

## **FL learning could contribute to the enhancement of cognitive functions in MCI older adults**

Evangelia Tigka<sup>a</sup>, Dimitrios Kazis<sup>b</sup>, Magda Tsolaki<sup>c</sup>, Panagiotis Bamidis<sup>d</sup>, Michail Papadimitriou<sup>e</sup>,  
Eleni Kassapi<sup>f</sup>

<sup>a</sup> Dept. of Medicine, Aristotle University of Thessaloniki, GR-54124, Greece

<sup>b</sup> 3<sup>rd</sup> Clinic of Neurology, “G. Papanikolaou” University General Hospital, GR-57010, Thessaloniki, Greece

<sup>c</sup> 1<sup>st</sup> Clinic of Neurology, AHEPA University General Hospital, GR-54621, Thessaloniki, Greece

<sup>d</sup> Medical Physics Laboratory, Dept. of Medicine, Aristotle University of Thessaloniki, GR-54124, Greece

<sup>e</sup> Primary School of Domokos, Fthiotida, GR- 35010, Greece

<sup>f</sup> Dept. of Italian Language and Literature, Aristotle University of Thessaloniki, GR-54124, Greece

**RUNNING TITLE:** FL learning contributes to the enhancement of MCI cognitive functions

**CORRESPONDING AUTHOR:**

Evangelia Tigka - Dept. of Medicine, Aristotle University of Thessaloniki, GR-54124, Greece

Telephone number: +30-6946-891407, Email: [e\\_tigka@yahoo.co.uk](mailto:e_tigka@yahoo.co.uk)

## **Abstract**

The purpose of the current research endeavour was to evaluate if the learning of English as a Foreign Language (EFL) could constitute an effective non-pharmacological intervention for older adults diagnosed with Mild Cognitive Impairment (MCI). Specifically, the focus was on the assessment of the impact of EFL learning on a variety of cognitive and psychological functions. To this aim, a total sample of 241 Greek older adults was recruited from the day care units for patients with dementia of the Greek Association of Alzheimer’s Disease and Related Disorders, in Thessaloniki, Greece. An experimental research design was adopted and two groups were formulated. The intervention group comprised 98 individuals who attended an 18-month EFL course and either had no prior knowledge of English or had attended some lessons decades before. The control group included 143 individuals who did not attend any cognitive stimulation programme within the premises of the day care units. A battery of neuropsychological tests, assessing general cognitive functioning, attention, verbal learning, memory, visuo-perceptual ability, executive function, and depression, was administered by the psychologists of the day care units to all of the participants. Neuropsychological data for the intervention group were collected at three time-points (i.e. pre-, mid-, and post-intervention), while neuropsychological data for the control group were collected at two time-points (i.e. pre- and post-research). Hypothesis testing revealed statistically significant differences both within the intervention group and between the intervention and control group across the evaluation time-points.

**Keywords:** language, learning, aged, dementia, memory

## **INTRODUCTION**

In today's multi-cultural societies, foreign language (FL) learning or second language acquisition (SLA), i.e. the ability to master a linguistic code other than one's mother tongue, is a common reality and a process easily accessible and highly versatile. Nonetheless, there is a large population by and large not engaged in SLA: older adults and more specifically older adults diagnosed with Mild Cognitive Impairment (MCI). MCI has scientifically been designated as an intermediate state of the cognitive function between normal aging and dementia [1]. Designing experimental procedures tailored to meet the cognitive needs of this – research-wise – atypical population is rather challenging, considering the prevalence of dementias and the globally augmenting number of older adults. In this respect, FL learning may successfully complement other non-pharmacological interventions which have been reported in the literature [2]. Additionally, through SLA we are in a position to control improvement in the mother tongue, regarding the FL as the experimental vehicle to reach this goal. Finally, the mastering of a natural language constitutes an undoubtedly holistic approach to the brain since it requires the engagement of multiple neural systems, cognitive skills, and learning strategies.

Which is the appropriate target language for an MCI older adult? Are there “easy” or “difficult” languages in general? The answer to both questions is proportional to the learner's mother tongue. The issue of language relatedness, namely the linguistic proximity between the mother tongue and the target language, unavoidably smoothens or hinders FL learning. The present study has been designed to investigate the following research questions: may the learning of a typologically unrelated to the mother tongue FL prove beneficial to MCI learners? Is there a possibility for potential positive effects to be transferred over to further cognitive functions beyond language? We, thus, implemented an 18-month course of English as an FL (EFL) and invited Greek older adults diagnosed with MCI to join the classes. The participants' EFL competence ranged between the A0 and A1 levels, according to the Common European Framework of Reference for Languages (CEFR) [3].

The languages involved in this research, i.e. Greek and English, were both alphabetic, the decoding of which heavily hinges on good phonological skills. However, the mapping between phonological and orthographic units (i.e. sounds to letters) differs dramatically between the two linguistic codes: Greek is very transparent in the grapheme-to-phoneme (letter or combination of letters-to-single sound) direction [4], while English is not, because there are many instances of one-to-many grapheme-phoneme mappings as well as one-to-

many phoneme-grapheme mappings [5, 6]. There are numberless examples which depict the striking difference between the two languages in this respect, such as the following: *μάτι* [/'matɪ/] vs *eye* [/'aɪ/]; *θαλαμηγός* [/θalamɪ'gɒs/] vs *yacht* [/'jɒt/]. Conversely, in the English words *thought*, *law*, *north*, *war*, and *awe*, the main vowel sound would be phonemically transcribed with the same symbol: /ɔ:/, meaning that the specific sound may have at least five orthographic variations. Evidently, the degree of orthographic transparency allows the speaker or the learner of an alphabetic language to make easily or not predictions about the pronunciation of novel linguistic units either in their mother tongue or in the target FL. Consequently, SLA is conditioned by the transparency of one's mother tongue.

Linguistic opacity has been encapsulated in the “Orthographic Depth Hypothesis” [5], according to which not only does the notion of transparency reflect the extent of consistent grapheme-phoneme correspondence but also the invariant grapheme-phoneme relationship. This theory has been complemented by the “Dual Route Cascaded Model” [7], which postulates that reading aloud is modulated by the simple or complex grapheme-phoneme conversion rules, i.e. language opacity. According to this model, in transparent languages, words are processed locally and serially from left to right, whereby graphemes are converted to phonemes via the non-lexical route. On the other hand, in opaque scripts, words are accessed in a global and parallel way, via the lexical-semantic route [8]. The varying degrees of linguistic opacity may induce changes in the reading strategies of bilingual readers, which has been confirmed in recent research [9]: apart from linguistic transparency, reading strategies are influenced by linguistic proficiency. Making an analogy between bilingualism and FL learning, we could suppose that native speakers of a transparent mother tongue would have to learn how to switch their reading strategy during the process of an opaque FL learning (serial reading → global reading). In this respect, the transfer effects of FL cognitive training might be comparable to recent findings of neuroplastic changes noticed in bilingual brain function and structure [10]. Evidently, training an older brain through this highly demanding process one would expect the engagement of vast neural networks, hence long-term positive effects.

Pharmaceutical attempts have not been able to decelerate the progression of MCI to dementia, which incited various non-pharmacological interventions recently reported in the literature [11-14]. It is estimated that 10% of people with MCI will be diagnosed with dementia within a year, although the progression is likely to accelerate [1]. Non-pharmacological interventions, mainly involving cognitive stimulation activities, have been shown to treat behavioural symptoms in dementia [15]. Additionally, it has been empirically

demonstrated that the combination of mental and physical exercise works for the benefit of the overall mental status [16].

As regards training the senior brain through another language, a vast body of scientific research concerning dementia has evolved around early, life-long or late bilingualism. Bilingualism has been described as the *native-like control of two languages* [17]; or *the property of an individual supposing the existence of two different language communities* [18]; or *the use of two languages* in everyday life [19]. It constitutes a linguistic experience which forces the brain to function in a way different than in monolinguals. Viewed through this prism, it has been hypothesised that bilingualism would be a protective cognitive shield against the onset of dementia [20-24] and MCI [25, 26]. Nonetheless, a recent critical overview of studies pivoting around bilingualism and its positive effects as regards dementia posited that a considerable body of data is inconsistent [27]. This inconsistency is due to methodological caveats and is accentuated by the unclear criteria of SLA which would suffice for a person to be called bilingual; age and manner of acquisition, simultaneity and proficiency in the second language, fluency, exposure, frequency of use, the possible concurrent knowledge of a third or a fourth language are variables which dramatically alter the scientific outcomes and interpretations [27].

On the other hand, FL learning is a more controllable situation than bilingualism, because it has specific traits as regards the course design and material, along with frequency and duration of lessons. Within the FL setting, the teacher decides on the quantitative and qualitative exposure of the learners to the FL, while the learners may use the FL for the purposes of the lesson but it is not necessarily the principal means of interaction in-class let alone in their everyday life [28]. SLA would, thus, qualify as a non-pharmacological intervention for MCI patients [29].

The principal objective of our research was to investigate whether systematic FL learning could activate different verbal behaviours, specifically verbal memory, in the mother tongue of Greek MCI seniors. A secondary objective was to evaluate any positive transfer effects of the learning process to other cognitive domains. A third objective was to decide whether it is worthwhile to include FL learning in the non-pharmacological intervention programs for older adults.

## **MATERIALS AND METHODS**

### **PARTICIPANTS**

We invited Greek MCI older adults to attend an 18-month EFL course (academic years 2016-2017 and 2017-2018), in an attempt to empower them not only cognitively but also socially and emotionally [30]. The participants either had no prior knowledge of English or had taken some lessons at a younger age that is 4 or more decades before. Their EFL competence ranged between the A0 and A1 levels, according to the CEFR [3]. The research was conducted at the day care units for patients with dementia of the Greek Association of Alzheimer's Disease and Related Disorders, in Thessaloniki, Greece. The experimental participants were recruited from a cohort of volunteers who had expressed their willingness to learn English – some in parallel with other non-linguistic intervention programs they attended at the day care units – and had agreed to participate in this research study.

A descriptive analysis was conducted on the demographic characteristics and neuropsychological diagnosis of the sample ( $N = 241$ ). Concerning the control group ( $n = 143$ ), most respondents were women (73%), who had completed 11 years of education on average ( $M = 11.17$ ,  $SD = 4.41$ ). Their mean age was 67 years at the onset of the research ( $M = 67.55$ ,  $SD = 8.65$ ) and 69 years at the end of the research ( $M = 68.56$ ,  $SD = 8.65$ ). Similarly, the intervention group ( $n = 98$ ) mostly comprised of women (89.8%), who had completed 12 years of education on average ( $M = 12.01$ ,  $SD = 3.78$ ). The mean age of the participants was 69 years prior to the intervention ( $M = 69.20$ ,  $SD = 6.18$ ), 70 years at the end of the first year of the intervention ( $M = 70.24$ ,  $SD = 6.25$ ), and 71 years at the end of the second year of the intervention ( $M = 70.72$ ,  $SD = 6.26$ ).

Information on the neuropsychological diagnosis of the sample was also gathered. Regarding the intervention group, it should be noted that prior to the intervention, five individuals were diagnosed as cognitively healthy, whereas one individual received a diagnosis only for depression and anxiety. In addition, the neurological diagnosis identified one more individual as cognitively healthy and another individual with a diagnosis only for depression. These participants were removed from subsequent analyses because cognitive impairment was considered a prerequisite of this study. In total, eight individuals were removed from the intervention group, which resulted in a group size of 90 participants.

All seniors signed informed consent forms to participate in this experimental research. The study was approved by the Bioethics Committee of the Medical Department, School of Health Sciences, Aristotle University of Thessaloniki, Greece (No. 389/16-10-2017).

### **COURSE DESIGN**

We opted for a multi-faceted course design concerning the teaching method and lesson hours per week, which yielded four experimental groups, namely 2-hours/week in-class, 1-h/w in-class, 2-h/w via Skype-and-in-class, and 1-h/w via Skype. The duration of the course was set at 56 hours a year for the 2-h/w groups and at 28 hours a year for the 1-h/w groups. The minimum required number of hours of attendance for any group was set at 14. This was based on previous research with young adults learning an FL which showed that there is a significant, measurable response of the brain to verbal stimuli of newly acquired FL vocabulary following only 14 hours of instruction [31]. The length of the lesson was set at 45 minutes. There were 6 participants in each in-class group, while there were 4 attending the Skype lessons, to avoid technical issues due to multiple simultaneous online connections.

### **COURSE IMPLEMENTATION**

During the first academic year, the participants were considered to be starting English afresh, so the reading, listening, and writing skills were cultivated through the phonics teaching method [32] accompanied by standard homework. The choice of phonics is an optimal way of acquainting an FL learner with the complex phonological system of English in the same way as English-speaking children do. Considering that the EFL target group comprised MCI older adults and that MCI often induces high levels of stress, a smooth beginning with an unknown or long-forgotten process was paramount. In addition to phonics, the participants were encouraged to build their communication skills through everyday dialogs; they suggested topics they wished to discuss (e.g. family, professions, hobbies and interests, leisure activities, meeting people), formulated them with their instructor, talked in pairs, and gradually started learning them by heart, simulating real-life events and occasions. Upon the completion of the course, the British Picture Vocabulary Scale III (BPVS3) [33] was administered for the assessment of English receptive vocabulary. It was particularly chosen because it is non-verbal, it has been standardised for English-speaking children ranging from 3 to 16 years of age, and it is suitable for those with English as an additional language. The BPVS3 verified that all of the participants were at the same language competence level (A0-A1).

During the second academic year, the content of the course evolved and the participants were instructed the language with an A1 level course book [34], which combined EFL with interesting topics. The language was always presented in context, either through lively dialogs or enjoyable texts. All four skills (reading, listening, speaking, and writing) were thoroughly practised both in class and at home. Upon the completion of the course, the

intervention group were evaluated on two “Reading and Writing” modules of sample exam papers for the Pre A1 and A1 levels of EFL [35]. The assessment showed that all of the participants had attained the Pre A1 level in EFL.

### **MEASURES**

A battery of neuropsychological tests, assessing general cognitive functioning, attention, verbal learning, memory, visuo-perceptual ability, executive function, and depression, was administered by the psychologists of the day care units to all of the participants. Neuropsychological data for the intervention group were collected at three time-points (i.e. pre-, mid-, and post-intervention), while neuropsychological data for the control group were collected at two time-points (i.e. pre- and post-research). The battery comprised the Greek versions of the following measures: the Mini-Mental State Examination (MMSE) [36], the Test of Everyday Attention (TEA), the Rey Auditory Verbal Learning Test (RAVLT) [37], the Rivermead Behavioural Memory Test (RBMT), the Rey-Osterrieth Complex Figure (ROCF), the Trail Making Test (TMT) [38], the Functional Cognitive Assessment Scale (FUCAS) [39], the Functional Rating Scale for Symptoms of Dementia (FRSSD), and the Geriatric Depression Scale (GDS) [40].

### **STATISTICAL ANALYSIS**

Assumption Testing: Field [41], and Tabachnick and Fidell [42] were advised for the evaluation of the assumptions. Considering that all group sizes were higher than 30 cases, normal Q-Q plots were advised to investigate the normality of distributions, because in large sample sizes Shapiro-Wilk’s test of normality may flag even minor deviations from normality as statistically significant. Also, boxplots were advised to examine the presence of outliers and the criteria adopted for their evaluation involved: (a)  $< 5\%$  cases  $> \pm 1.96$ ; (b)  $< 1\%$  cases  $> \pm 2.58$ ; (c) no more than 2 cases  $> \pm 3.29$ .

- *Pearson’s chi-square test of association:* Three Pearson’s chi-square tests of association were conducted to evaluate the relationship between: (a) gender and attrition rate; (b) group of allocation and attrition rate; (c) gender and group of allocation. The examination of cells showed that all cells had expected frequencies greater than five.
- *Independent samples t-test:* Normal Q-Q plots showed approximately normal distributions in age and education between individuals who participated at post-intervention time-point and those who did not. Furthermore, approximately normally



distributed data were identified between the control and the experimental group for baseline differences in age and education, as well as in neuropsychological functions. Nevertheless, boxplots showed an unacceptable number of outliers in education between individuals who participated at the post-intervention time-point and those who did not. Also, Levene's test indicated heterogeneous variances: (a) in age ( $p = .019$ ) and education ( $p = .009$ ) between individuals who participated at the post-intervention time-point and those who did not; (b) in baseline age ( $p = .006$ ) and education ( $p = .003$ ) between the control and the experimental group; (c) in baseline TMT ( $p = .001$ ), FRSSD ( $p = .030$ ), and GDS ( $p = .004$ ) between the control and the experimental group. The non-parametric Mann-Whitney  $U$  test was employed to control the presence of outliers in education between individuals who participated at the post-intervention time-point and those who did not, whereas adjusted degrees of freedom were used to remedy the violation of homogeneity of variance.

- *Repeated measures ANOVA*: Normal Q-Q plots revealed approximately normal distributions for all neuropsychological tests among the pre-, mid-, and post-intervention time-points for the intervention group. Nevertheless, boxplots showed a high number of outliers in FRSSD at the post-intervention time-point and the non-parametric Friedman test was conducted, instead, to account for the potential influence of outliers on the dependent variable.
- *Mixed ANOVA*: Normal Q-Q plots showed approximately normal distributions for all neuropsychological tests both for the control and the intervention group at the pre- and post-intervention time-points. However, boxplots displayed a high number of outliers in FRSSD intervention group at post-intervention time-point, as well as in GDS control group at pre-intervention time-point. Additionally, Levene's test indicated heterogeneity of variances in MMSE, RBMT, TMT, FUCAS, FRSSD, and GDS (all  $ps < .05$ ). Finally, the assumption of sphericity was not relevant to our research design, as the within-subjects factor had only two levels (pre- & post-intervention time-point).

In order to account for the outliers and violation of homogeneity of variances in the six neuropsychological variables, a difference score for pre- and post-intervention time-points was calculated for each variable. Pre-intervention scores were subtracted from post-intervention scores, so that positive differences indicate higher scores in post-intervention time-point and negative differences reflect lower scores in post-intervention time-point. After the calculation of difference scores, non-parametric Mann-Whitney  $U$  tests were employed to

examine if there was a statistically significant improvement in the neuropsychological tests from pre-intervention to post-intervention time-point between the control and the intervention group.

Attrition analysis: An attrition analysis was conducted to investigate if there was a statistically significant difference in the number of individuals who participated at the post-intervention time-point and those who did not between demographic groups, as well as between control and experimental group. Demographic variables included gender, age, and education. No significant differences in the number of individuals who participated at post-intervention time-point and those who did not were identified for all demographic groups. However, a Pearson's chi-square test of association indicated a statistically significant difference between control and experimental group in the number of individuals who participated at the post-intervention time-point and those who did not. According to descriptive statistics, all individuals (100%) in the control group participated at the post-intervention time-point, whereas 71% of the individuals in the intervention group did so. The inferential analysis indicated a statistically significant relationship of moderate strength between attrition rate and group of allocation,  $\chi^2(1, N = 233) = 46.50, p < .001$ , Cramer's  $V = 0.45$ .

## **RESULTS**

Demographic differences: A Pearson's chi-square test of association was performed to examine if there was a statistically significant difference in the number of men and women between control and experimental group. According to descriptive statistics, 73% of the control group were women, while 90% of the intervention group were women. Moreover, the proportion of control group who were women was significantly lower (56%) than the one of men (81%). In contrast, the proportion of female participants in the intervention group was significantly higher (44%) than the male ones (19%). The inferential analysis indicated a statistically significant relationship of small strength between group of allocation and gender,  $\chi^2(1, N = 233) = 10.08, p < .001$ , Cramer's  $V = 0.21$ .

Furthermore, two independent samples t-tests were employed to investigate if there was a statistically significant difference in age and years of education between the control and the experimental group. Results indicated a non-statistically significant difference in age between the control ( $M = 67.55, SD = 8.65$ ) and the experimental group ( $M = 69.43, SD = 6.32$ ),  $t(185.64) = -1.81, p = .072, d = -0.27$ . Also, a non-statistically significant difference in years

of education between the control ( $M = 11.17$ ,  $SD = 4.41$ ) and the experimental group ( $M = 11.83$ ,  $SD = 3.79$ ) was identified,  $t(209.93) = -1.21$ ,  $p = .23$ ,  $d = -0.17$ .

Neuropsychological differences: A series of independent samples t-tests was conducted to examine if there was a statistically significant difference in baseline neuropsychological functions between the control and the intervention group. Results revealed a statistically significant difference in 4 out of 9 baseline neuropsychological functions. Particularly, significant differences were identified in:

- a) MMSE between the control ( $n = 143$ ,  $M = 27.27$ ,  $SD = 1.94$ ) and the intervention group ( $n = 72$ ,  $M = 28.15$ ,  $SD = 1.67$ ),  $t(213) = -3.29$ ,  $p = .001$ ,  $d = -0.45$
- b) RAVLT between the control ( $n = 142$ ,  $M = 39.22$ ,  $SD = 10.78$ ) and the intervention group ( $n = 72$ ,  $M = 45.33$ ,  $SD = 10.48$ ),  $t(212) = -3.96$ ,  $p < .001$ ,  $d = -0.54$
- c) ROCF between the control ( $n = 142$ ,  $M = 29.94$ ,  $SD = 4.47$ ) and the intervention group ( $n = 72$ ,  $M = 32.03$ ,  $SD = 3.43$ ),  $t(212) = -3.48$ ,  $p = .001$ ,  $d = -0.47$
- d) FUCAS between the control ( $n = 143$ ,  $M = 44.26$ ,  $SD = 2.29$ ) and the intervention group ( $n = 72$ ,  $M = 43.40$ ,  $SD = 1.66$ ),  $t(213) = 2.83$ ,  $p = .005$ ,  $d = 0.39$

As regards the remaining five neuropsychological functions, results indicated non-statistically significant results in TEA, RBMT, TMT, FRSSD, and GDS between the control and the intervention group.

Hypothesis Testing – Hypothesis 1: A combination of one-way repeated measures ANOVAs and Friedman tests were conducted to explore if there were any statistically significant differences in the neuropsychological performance of the intervention group among the pre-, mid-, and post-intervention time-points.

A one-way repeated measures ANOVA suggested a statistically significant effect of time on the RAVLT performance,  $F(2, 78) = 9.37$ ,  $p < .001$ ,  $\eta_p^2 = .19$ . Descriptive statistics showed that the RAVLT performance improved from pre-intervention ( $M = 47.70$ ,  $SD = 11.10$ ) to mid-intervention ( $M = 51.28$ ,  $SD = 10.63$ ) to post-intervention time-point ( $M = 52.60$ ,  $SD = 11.42$ ). Bonferroni adjusted pairwise comparisons revealed a statistically significant difference in the RAVLT performance between: (a) the pre- and mid-intervention time-points,  $Mdf = -3.58$ , 95%CI [-6.41, -.74],  $SE = 1.13$ ,  $p = .009$ ; (b) the pre- and post-intervention time-points,  $Mdf = -4.90$ , 95%CI [-8.01, -1.79],  $SE = 1.24$ ,  $p = .001$ . The difference in the RAVLT performance between the mid- and post-intervention time-points was indicated as non-statistically significant,  $Mdf = -1.33$ , 95%CI [-4.16, 1.51],  $SE = 1.13$ ,  $p = .75$  (see Figure 1 for estimated marginal mean differences).

Furthermore, a Friedman test indicated a statistically significant effect of time on the FRSSD performance,  $\chi^2 (2, N = 38) = 7.78, p = .020$ . Descriptive statistics revealed that the FRSSD performance improved from pre-intervention ( $Mdn = 4.00$ ) to mid-intervention ( $M = 3.00$ ) to post-intervention time-point ( $M = 3.00$ ). Nevertheless, Bonferroni adjusted pairwise comparisons suggested non-statistically significant differences in the FRSSD performance between: (a) pre- and mid-intervention time-point,  $p = 1.00$ ; (b) mid- and post-intervention time-point,  $p = .13$ ; (c) pre- and post-intervention time-point,  $p = .15$ . It should be noted, though, that unadjusted pairwise comparisons indicated a statistically significant difference in the FRSSD performance between pre- and mid-intervention time-point,  $p = .045$ .

One-way repeated measures ANOVAs indicated a non-statistically significant effect of time on the MMSE, TEA, RBMT, ROCF, TMT, FUCAS, and GDS.

Hypothesis Testing – Hypothesis 2: A combination of two-way mixed ANOVAs and Mann-Whitney  $U$  tests were employed to evaluate if there was a statistically significant difference in the neuropsychological performance of older adults between the control and the experimental group, between pre- and post-intervention time-points.

Concerning the RAVLT performance, a two-way mixed ANOVA indicated a non-statistically significant interaction between group and time,  $F (1, 186) = .15, p = .70, \eta_p^2 = .001$ . A statistically significant effect of time on the RAVLT performance was identified, though,  $F (1, 186) = 23.30, p < .001, \eta_p^2 = .11$ . Bonferroni adjusted pairwise comparisons showed that independently of group of allocation, the RAVLT performance improved significantly from pre-intervention ( $M = 43.04, SE = .91$ ) to post-intervention time-point ( $M = 46.65, SE = .95$ ),  $Mdf = -3.60, 95\%CI [-5.08, -2.13], SE = .75, p < .001$ . In addition, a statistically significant effect of group was observed,  $F (1, 186) = 21.57, p < .001, \eta_p^2 = .10$ . Bonferroni adjusted pairwise comparisons indicated that the intervention group ( $M = 48.80, SE = 1.47$ ) had a significantly better performance than the control group ( $M = 40.89, SD = .85$ ),  $Mdf = -7.91, 95\%CI [-11.27, -4.55], SE = 1.70, p < .001$  (see Figure 2 for estimated marginal mean differences).

As to the RBMT performance, a Mann-Whitney  $U$  test suggested that the intervention group ( $n = 47, Mdn = -.50$ ) performed significantly better than the control group ( $n = 142, Mdn = -1.75$ ) from pre- to post-intervention time-point  $U = 4,161.50, z = 2.54, p = .011, r = .18$ .

Finally, concerning the ROCF performance, a two-way mixed ANOVA indicated a non-statistically significant interaction between group and time,  $F (1, 185) = .079, p = .78, \eta_p^2 < .001$ , as well as a non-statistically significant effect of time,  $F (1, 185) = .003, p = .96$ ,

$\eta_p^2 < .001$ . However, a statistically significant effect of group on the ROCF performance was observed,  $F(1, 185) = 10.83, p = .001, \eta_p^2 = .055$ . Bonferroni adjusted pairwise comparisons indicated that the intervention group ( $M = 32.06, SE = .57$ ) had a significantly better performance than the control group ( $M = 29.89, SD = .33, Mdf = -2.18, 95\%CI [-3.48, -.87], SE = .66, p = .001$  (see Figure 3 for estimated marginal mean differences).

Nevertheless, a two-way mixed ANOVA indicated non-statistically significant differences in the TEA. Particularly, a non-statistically significant interaction between group and time,  $F(1, 175) = .047, p = .83, \eta_p^2 < .001$ , as well as a non-statistically significant effect of time was identified,  $F(1, 175) = .98, p = .32, \eta_p^2 = .006$ . Also, a non-statistically significant effect of group was observed,  $F(1, 175) = .12, p = .73, \eta_p^2 = .001$ . Mann-Whitney  $U$  tests suggested non-statistically significant differences in the MMSE, TMT, FUCAS, FRSSD, and GDS.

## **DISCUSSION**

The principal objective of our research was to investigate whether the systematic FL learning which bears non-symmetrical features with the mother tongue of MCI seniors could activate different verbal behaviours, specifically mother tongue verbal memory. Moreover, we sought to investigate whether the benefits from this learning process would positively affect other cognitive functions, apart from language. Thirdly, we aimed at suggesting an alternative intervention programme to be included in the “curriculum” of day care units for patients with dementia. To the best of our knowledge, this is the first time that such research has been conducted.

A total of 241 Greek MCI older adults participated in this study, 98 of which joined the English classes for two academic years (2016-2017; 2017-2018) receiving 18 months of instruction. A battery of neuropsychological tests was administered to all of the participants. These data were collected at three time-points for the intervention group (i.e. pre-, mid-, and post-intervention), and at two time-points for the control group (i.e. pre- and post-research). Most of the control group individuals were women, a percentage which was much higher for the intervention group. Age and years of education between the two groups were matched. The EFL competence of the intervention group ranged from the A0 to the A1 level before the onset of the research; upon the end of the second year of the intervention, the participants’ EFL competence was consolidated at the Pre A1 level.

Two experimental hypotheses have been formulated which were tested with the statistical analysis: initially, we explored whether the intervention induced any statistically

significant differences in the neuropsychological performance of the participants across the three assessment time-points, i.e. pre-, mid-, and post-intervention. Afterwards, we evaluated whether there were any statistically significant differences in the neuropsychological performance between the intervention and the control group, before and after the intervention.

The within-group analysis revealed a significant effect of time concerning the performance on the RAVLT [ $F(2, 78) = 9.37, p < .001, \eta_p^2 = .19$ ]. More specifically, it was shown that the scores of the participants on the RAVLT were considerably improved between pre- and mid-intervention ( $Mdf = -3.58, 95\%CI [-6.41, -.74], SE = 1.13, p = .009$ ) as well as between pre- and post-intervention ( $Mdf = -4.90, 95\%CI [-8.01, -1.79], SE = 1.24, p = .001$ ). Baseline evaluation on this measure had shown high scores for the participating older adults; their initial good performance was not only maintained through the 18 months of the English course but also improved. A similar time-related improvement was noted on the FRSSD [ $\chi^2(2, N = 38) = 7.78, p = .020$ ] which, nonetheless, was not verified as being statistically significant by the Bonferroni adjusted pairwise comparisons. However, unadjusted pairwise comparisons indicated a statistically significant difference in the FRSSD performance between the pre- and mid-intervention time-points ( $p = .045$ ). Had the group size been larger, the significance denoted by descriptive statistics might have been verified.

The between-group analysis between the pre- and post-intervention time-points revealed that the intervention group had a significantly better performance on the RAVLT than the control group ( $Mdf = -7.91, 95\%CI [-11.27, -4.55], SE = 1.70, p < .001$ ). Interestingly, the RAVLT appears to be a measure sensitive enough as to capture the effect of the intervention, both for the within- and the between-group comparisons. Along the same line, the performance of the intervention group on the RBMT was significantly better than the control group ( $U = 4,161.50, z = 2.54, p = .011, r = .18$ ). Finally, a statistically significant effect of group on the ROCF performance was observed, since the intervention group had a significantly better performance than the control group ( $Mdf = -2.18, 95\%CI [-3.48, -.87], SE = .66, p = .001$ ).

The common denominator of the RAVLT, the RBMT, and the ROCF is memory function, which is evaluated from a different perspective: the RBMT assesses aspects of everyday memory function over time along with prospective memory skills and the ability to learn new information; the RAVLT focuses on the ability to encode, combine, store and recover verbal information in different stages of immediate memory and evaluates the effect of interference stimulus, delayed memory and recognition; the ROCF measures visuo-spatial,

memory, problem solving and motor skills. The performance of the intervention group on these scales is notable given that memory usually declines with age and that the participants' main common feature is memory frailty, due to MCI. We could, thus, assume that the intervention has had a substantial transfer effect on their mnemonic function. During the FL learning process, the trainees were constantly challenging their memory skills since they needed to store, maintain and retrieve the taught knowledge which was encoded in another language. The regular involvement with an FL requires that the brain engages a vast neural network, which leads to the discovery of strategies and the deployment of complex cognitive skills. Along the same lines, research has shown that, throughout the lifespan, cognitive abilities reshape the mind architecture by means of development, adaptive abilities, and functioning [43-47].

The statistical analysis revealed that the experimental group was in general better than the control group across most of the tasks. This might be explained by the fact that quite a few of the older adults who volunteered to join the English course concurrently attended other cognitive or physical stimulation programmes at the day care units. Apparently, the engagement with other activities may have constituted an advantage over the passive control group. It should be stressed here that both the experimental and the control groups were recruited from a cohort of individuals who are generally open to research, as various experimental studies are conducted at the day care units. This might account for the generally increased performance level on the improved measures. Probably, if the experimental group had been compared to active controls, different results may have been yielded; however, there were not sufficient enlisted active controls to create a solid group.

The findings of our research highlight the importance of long-term learning processes for older adults with MCI. They are in line with recent research which has shown that, compared to young brains, senior brains may successfully perform cognitive tasks and reach ceiling scores as the matched young brains, the difference being in the length of the time required for this attainment, due to cognitive control decline [48].

Various researchers have attempted to reinforce memory in MCI patients by means of various non-pharmacological interventions, such as memory exercises, teaching memory strategies, and errorless learning techniques [49]. However, the implementation of a year-long FL course could be more effective than detached techniques which usually last for a few weeks. In the future, it would be interesting to examine brain connectivity and delineate the networks engaged during or after the process of FL learning in MCI older adults. Particularly,

an experiment with event-related potentials may capture changes in the brain more accurately than standardized neuropsychological assessment scales [31].

Some scientific groups have examined brain changes in healthy seniors due to language training [45, 50, 51]. Other researchers have attempted FL course implementations but with different specifications from our study, in terms of participants, duration, nature, structure, content, and focus. Ramos et al. [52] searched for a probable relationship between language learning and switching ability in older adults. They trained monolinguals in FL learning for a whole year and assessed them on a colour-shape switching task, before and after the FL course. They yielded statistically non-significant results in the post-test. Ware et al. [53] investigated whether it would be feasible to teach EFL to a small group of French healthy seniors for 4 months using technology. The lessons were thematic and researchers used questionnaires pre- and post-intervention to measure cognitive level and subjective feelings of loneliness or social isolation. The programme proved feasible for the target group and most participants enjoyed it despite its demanding nature. Bak et al. [54] studied the impact of a one-week intensive FL course to attentional functions in a group of participants whose age ranged from 18 to 78 years. Their results corroborated their experimental hypothesis suggesting that even a short period of intensive language learning can produce positive effects.

This study, in spite of its limitations, presents evidence on the efficacy of FL learning for people with cognitive decline. It also provides support for the advantages of lifelong learning and new impetus for future research. FL learning may act as a safeguard for older populations since a complicated brain network is engaged throughout the process and numerous cognitive strategies need to be implemented.

### **ACKNOWLEDGEMENTS**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The first author is grateful to Mr Dimitrios Bekiaridis-Moschou, Mrs Anastasia Tsalkitzoglou, Ms Maria Katsiperi, and Ms Ifigenia Dosi for their voluntary assistance to the delivery of the lessons. She is also thankful to the personnel of the day care units of the Greek Association of Alzheimer’s Disease and Related Disorders of Thessaloniki, Greece, for their invaluable help and administrative support throughout the research. Finally, the first author wishes to thank professors D. Kazis, M. Tsolaki, P. Bamidis, and E. Kassapi for their guidance and support.



### **CONFLICT OF INTEREST**

The authors have no conflict of interest to report.

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**FIGURES**

Figure 1. Estimated marginal mean differences in RAVLT performance among time points  
(Error bars represent 95% CIs).

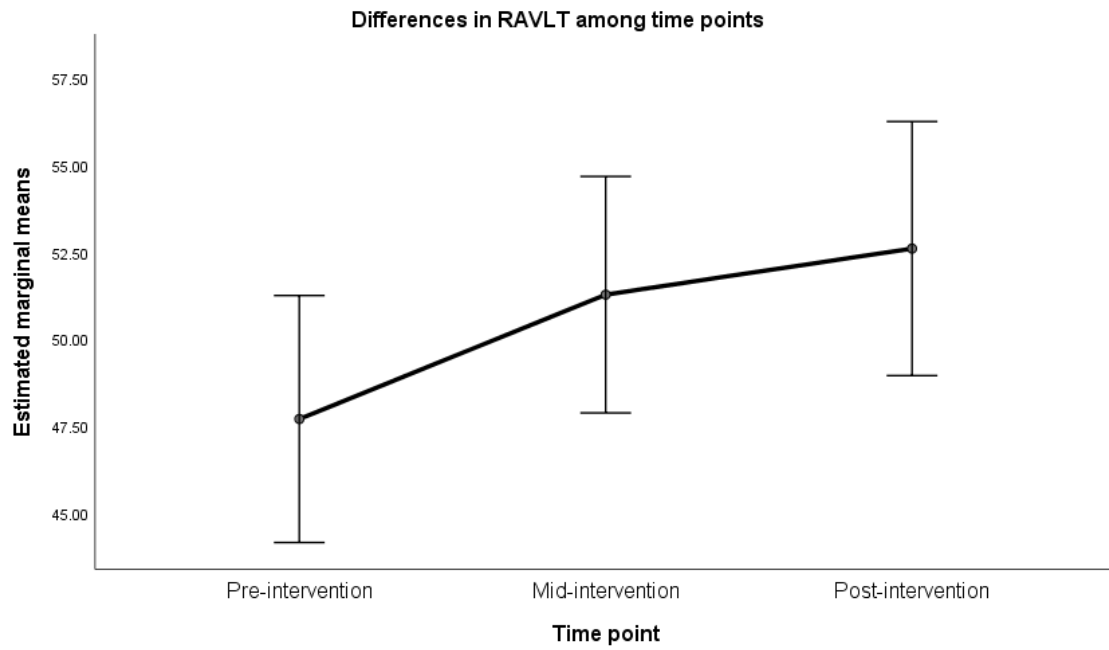


Figure 2. Estimated marginal mean differences in RAVLT performance between control and intervention group across time points (Error bars represent 95% CIs).

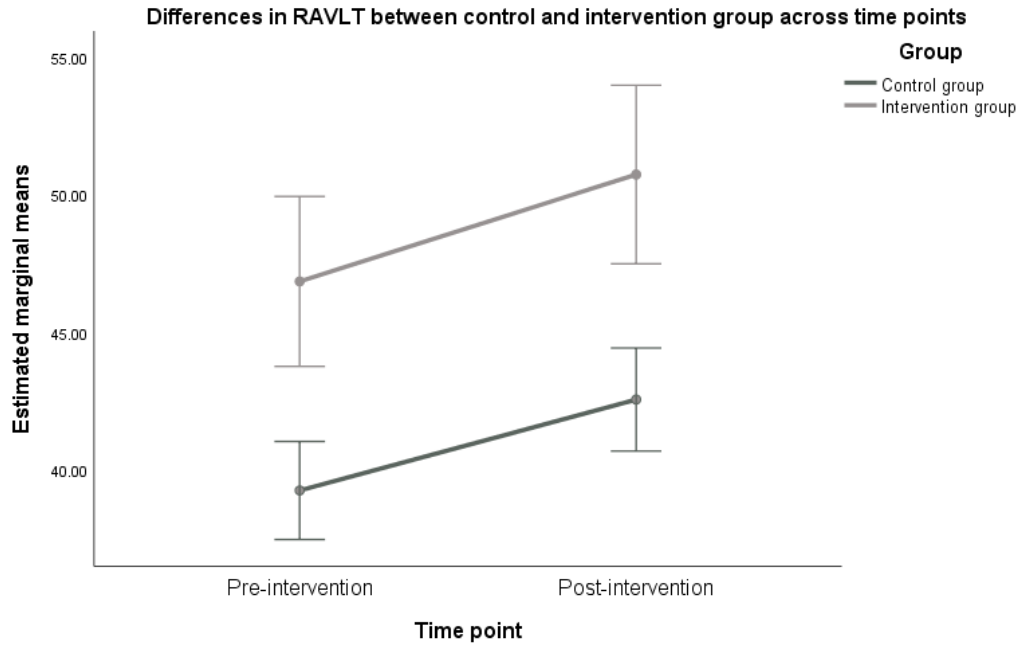


Figure 3. Estimated marginal mean differences in ROCF performance between control and intervention group across time points (Error bars represent 95% CIs).

