Computer-based cognitive intervention for dementia

Sociable: motivating platform for elderly networking, mental reinforcement and social interaction

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Abstract— *Recent research results manifest that mental activity, as well as social interaction are key prerequisites for preventing or delaying the progression of dementia.*
The primary objective of the present study is to evaluate the effects of a novel computer-based cognitive training and social activation program on the cognition, the affection and the functional abilities of cognitively intact elderly, patients with MCI and patients with mild Alzheimer's disease (AD). We performed a randomized, controlled trail of a computer-based cognitive training on 348 elderly subject distributed in three target groups, who attended a training program of 24 sessions of 60 minutes of duration (individual or in group), twice per week for 12 weeks.
Outcome measures showed that the treatment group, who performed exercises specifically designed to enhance the cognitive functions, compared to the not intervention control group, improved the cognitive status with significant evidence mainly on memory and executive functions.

Keywords—Information and Communication Technology, Mild Cognitive Impairment, Alzheimer's Disease, Computer-based Cognitive Training, Social Activation

I. INTRODUCTION

Progressive aging of the population worldwide in recent decades has as one of its consequences an increase in age related pathologies, including dementia which is a highly invalidating condition characterized by progressive loss of cognitive competence in association with personality changes and behavioral disturbances. [1]
In the last few years there has been an increase in the potential of diagnostic tools and pharmacological treatments for dementia; moreover, considerable interest has been expressed regarding non pharmacological interventions, with the aim to ameliorate patients' cognitive conditions and/or behavior and improve their abilities in the performance of daily living activities, and, consequently, their quality of life. [2]
Effectiveness of cognitive training in improving cognitive and functional performance of patients affected by Alzheimer's disease (AD) is still greatly debated. [3]
Recent results have demonstrated the efficacy of non-pharmacological interventions, alone or in combination with pharmacotherapy, especially in the early stages of the disease, in reducing progression of cognitive decline and delaying the time of institutionalization.[4]
Computer-based programs specifically targeted to dementia have been developed as a support in rehabilitation of cognitive areas and everyday functions. Computer-based cognitive training has the main advantage to allow individualized rehabilitation programs, tailored to support functions relatively well preserved and enhance the functions impaired. [5] [6] [7]
Computer assisted cognitive rehabilitation in dementia seems to be a promising area of intervention and the data available support the hypothesis that computerized techniques can improve cognitive performances in patients with dementia. [7] [8]
SOCIABLE was highly motivated by the fact that the combination of physical and mental activity with social engagement is more effective than any of these factors alone. Hence, the present study evaluates the effects of a radically new ICT based approach for integrated support of mental activity, as well as of social interaction for cognitively intact elderly and patients with MCI and mild AD.

II. OBJECTIVES

The main objective of the SOCIABLE project is to pilot and evaluate a radically new ICT based approach to the cognitive training and social activation of elderly people at the early stage of dementia, with a view to preventing and delaying the progression of dementia through pleasant cognitive training gaming activities specifically designed for elderly people.
Another objective is to provide an automated tool for managing the elderly data and collecting measurements that support the assessment of the cognitive status of people with mild cognitive deficits by medical experts.
This innovative ICT solution allows to activate and/or increase the quality and quantity of elderly people's social interactions with other members of the ageing society, as well as with their relatives.

III. MATERIALS AND METHODS

A. Participants

A total of 348 elderly subjects aged 65 + were recruited for the Clinical Trial in the pilot sites involved in the Project, located in 4 different countries in Europe (Italy, Greece, Spain, Norway), selected referring to the following target groups: [9]

- Group A: normal (cognitively intact) elderly aged 65+
- Group B: patients aged 65+ with Mild Cognitive Impairment (MCI) according to the Petersen criteria, 2001 [10] (MMSE score 25-30).
- Group C: patients aged 65+ with mild Alzheimer disease (AD) according to the NINCDS-ARDRA criteria (MMSE score 20-24)

In the TABLE I the distribution of the elderly subjects per groups in the different countries.

TABLE I

Country	A: NH	B: MCI	C: AD	Total
Greece	70	26	24	**60**
Italy	14	80	46	**50**
Norway			48	**48**
Spain	40			**40**
TOTAL	**124**	**106**	**118**	**348**

1) Eligibility Criteria:

Group A: this group includes elderly people aged 65+, without degenerative diseases. Normal elderly people have been selected according to MMSE score and according to the absence of cognitive impairments assessed through the administration of a comprehensive neuropsychological battery.

Group B: this group includes elderly people aged 65+, with diagnosis of MCI, in particular of amnestic-MCI (aMCI).

The Diagnostic Criteria (Peterson, 1999) [11] [12] for amnestic MCI (aMCI) are:

- Memory concerns, usually expressed by the patient, preferably corroborated by an informant (relative);
- Objective memory impairment for age (evidenced by tests);
- Preservation of general cognitive functioning;
- Preservation of functional abilities of daily living;
- Absence of diagnosed dementia.

Group C: this Target Group includes elderly people aged 65+ with diagnosis of mild AD. For the diagnosis of Mild Alzheimer's Disease, the reference is to the Diagnostic Criteria of DSM-IV (Diagnostic and Statistical Manual for Mental Disorders, American Psychiatric Association) [13] and National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) – Alzheimer's Disease and Related Disorders Association (ADRDA) criteria, and the MMSE score (20-25).

a) Inclusion criteria:

- Aged 65 years +.
- Fluent in native language.
- A minimum of 5-years formal education.
- Presence of a formal caregiver.
- Mini Mental State Examination score: 26-30(GROUP A); 25-30 (GROUP B); 20-24 (GROUP C).
- score on the Clinical Dementia Rating (CDR): 0 for GROUP A; 0.5 for GROUP B; at least 1 for GROUP C
- Absence of sensory deficits.
- Willingness to commit.
- Fulfillment of the NINCDS-ADRDA criteria for probable AD.

b) Exclusion criteria:

- Major neurological (e.g. stroke, transient ischemic attack) or psychiatric illness (e.g. depression not controlled by medication).
- Traumatic brain injury.
- Current substance abuse.
- Significant communicative / motor / sensorial impairments.

2) Assesment:

All subjects selected for the trial underwent a standard neuropsychological assessment through the administration of a complete battery of neuropsychological tests testing the main cognitive domains and rating scales for the affective and functional status [14]. The battery enclosed several standardized neuropsychological tests and rating scales as described in the TABLE II:

TABLE II

COGNITION	TEST
Orientation	Mini Mental State Examination [15]
Abstract reasoning	Clock Drawing Test [16]
Verbal memory (long term)	Rey Auditory Verbal Learning Test - immediate/delayed (RAVL) [17]
Constructional praxis	Rey's Complex Figure (copy) [18]
Visuo-spatial memory	Rey's Complex Figure (delayed recall) [18]
Verbal memory (short term)	Digit Span [19]
Executive functions	Phonological Verbal Fluency [17]
Attention	Trail Making Test (part A and B) [20] [21]
Language	Naming Test [22]
Affection	Geriatric Depression Scale (GDS) [23][24]
Functional Abilities	Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL) [25][26]
Severity of Dementia	Clinical Dementia Rating (CDR) [27]

B. Study Design

The efficacy of SOCIABLE treatment was evaluated with a multi-national, multicenter, randomized controlled study.
Subjects were randomized to initiate immediately the treatment or to delay for three months its initiation. The group with delayed treatment worked as control for the group of immediate treatment.
This solution has been adopted to guarantee the SOCIABLE treatment to all the included subjects.
The treatment consisted in cognitive training sessions with SOCIABLE platform. During the control condition subjects didn't receive any treatment.
For the purpose of the involvement of the control group the users were segmented into four equal groups (namely G1, G2, G3, G4), starting the treatment in subsequent quarterly period so that G2 and G4 worked as control groups respectively for G1 and G2. For this reason the whole trial period was subdivided in four quarterly phases, each one involving one quarter of the total number of users.
Subject were randomly allocated in the experimental or control group, separately for each pilot site and for each group (normal elderly, MCI and mild AD)
The analysis was performed on a total of 348 subjects, half in experimental group (G1+G3) and half in control group (G2+G4).

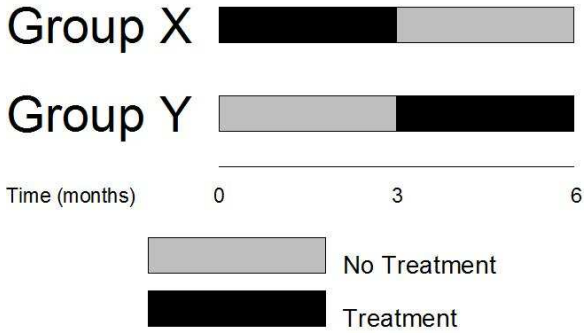

Fig. 1: *Description of the different treatment and NO treatment sessions of the experimental group (X) and control group (Y). A different assessment was conducted at the 0, 3 and 6 month.*

C. Procedure

All participants to the study attended a total of 24 sessions of 60 minutes of duration, twice per week for 12 weeks.
The SOCIABLE Program was structured as follow
Training frequency: two sessions per week, 60 min per session (30 min for cognitive training - 30min for social activation) for twelve weeks (24 sessions)
Training phase: week 1 – week 12
Follow-up: a delayed follow-up examination after 3 months without training to determine the duration of the effects.
The treatment consisted in cognitive training sessions with surface tables or surface PCs conducted in groups of 2-3 subjects or individually, conducted and supervised by a neuropsychologist, who scheduled for each session the set of activities appropriated, gave the instructions and managed the execution of each game.
The sequence and level of difficulty of the cognitive activities in each training session was programmed in order to balance them for the different cognitive functions and specifically for the main impaired functions for each user/group.

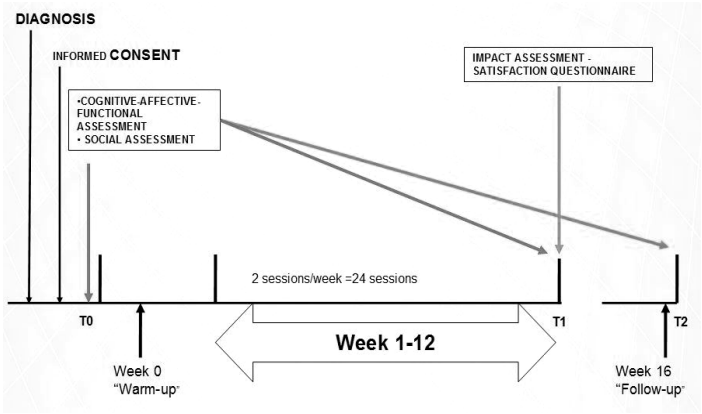

Fig. 2: *Flow-chart of the timing of the steps and in the medical evaluation process*

In order to evaluate the impact of the SOCIABLE program on the different cognitive skills, trained by the games, and the effect on the social interaction and mood of the elderly involved, the complete assessment battery was administered at three different stages of the program:

- T0: before starting the cognitive training
- T1: after the cognitive training program
- T2: as follow up assessment after 3 months from the end of the program

D. Software for Cognitive Training

The Sociable novel ICT based model for cognitive training and social activation of the elderly people was based on the use of a novel multi-touch surface computing platform (conveniently called SOCIABLE platform) as a vehicle for ergonomic, motivating and pleasant environment for cognitive training activities. From a technical and technological perspective this surface computing platform comprised a back-office application (enabling medical experts to manage patient data and configure the SOCIABLE training sessions), a number of cognitive training games (25 Cognitive training activities covering the main cognitive skills, each ones with three different difficulty levels) and the book-of-life application (a personal diary, created by the elderly, using the technological support, containing life experiences, memories and thoughts, to be shared with other users), which were executed over surface tables (within care centers/hospitals) and/or over surface PCs (within the elderly homes).

The set of cognitive activities included “games” specifically created to stimulate the main cognitive abilities, usually affected in the early stage of dementia. Each cognitive function was stimulated by a specific group of games, more specifically: 6 memory games (e.g. “hide & find” where the user hides a set of objects in a room, and has to find after a 15 minutes waiting time, while getting distracted with a different activity; “find the pairs” where the user has to find the pairs of matching images, placed with the picture side down), 6 executive functions games (e.g. “analogies” where the user has to guess the answer completing the visual or verbal analogy, based on the hint of the given analogy, “picture sort” where the user has to sort a set of photos in the correct box by guessing the hidden rule), 3 attention games (e.g. “guess who” where the user has to guess the mystery person, among pictures of different people, by eliminating the not correct ones, based on clues provided; “lost in the city”, a visuo-spatial speed game), 3 logical reasoning games (e.g. “incomplete grids”, where the user has to complete a grid with the missing piece; “symbol addition” mathematical calculations with symbols), 2 language games (“synonyms”; “antonyms”), 2 orientation games (“my home”, that simulates a home environment where the user has to move following the instructions; “travelling in Europe”).

IV. DATA ANALYSIS AND RESULTS

The main outcome for the study was the progression over time of the performance in the different domains assessed with the defined battery of neuropsychological tests. The difference in the test scores at enrollment and after three months is compared in the two groups of subjects randomly assigned to immediate or delayed treatment.

The data collected through the different neuropsychological tests and affective and functional scales were analyzed through a repeated measures analysis of variance 3 x 2 ANOVA with as within factor the assessment scores at the three different time (T0 at time 0, T1 after the 3 months treatment, and T2, the follow up assessment after other 3 months from the end of the treatment) and between factor the group (experimental vs control).

We were interested in the interaction between the two factors that indicates the presence of a treatment effect. In fact, in presence of a treatment effect, the experimental group should have an increase of test scores between T0 and T1, whereas the control group between T1 and T2. For those tests that showed a significant effect of the treatment, we also tested the follow-up maintenance of the training effects. With this aim, we tested, with a mixed 2x2 ANOVA, the interaction between time (T0 and T2) and group, experimental and control group. We assumed that, in the case of follow-up effects, the experimental group should show a greater difference between T0 and T2 because of the effect of the training and its carry-over effect during the follow-up period compared to the control group that had only the training effect. For the functional scales, since the variability of the scores was very low, we performed the χ^2 analysis. We coded as 0 all the cases in which the users worsened between T0 and T1 and between T1 and T2, and 1 all the cases in which the users improved or remained stable. Then we compared the proportion of users that worsened/improved during the rest period and the training period.

A. Results

TABLE III reports all the tests of the battery with the significance of the interaction between group and time period for all three groups together and for each one separately: healthy elderly (HE), Mild Cognitive Impairment (MCI) and mild Alzheimer’s Disease (AD).

TABLE IV reports all the behavioral and functional scales of the battery and the significance of χ^2 tests for all three groups together and for each one separately: eealthy elderly (HE), Mild Cognitive Impairment (MCI) and mild Alzheimer’s Disease (AD).

TABLE III

		P Values of the ANOVA			
COGNITIVE ABILITIES	**TEST**	**ALL**	**HE (A)**	**MCI (B)**	**AD (C)**
GLOBAL COGNITION	MMSE	**<.001**	*0.113*	**0.002**	**0.004**
REASONING	Clock Drawing Test	*0.095*	ns	ns	*0.084*
MEMORY-VERBAL-SHORT	Digit Span forward	**0.041**	*0.062*	**0.024**	ns
MEMORY-VERBAL	Rey Auditory Verbal Learning Test (RAVL)– immediate	**0.003**	*0.138*	*0.060*	**0.002**
MEMORY-VERBAL-LONG	Rey Auditory Verbal Learning test (RAVL) – delayed	**<.001**	**0.001**	**0.012**	**0.001**
MEMORY-VISUOSP-LONG	Rey’s Complex figure – recall	*0.154*	ns	ns	ns
PRAXIS	Rey’s Complex figure – copy	**0.025**	**0.003**	ns	ns
EXECUTIVE FUNCTIONS	Phonological Verbal Fluency	**0.004**	**0.008**	**0.012**	ns
EXECUTIVE FUNCTIONS	Trial Making Test B	*0.111*	*0.092*	ns	ns
EXECUTIVE FUNCTIONS	Digit Span backward	**0.002**	*0.061*	ns	**0.014**
ATTENTION	Trial Making Test A	*0.118*	*0.158*	ns	*0.057*
LANGUAGE	Naming Test	**0.012**	**0.03**	ns	ns

TABLE III: *Significance of the interaction between time (t0-t1-t2) and group (experimental/control) for all the three groups together and separately for healthy subjects, MCI and mild AD (in bold font significant results, in italic font the approaching significance results, ns= non significant results).*

TABLE IV

			P values of the Chi-squared			
BEHAVIORAL	**DEPRESSION**	**Geriatric Depression Scale**	**0.004**	**0.148**	**0.104**	**0.107**
FUNCTIONAL		**ADL**			ns	ns
		IADL			*ns*	**0.123**
		CDR			ns	ns

TABLE IV: *Significance of the χ^2 test between treatment and rest period for all the three groups together and separately for healthy subjects, MCI and mild AD (in bold font significant results, in italic font the approaching significance results, ns= non significant results).*

B. *Discussion of Results*

When we conducted the analysis with all the three groups taken together (column ALL in TABLE III), a significant or approaching significance effect of the treatment emerged for almost all the measures of the assessment (as you can see in TABLE IV bold p values). In particular, the treatment exerted a significant positive effect on the global cognitive measure expressed by the MMSE, on memory and executive functions, which were the two cognitive functions most treated during the training. A positive effect was also present in constructional praxis and language measures.

The analysis conducted separately for each group of subjects revealed:

- For healthy elderly an effect of the treatment was present for almost all the cognitive functions. The effect was not evident for reasoning and global cognition tests (MMSE and Clock Drawing Test) probably connected to a ceiling effect.
- For MCI patients a positive effect was present for global cognition, memory and executive functions.
- For mild AD patients a positive effect was present for global cognition, memory, and executive functions. A trend was also present for IADL functional scale.

A follow up effect emerged only for healthy elderly at the memory test 'RAVL Test delayed' ($p<.05$) and a trend toward significance emerged at the language test 'Naming Test' ($p=.1$).

V. CONCLUSIONS

Overall, in mild Alzheimer's disease and during its prodromal phase, i.e. the Mild Cognitive Impairment, the SOCIABLE intervention had a positive effect on global functioning, as expressed by the MMSE score. Additionally, we observed a positive effect on memory and executive functions, which were the two cognitive functions that were the ones most actively treated during the training. Patients showed an improvement in social as well as in functional abilities, as an indirect evidence of efficacy of the training that corroborate its effects. Mood showed an opposite trend getting worse after training, probably due to the increase of self-consciousness related to the improvement of cognitive functioning.

All the cognitive functions of healthy elderly were improved after training, and in particular memory, language, praxis and executive functions. Moreover, they showed a follow-up effect during the rest period after training in memory and a positive trend in language. This was not the case of Alzheimer's Disease patients.

In conclusion, these results indicate that SOCIABLE is an effective intervention suitable for patients suffering from MCI and mild AD. Additionally, SOCIABLE has also been proven to be useful for cognitively intact elderly as a means of cognitive decline prevention. The final evaluation has also revealed positive results concerning the satisfaction and ease of use associated with the SOCIABLE platform and services. For example, it was found that the educational level of the users was a decisive factor associated with the ease of use and the learning curve associated with the SOCIABLE platform i.e. elderly with higher education could easier learn how to use the platform. As a result of the positive impact of SOCIABLE it has been proven that all the subjects involved showed more confidence in the use of the ICT, leading also to an increased use of computers comparing to the period before their SOCIABLE experience.

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