S. E. (1999). Language-specific knowledge and short-term memory in bilingual and non-bilingual children. *The Quarterly Journal of Experimental Psychology*, 52A, 303–324.
- Thurstone, L. L., & Thurstone, T. G. (1963, Italian Edition 1981). *PMA, Batteria delle attitudini mentali primarie (PMA, Test of primary Mental Abilities)* (pp. 11–17). Firenze: Organizzazioni Speciali.
- Ungaro, S. (1999). *Difficoltà di apprendimento della lingua straniera (Foreign language learning difficulties)*. Unpublished master's thesis. University of Padova, Padova, Italy.
- Wechsler, D. (1987). *Manual for Wechsler Memory Scale-Revised*. New York: The Psychological Corporation.