ABOUTOpen Digital Health

AboutOpen | 2019; 5(1): 24-30
ISSN 2465-2628 | DOI: 10.33393.abtpn.2019.282

ORIGINAL RESEARCH ARTICLE

Open Access

Efficacy of tablet-based applications for mental training in preserving cognitive abilities of older adults: a proof-of-concept study

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Abstract

Background and aims: Nonpathological, age-related cognitive decline is among the most feared consequences of aging. Evidence suggests that the continued use of mental abilities can slow down cognitive decline. We developed two tablet-based applications for the mental training (ElasticaMente) and social interaction/entertainment (iNonni) of older adults. The aim of this study was to evaluate their effect on cognitive performance.

Materials and methods: This was an exploratory study of 8 months duration. Sixty healthy residents of a senior community center aged ≥60 years were recruited and divided into three groups: participants in Groups 1 and 2 received a tablet with ElasticaMente and iNonni (Group 1, *n* = 20) or with iNonni only (Group 2, *n* = 20); participants in Group 3 (*n* = 20) did not receive any tablet. Participants in Groups 1 and 2 were instructed to use the applications three times a week (each session ~45 minutes). Cognitive performance was assessed at baseline (T0) and after 8 months (T1) using a battery of six validated tests.

Results: In Group 1, cognitive test scores remained consistently stable from T0 to T1, suggesting maintenance of cognitive abilities. In contrast, in Groups 2 and 3, scores worsened from T0 to T1 across all tests. Comparison of the changes from T0 to T1 revealed statistical significance for Group 1 versus Group 3, but not for Group 1 versus Group 2 and Group 2 versus Group 3.

Conclusion: The 8 months use of the applications ElasticaMente and iNonni was associated with a significant benefit in terms of preserved cognitive performance compared with no tablet-based activity. The potential contribution of ElasticaMente to the attenuation of cognitive decline should be further investigated.

Keywords: Aging, Cognitive decline, Cognitive training, Mental training, Older adults

Introduction

Age-related decline in cognitive abilities may be associated with substantial difficulties in everyday life, loss of functional independence, and impaired quality of life (1). Cognitive decline is among the most feared aspects of getting old (1). With a progressively aging population worldwide, there has been a growing interest in preserving cognitive function in advanced age, and great effort has been devoted to understanding how the decline of cognitive abilities may be delayed or reduced (1). Evidence suggests that an engaged and active lifestyle and participation in mentally stimulating activities have a protective effect and mitigate cognitive decline (2-5). It is thought that the continued use of cognitive abilities through activities that require a mental effort directly affects the brain both structurally and functionally (neuroplasticity), a concept closely related to the "cognitive reserve" hypothesis (1, 6-9). According to this hypothesis, individuals with a greater reserve will cope with brain aging or damage better than those with a lower reserve (10).

Based on the concepts of brain plasticity and cognitive reserve, over the past few decades, a variety of training tools and programs have been developed to boost and preserve cognitive abilities in adults and older adults, and many of them have been evaluated in clinical trials (9, 11-17). In the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial sponsored by the US National Institutes of Health, participants (2,832 healthy volunteers aged 65-94 years) were randomly assigned to a 10-session group training for memory, or reasoning, or visual speed of processing, or to no-contact (control group); 4-session booster training at 11 and 35 months after training was provided to a random sample of participants who completed training (11). The ACTIVE trial demonstrated that each of the three cognitive interventions tested – memory, reasoning, and visual speed

Received: April 15, 2019
Accepted: May 8, 2019
Published online: May 29, 2019

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of processing – produced an immediate improvement in the cognitive ability trained that persisted, with some dissipation, during the 5-year follow-up of the study (11, 18). Benefits in terms of reasoning and speed-of-processing performances persisted for 10 years (15). Of note, the group trained in reasoning also reported significantly less difficulty in the instrumental activities of daily living than the control group at 5 years, suggesting an impact of mental training also on the performance of daily tasks (18). Meta-analyses of randomized studies investigating the impact of cognitive training in healthy older adults have also been performed (19-22). According to a meta-analysis of 263 studies addressing interventions to prevent age-related cognitive decline, mild cognitive impairment, or clinical Alzheimer's-type dementia, evidence of moderate strength shows that cognitive training of older adults with normal cognitive abilities improves performance in the cognitive domains trained, while no transfer of benefits to other cognitive domains and benefits beyond 2 years has been conclusively demonstrated (20). Another meta-analysis of 31 controlled randomized trials found moderate effects of cognitive training on overall cognitive function and executive function, and small effects on memory, attention, and visual-spatial performance in healthy older people (19).

In recent years, interactive digital media and the potential of mobile technologies have attracted considerable attention also in the field of cognitive training programs including those targeting the elderly population (23-25). With regard to mobile devices, tablets are considered particularly suitable for this age group, as they are easier to carry and operate than laptops, and their screen size is better than that of smartphones for older adults who often suffer from visual impairments (25).

We have recently developed two tablet-based applications for older adults, one for mental training in the domains of memory, attention, and logical thinking and the other for social interaction and entertainment. We report here the results of an exploratory study in which we tested whether the use of these applications had an impact on mental performance as assessed by a battery of validated cognitive tests.

Materials and methods

Study design and participants

This was an exploratory study conducted to investigate the effect of two tablet-based applications for mental training (ElasticaMente) and social interaction/entertainment (iNonni) on cognitive abilities. The two applications were developed to activate and possibly boost cognition in healthy elderly individuals. Study participants were recruited among elderly female and male residents of a senior community center in Italy (Azienda Pubblica di Servizi alla Persona "ITIS," Trieste, Italy). Exclusion criteria included the following: age <60 years; confirmed diagnosis of neurodegenerative disease (Alzheimer's disease, Parkinson's disease, frontal dementia); Mini-Mental State Examination (MMSE) score ≤ 21; overt and disabling sensory disorders (visual and/or auditory); overt motor disorders that did not allow the correct use of the mobile device (e.g., poor manual dexterity).

Subjects suitable for participation in the study were pseudo-randomly assigned to three groups: Group 1, participants receiving the tablet with the two applications, ElasticaMente and iNonni; Group 2, participants receiving the tablet with the application iNonni only; Group 3, participants receiving no tablet. Randomization was not complete because some baseline participant characteristics were known and taken into account, so as to ensure a balanced distribution among the three groups (mean age for Groups 1, 2, and 3 were, respectively, 80.0, 79.8, and 82.8 years; see Tab. II for details), gender (Tab. II), MMSE score (Tab. III), and education degree. The study was conducted from April 2016 to December 2016 (8-month duration of observation). Prior to initiation of the observation, subjects of Groups 1 and 2 were instructed on how to use the tablet and the applications. Participants were then encouraged to use the applications three times a week, for sessions of approximately 45 minutes each. During the 8 months of the study, participants of Groups 1 and 2 were seen by the study staff at intervals of 2 months, in groups and individually, to discuss any problems with tablet and application use. The ethics committee of the center approved the study. Participants signed a written informed consent form and were fully anonymized.

Design and description of the two applications

The applications ElasticaMente and iNonni were conceived and developed by Fablab SRL, Trieste, Italy, for Apple and Android tablets. The aim of ElasticaMente is to activate and enhance cognitive abilities in healthy elderly people. The various exercises, their level of difficulty, the scoring system, and reward mechanisms have been designed specifically for an elderly target, after consulting with a neuropsychologist with expertise in this age group, who is coauthoring the present article (FV). ElasticaMente comprises three main areas conceived for the training of specific cognitive abilities, namely memory (five games), attention (four games), and logical thinking (six games), and developed using validated neuropsychological tests as a model. The active involvement of the player is stimulated by levels of increasing difficulty, scores, limitation of the time available to perform a given task, and positive feedback. The application iNonni (www.i-nonni.it) was conceived as a tool for facilitating social interaction, providing information related to health, and proposing leisure activities. It consists of four sections that provide the following functions: in the "communicate" section it is possible to interact with small circles made up of family members, friends, and caregivers through calls, video calls, texts, and image exchanges; the "spare time" section includes suggestions for leisure-time activities that individuals could personalize thanks to a simplified web search engine; the "wellness" section gives access to updated information regarding healthcare and medications, and contains a geolocation service that allows to display the nearest pharmacy; the "learn" section allows to increase general knowledge through courses addressing issues of current interest.

Assessments and outcome measures

Assessments were made at study entry (baseline or T0) and at the end of the study, that is, after 8 months (T1). Trained

personnel performed the assessments. At study entry, the demographic characteristics and information about current medications were recorded. The cognitive status of all participants at baseline and after 8 months was assessed using a battery of six validated tools widely used in clinical and psychological studies, namely the MMSE (validated Italian version) (26, 27), Montreal Cognitive Assessment (MoCA, validated Italian version) (28, 29), Esame Neuropsichiatrico Breve (ENB, brief neuropsychiatric examination) (30), Frontal Assessment Battery (FAB, validated Italian version) (31-33), backward digit span (34), and Colored Progressive Matrices (CPM) (35) (Tab. I).

The MMSE is a 30-point questionnaire extensively used to measure overall cognitive function (26, 27). A total score ≥24 points indicates normal cognition. Administration of the test takes between 5 and 10 minutes and examines functions including registration (repeating named prompts), attention and calculation, recall, language, ability to follow simple commands, and orientation. The MoCA, created in 1996, is validated in several languages in the setting of mild cognitive impairment and, like the MMSE, is a measure of overall cognitive function (28, 29). It is administered in approximately 10 minutes and assesses several cognitive domains, including short-term memory recall, visuospatial abilities, executive functions, phonemic fluency and language, verbal abstraction, attention and concentration, and orientation to time and space. MoCA scores range from 0 to 30. A score ≥26 indicates a normal cognitive state. The ENB (developed in Italy) is a battery of 15 subtests evaluating several cognitive domains (30). For each subtest, the overall rate of success is calculated as a percentage of the maximum score for that subtest; the total overall score of the ENB assessment is the mean of the percentages calculated for each subtest. Administration of the ENB takes between 1 hour and 1 hour and a half, depending on the subject. The FAB assesses frontal lobe functions (31-33). It consists of six subtests exploring the following: conceptualization, mental flexibility, motor programming, sensitivity to interference, inhibitory control, and environmental autonomy. It takes approximately 10 minutes to administer. The total score ranges from 0 to 18 and is obtained by summing up the six individual task scores. A total score ≥13.4 indicates normal function. Digit span is a standard test of verbal short-term memory performance (34). Participants see or hear a sequence of numerical digits and are asked to recall the sequence correctly, with increasingly longer sequences being tested in each trial. The participant's span is equivalent to the longest number of sequential digits that are accurately remembered. Digit span tasks can be given forward or backward; backward digit span means that participants are asked to recall the sequence in reverse order. The average backward score for adults is 6. CPM are a type of Raven's Progressive Matrices, designed for children, the elderly, and mentally and physically impaired individuals (35). Raven's matrices are nonverbal tests used to measure abstract reasoning and provide an estimate of fluid intelligence (36). In each test item, the subject is asked to identify the missing element that completes a pattern. Many patterns are presented, in the form of a 6 × 6, 4 × 4, 3 × 3, or 2 × 2 matrix, which gives the test its name. A total score ≥17.5 indicates normal abstract reasoning skills. Adherence to the study instructions was assessed by monitoring application use of each participant via a web-based dashboard.

TABLE I - Battery of validated tests used for the assessment of cognitive abilities

Test	Evaluated abilities	Administration time	Maximum score
MMSE Folstein et al (26) Measso et al (27)	Overall cognitive function	10 min	30
MoCA Nasreddine et al (28) Santangelo et al (29)	Overall cognitive function	10 min	30
ENB Mondini et al (30)	Battery of 15 tests assessing several cognitive abilities	60-90 min	100%
FAB Dubois et al (32) Iavarone et al (33) Appollonio et al (31)	Frontal lobe functions	10 min	18
Backward digit span Jones and Macken (34)	Verbal short-term memory	20 min, on average	Longest number span correctly remembered
CPM Measso et al (35)	Abstract reasoning	Variable	36

CPM = Colored Progressive Matrices; ENB = Esame Neuropsichiatrico Breve; FAB = Frontal Assessment Battery; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment.

Statistical analysis

Data were summarized by descriptive statistics. Participants who dropped out of the study were excluded from the analysis. Changes in the scores of the cognitive assessments from T0 to T1 were analyzed using Student's t-test. Comparisons of the changes in scores among the three study groups were performed using the analysis of variance (ANOVA) test; the Bonferroni method was used for pairwise comparison of groups. The correlation between cognitive test scores and number of game sessions played was analyzed using the Spearman method. Statistical significance was set at $p \leq 0.05$.

Results

Of the 60 participants enrolled, 41 (68.3%) completed the 8-month observation and were included in the analysis.

The primary endpoint of the study was the difference in the mean change from T0 to T1 in the scores of the various cognitive tests among the three groups. The secondary endpoint was the correlation between the number of game sessions played by the subjects of Group 1 and the changes in the scores of the cognitive tests from T0 to T1.

Dropout rates in the three groups were similar: 6/20 (30%) in Group 1 (tablet with ElasticaMente + iNonni), 7/20 (35%) in Group 2 (tablet with iNonni), and 6/20 (30%) in Group 3 (no tablet). As for the reasons for early interruption, four participants in Group 1, five in Group 2, and five in Group 3 dropped out because they were no longer interested in the study, while two participants in both Groups 1 and 2, and one participant in Group 3 discontinued due to health problems. Demographic characteristics were similar among the three observation groups, with no statistically significant differences in age and gender (Tab. II). The mean age (±standard deviation) of participants was 80.9 (7.4) years, and the majority were female (68.3%).

The total scores of the six cognitive assessments performed at baseline (T0) and after 8 months (T1) are shown in Table III. Participants in the three groups had normal cognitive abilities at baseline, as confirmed by the achievement at T0 of mean total scores falling within the range indicative of normal cognitive abilities (Tab. III). Such scores did not change significantly from T0 to T1 in subjects using the training application ElasticaMente for 8 months along with the social interaction/entertainment application iNonni (Group 1); subjects using the application iNonni only (Group 2) experienced a decrease (worsening) in all cognitive test scores from T0 to T1, with statistically significant differences from baseline for the MoCA, ENB, FAB, and CPM tests (Tab. III). In subjects who did not receive the tablet and did not use any study application, cognitive scores significantly decreased from baseline to 8 months, across all tests performed with the exception of the CPM assessment (Tab. III). The decreases were numerically more substantial than those observed in Group 2.

Based on the analysis of the changes in cognitive test scores from T0 to T1, subjects in Group 1 appeared to have a benefit in terms of maintenance of cognitive abilities, while subjects in Groups 2 and 3 showed a loss in cognitive abilities. Such loss appeared to be more substantial in participants of Group 3 who did not perform any tablet-based activities.

ANOVA showed that the differences among the three groups in the changes from baseline to 8 months in the scores of the cognitive assessments were statistically significant for three of the six tests used: MMSE (p = 0.04), ENB (p = 0.02), and backward digit span (p = 0.01) (Tab. IV); results for MoCA were consistent with other variables but fell just short of statistical significance (p = 0.06). Pairwise comparison of the changes from T0 to T1 in the test scores showed that the differences between Groups 1 and 2 and between Groups 2 and 3 failed to reach statistical significance across all tests (Tab. IV). By contrast, differences in the changes observed in Group 1 versus Group 3 were statistically significant for the MMSE (p = 0.03), ENB (p = 0.02), and backward digit span (p = 0.01) tests, or close to statistical significance for MoCA (p = 0.07) and FAB (p = 0.11) (Tab. IV).

No statistically significant correlation was found between the scores of the six cognitive tests after 8 months and the number of ElasticaMente games played by participants in Group 1. A trend toward higher scores with increased number of games played was observed for MMSE, MoCA, and CPM tests.

Participants of Groups 1 and 2 were overall satisfied with the application iNonni; Group 1 participants liked the application ElasticaMente and found it user-friendly; overall, the various games were found to be entertaining and stimulating. When asked about the impact of tablet use on their lives, participants of Groups 1 and 2 reported feeling more useful, more capable of influencing their future actions, and having improved interactions with their family, friends, and caregivers.

TABLE II - Demographic characteristics of the study population

	Overall population (*n* = 41)	**Group 1 ElasticaMente + iNonni (*n* = 14)**	**Group 2 iNonni (*n* = 13)**	**Group 3 No tablet (*n* = 14)**
Age (y), mean (SD)	80.9 (7.4)	80.0 (8.3)	79.8 (8.1)	82.8 (5.7)
Gender, *n*(%)				
Female	28 (68.3)	11 (78.6)	8 (61.5)	9 (64.3)
Male	13 (31.7)	3 (21.4)	5 (38.5)	5 (35.7)

SD = standard deviation.

Discussion

This exploratory study investigated the effect of the use of tablet-based applications for mental training (ElasticaMente)

TABLE III - Summary of the results of the cognitive assessments performed at baseline (T0) and after 8 months (T1) in the three study groups

	Group 1 ElasticaMente + iNonni (*n* = 14)			**Group 2 iNonni (*n* = 13)**			**Group 3 No tablet (*n* = 14)**		
Assessment	**T0**	**T1**	**p**	**T0**	**T1**	**p**	**T0**	**T1**	**p**
MMSE	28.6 (2.2)	28.5 (3.9)	0.81	28.7 (2.0)	26.5 (5.6)	0.10	28.1 (2.7)	24.5 (4.8)	0.002
MoCA	26.6 (2.8)	26.1 (6.3)	0.68	26.1 (3.1)	22.8 (5.9)	0.005	25.0 (4.6)	20.9 (6.9)	0.003
ENB	73.1 (11.8)	73.4 (14.5)	0.89	70.1 (13.9)	63.1 (18.4)	0.004	68.4 (11.7)	59.7 (17.3)	0.006
FAB	16.6 (2.1)	16.0 (3.8)	0.47	15.6 (3.0)	14.1 (4.0)	0.01	16.4 (4.6)	13.4 (2.8)	0.01
Backward digit span	6.6 (1.4)	7.0 (1.6)	0.23	6.1 (1.8)	5.5 (1.3)	0.12	6.5 (1.9)	5.4 (1.6)	0.01
CPM	27.6 (6.9)	26.0 (8.1)	0.42	25.5 (4.7)	22.9 (6.8)	0.006	24.1 (6.4)	22.7 (5.4)	0.17

Results are presented as mean values (±SD) of the total score achieved in each test. T0 and T1 scores were compared using t-test.
CPM = Colored Progressive Matrices; ENB = Esame Neuropsichiatrico Breve; FAB = Frontal Assessment Battery; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; SD = standard deviation.

TABLE IV - Mean changes from baseline (T0) to 8 months (T1) in the scores of cognitive tests, in the three groups

Assessment	Group 1 ElasticaMente + iNonni (*n* = 14)	Group 2 iNonni (*n* = 13)	Group 3 No tablet (*n* = 14)	p (ANOVA)
MMSE	−0.1 (2.2)*	−2.1 (4.3)	−3.6 (3.6)	0.04
MoCA	−0.5 (4.5)	−3.3 (3.5)	−4.1(4.2)	0.06
ENB	−0.3 (7.8)*	−7.1 (7.1)	−8.7 (9.9)	0.02
FAB	−0.6 (2.9)	−1.5 (1.8)	−3.1 (3.9)	0.10
Backward digit span	0.43 (1.3)*	−0.6 (1.3)	−1.1 (1.4)	0.01
CPM	−1.6 (7.1)	−2.6 (2.8)	−1.4 (3.5)	0.78

Changes are shown as mean values (±SD).
ANOVA = analysis of variance; CPM = Colored Progressive Matrices; ENB = Esame Neuropsichiatrico Breve; FAB = Frontal Assessment Battery; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; SD = standard deviation.
*p<0.05 for the comparison of Group 1 versus Group 3.

and social interaction/entertainment (iNonni) on cognitive abilities in healthy elderly individuals. Subjects using both applications maintained their cognitive abilities over 8 months, as highlighted by the consistent lack of statistically significant changes from T0 and T1 in the scores of all cognitive tests performed. In contrast, subjects using the tablet provided with the social interaction/entertainment application only, and therefore not performing any cognitive training during the 8 months of observation, consistently reported worse test scores at T1 compared with T0, with changes being statistically significant in most assessments (ENB, MoCA, FAB, and CPM). Even worse outcomes were observed for the study participants who did not receive a tablet and were not engaged in any tablet-based activity, as suggested by a substantial and statistically significant decline from T0 to T1 in the scores of all cognitive tests but CPM.

Differences in the changes in the test scores of all tests, with the exception of CPM, were found to be statistically significant or close to statistical significance among the three groups (ANOVA test); however, the pairwise comparison of groups (Bonferroni method) showed that changes in scores from T0 to T1 were statistically significant only for the comparison of the group using the tablet with both applications versus the group using no tablet. No statistical significance was achieved for the comparison of score changes reported by the group using the tablet with both applications versus the group using the tablet with the social interaction/entertainment application only, and by the group using the tablet with the social interaction/entertainment application only versus the group with no tablet. These results therefore suggest that using the tablet with both applications may confer a benefit in terms of maintenance of cognitive performance compared with no tablet-based activity.

Furthermore, our results show a trend suggesting cognitive performance maintenance in subjects using both applications compared with those using only the social interaction/entertainment application. Group 1 participants were included in a stronger relational environment (that could act as a protection against isolation, social loneliness, and mood decline, with important benefits for cognitive health as well).

Notably, the proportions of subjects who prematurely interrupted the study because they were no longer interested in participating were relatively low, considering the 3-day/week training schedule and prolonged study duration, and were similar among groups (20% in Group 1 and 25% in both Groups 2 and 3).

The decline in cognitive abilities observed consistently with all six tests over 8 months in subjects using the tablet without the application for mental training, and more so in those using no tablet at all, was substantial and perhaps expected for individuals with a mean age around 80 years; they were not encouraged to use and train their cognitive functions, as it happened for participants of Group 2 and, even more, for individuals included in Group 3.

In fact, surprisingly, such decline was not observed in subjects using the tablet with both applications. However, the exact contribution of the mental training application ElasticaMente to this finding is currently unclear. It cannot be excluded that significantly better outcomes in subjects using both applications compared with those who did not receive the tablet were the consequence of an increase in activity and engagement caused by the novelty of tablet use, the contact with the study personnel, and the attendance of the meetings where participants in Groups 1 and 2 were taught how to use the tablet and the applications, rather than the results of mental training with ElasticaMente. However, participants of Group 2, who also engaged in tablet-based activities, failed to report a significant benefit compared with the nontablet group. As highlighted by a large body of published evidence, any intervention that engages elderly individuals and encourages them to be active is better, also in terms of cognitive performance, than being inactive and/or socially isolated (1, 3, 5). Recent evidence suggests that acquiring new skills in advanced age, including those related to the use of new mobile technologies, tablets in particular, may potentially reduce or delay age-related cognitive decline (2, 37). A well-designed recent study in 54 older adults (aged 60-90 years), who were computer novices, investigated whether receiving extensive iPad training and learning practical applications could be associated with improved cognition and better everyday function (2). Participants were engaged 15 hours/week for 3 months. Eighteen participants received iPad training and were compared with two separate controls, a placebo group that engaged in passive tasks not requiring intensive new learning and a social group that had regular social interaction, but no new learning activity. All participants underwent pre- and postengagement cognitive tests. Compared with the two control groups, participants of the iPad group showed greater improvements in episodic memory and processing speed, suggesting that learning new skills was more effective than engaging in social or nonchallenging activities. In another study, 48 older adults aged 65-76 years with no or minimal tablet experience were recruited; 22 of them attended a weekly 2-hour class for 10 weeks during which they were taught how to use a tablet and a number of applications (37). All participants underwent a battery of

cognitive tests, as well as psychological assessments and evaluations of health and well-being. Compared with the control group, participants who underwent tablet training achieved greater performance improvements in the domain of processing speed, a domain that declines early in the aging process (37). The authors pointed out that being able to use a tablet potentially had the added advantage of facilitating a number of activities in everyday life, including social networking and online banking.

Our study has several limitations including the small sample size and the fact that participants in Group 1 were quite free to use the application ElasticaMente as they preferred, provided they used it at least three times a week in sessions of at least 45 minutes each. As a consequence, the mental training programs of participants in Group 1 were different, both in terms of number and type of games played. Surprisingly, no significant correlation was found between cognitive test scores at T1 and number of training sessions in Group 1. This could be due to the small size of the study sample not allowing this type of analysis. Despite these limitations, we believe that the present study provides useful information concerning the cognitive status of a real-life population aged ≥80 years, over an observation period of 8 months and based on a comprehensive battery of cognitive tests.

In conclusion, the present findings show that a tablet-based approach to maintenance of cognitive performance is feasible also in advanced old age and that using the two applications ElasticaMente (cognitive training) and iNonni (social interaction/entertainment) was associated with a significant benefit in terms of stable cognitive performance compared with no tablet-related activity. These preliminary findings need to be confirmed in studies involving a larger population of older adults. The contribution of the cognitive training application to the outcomes also needs to be addressed in more detail. Finally, participants in the two groups who learned how to use a tablet perceived a number of benefits including an increased sense of usefulness, greater autonomy in decision making, and improved social interactions. This aspect, as well, will need to be addressed with appropriate tools in future studies.

Acknowledgments

Editorial assistance and statistical analysis were provided by Health Publishing & Services Srl., Milan, Italy. We thank Ray Hill, an independent medical writer, who provided English language editing and journal styling prior to submission on behalf of Health Publishing & Services Srl. FabLab is the owner of the tablet-based application used in the study.

Disclosures

Financial support: This study was supported by an unconditional grant from Sanofi, Italy.

Compliance with ethical standards

Conflict of interest: MMT is a former employee of FabLab SRL. No potential conflict of interest was reported by the other authors and none of the authors have any financial interest or benefit arising from direct applications of this research.

Data availability: The data that support the findings of this study were extracted from the medical records/personal reports of the study participants and anonymized and are available from the corresponding author, MMT, upon reasonable request.

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