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Original article

SWEET-HOME ICT technologies for the assessment of elderly subjects

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Abstract

Functional assessments are designed to ascertain a person's ability to perform activities of daily living (ADL) and provide valuable diagnostic as well as care-planning information. Currently, the gold standard for the assessment of functional ability involves clinical rating scales. However, scales are often limited in their ability to provide objective and sensitive information. In contrast, information and communication technologies (ICT) may overcome these limitations by capturing more fully the functional, as well as behavioral and cognitive disturbances associated with Alzheimer disease (AD). In this context, the ANR Tec San 2009 SWEET-HOME project aims at building an innovative framework for modeling ADL. The first result of the SWEET-HOME project has been the installation in a classical consultation setting of a specific room equipped with audio and video sensors. This leads to the following results: (1) physical activity recognition done by patients, (e.g., balance test, repeated transfers between sitting and standing): the monitoring system is able to detect the full set of activities with a detection rate varying from 96.9% to 100% (true positive rate); (2) activity of daily living: the monitoring system had an average sensitivity of 90% and an average precision of 83.51%. Using a functional score it is possible to differentiate AD patients from healthy controls; (3) acceptability of the system: results of the survey (all the 64 participants who accepted to be assessed using the system) indicated that the assessment has been perceived as pleasant (83%).

The elderly population is expected to grow dramatically over the next 20 years. The number of people requiring care will grow accordingly while the number of people able to provide care will decrease. Without receiving sufficient care, elderly are at risk of loosing their independence. This is particularly important for persons suffering from neuropsychiatric diseases.

Alzheimer disease (AD) and related disorders represent a major challenge for health care systems with aging populations. In AD, "dementia" is diagnosed when the disease has reached the stage that the cognitive or behavioral (neuropsychiatric) symptoms interfere with social functioning or instrumental activities of daily living [1]. The National Institute on Aging and Alzheimer's Association workgroup [2] recommended that core clinical criteria, based on "functional impairment", be used to diagnose all causes of dementia, including AD, in all clinical settings. In order to determine whether functional impairment is present, the standard clinical assessment relies on questions posed to caregivers using retrospective recall of events at home, some standardized rating scales and/or the observations by a trained occupational therapist of a patient's performance during daily leisure and living activities. However, all these techniques are limited in that they cannot provide an accurate, objective and continuous measure of functional ability and no single assessment captures all areas of interest.

Finding an acceptable method of assessing functional impairment is vital since disease domains other than cognition are increasingly recognized as important outcome measures for treatment trials well as in clinical trials of anti-dementia drugs. The choice of outcome measures in these trials is often constrained by tradition and availability, and cognition-based psychometric measures are usually the preferred option. The Alzheimer's Disease Assessment Scale Cognitive subscale (ADAS-Cog), is the primary neuropsychological outcome measure for most trials in AD [3]. However, the clinical relevance

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and "meaningfulness" of such measures has been questioned as they may not adequately identify responders to therapy or address important aspects of outcome [4,5]. Functional ability, on the other hand, may impact on significantly on all aspects of the disease manifestation as well as on several caregiver aspects, and may be a more sensitive marker of disease progression or treatment response.

For this reason, information and communication technology (ICT), in particular, techniques involving imaging and video processing are of interest. Such techniques enable the patients' performances and actions in real time and real life situations to be captured and accurately evaluated. ICT methods, if used to focus on caregiver-clinician-patient desired functional outcomes, may provide more clinically relevant information to identify a meaning full response to treatment as well as to enable an accurate diagnosis of dementia. Furthermore, unanticipated changes that conventional psychometric measures may fail to capture, can be identified by such methods [6].

In this context, the ANR Tec San 2009 SWEET-HOME project aims at building an innovative framework for modeling activities of daily living (ADLs). This will be illustrated in this article with some results coming from the clinical assessment done with elderly subjects in the observation room designed for the SWEET-HOME project.

1. Methods

1.1. Ecological assessment of autonomy based on a video monitoring system and multisensors

The aim of the ecological assessment of autonomy was to determine the extent to which the participant could undertake a list of daily activities with the respect of constraint after having been given a set of instructions. The clinical scenario was divided in several parts covering basic to more complex goal directed activities:

- directed activities in order to identify characteristics of gait and walk parameters;
- semi-directed activities in order to determine the extent to which the participant could undertake a list of daily activities [7].

The SWEET-HOME project was carried out in French and Taiwanese experimental sites. The ecological assessment of IADL was conducted in a specific observation room. The first one was developed at the Nice Research Memory Center. This room was equipped with everyday objects for use in ADLs and IADLs, e.g. an armchair, a table, a tea corner, a TV, a PC, and a library. The room was equipped with household appliances. Experimental data was recorded using a 2D video camera (AXIS®, Model P1346, 8 fps - frames per second), and an ambient audio microphone (Tonsion, Model TM6, Software Audacity, WAV file format, 16 bit PCM/16 kHz). A motion sensor (e.g., MotionPod®) was fixed on the chest of the participant to quantify their movements. MotionPod® sensor provides an index of activity and estimation about the patient posture (standing, sitting, lying, walking), both of them with a resolution of one data per second.

The Taiwanese experiments took place in indoor and outdoor environments. For the indoor experiments a room equipped with household appliances was used and experimental data was recorded using eight ambient 2D video cameras (AXIS, Model 215PTZ, 30 fps). For outdoor experiments a tri-axial accelerometer mounted on the shoes of the participants was used to analyze their gait parameters [8].

Table 1
List of the activities proposed to the patient during the semi-directed clinical scenario.

Walk to the reading table and read something for 2 minutes
Walk to the coffee corner where the kettle is and boil some water
Walk to the phone and compose this number: xxxxxx
Take the watering can and water the plant
Walk to the television and turn it on with the remote control
Walk to the reading table, take the playing cards and classify them by color (reds with reds, blacks with blacks)
Take the green "ABCD" folder on the desk with the A, B, C, D sheets in it
Match the A, B, C, D sheets from the folder to one's dispersed all over the room; A with A, etc.
Put the "ABCD" folder back on the desk
Get out of the room

1.2. Study participants and clinical assessment

The study was promoted by the Nice University Hospital and funded by the National Research Agency in France (ANR, ANR-09-TECS-016-01). Ethical approval was received from the Protection of Persons Committee "Sud méditerrannée V" (CPP, N° 11029 from 2011/05/24) and the "Agence française de sécurité sanitaire des aliments et des produits de santé" (AFSSAPS n° B110465-30 from 2011/04/14). The informed consent was retrieved before the first assessment. Subjects were recruited at the Nice Research Memory Center including subjects with Alzheimer's Disease, Mild Cognitive impairment and normal healthy controls [9]. In addition to the demographic and clinical assessments French participants also had to fulfill a survey in order to rate the acceptability of the experiment and use of the sensors.

The indoor directed activity step of the scenario includes repeated transfer and walking test. In Taiwan the directed activities were done in an outdoor environment aiming at analyzing different gait parameters using the tri-axial accelerometers and the stride algorithm developed in the project. The participant is asked to walk around the ring region in the NCKU campus. During this walking period he/she performs a simple walking test of 40 m on a straight line; and a dual task test where he/she needs to walk the same distance while counting down from 100 to 1. For the semi-directed activities part of the scenario the participant have to undertake a list of daily activities in a given order, after having been given a set of instructions (Table 1).

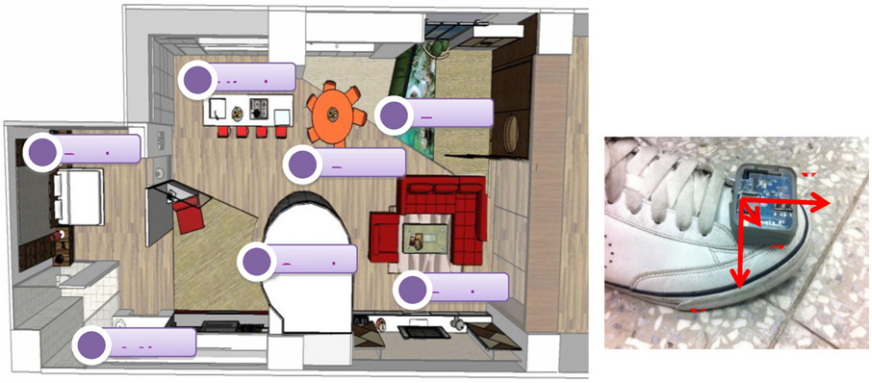

Fig. 1. The Taiwanese experiments room and the accelerometer mounted on the shoes for the outdoor experiment.

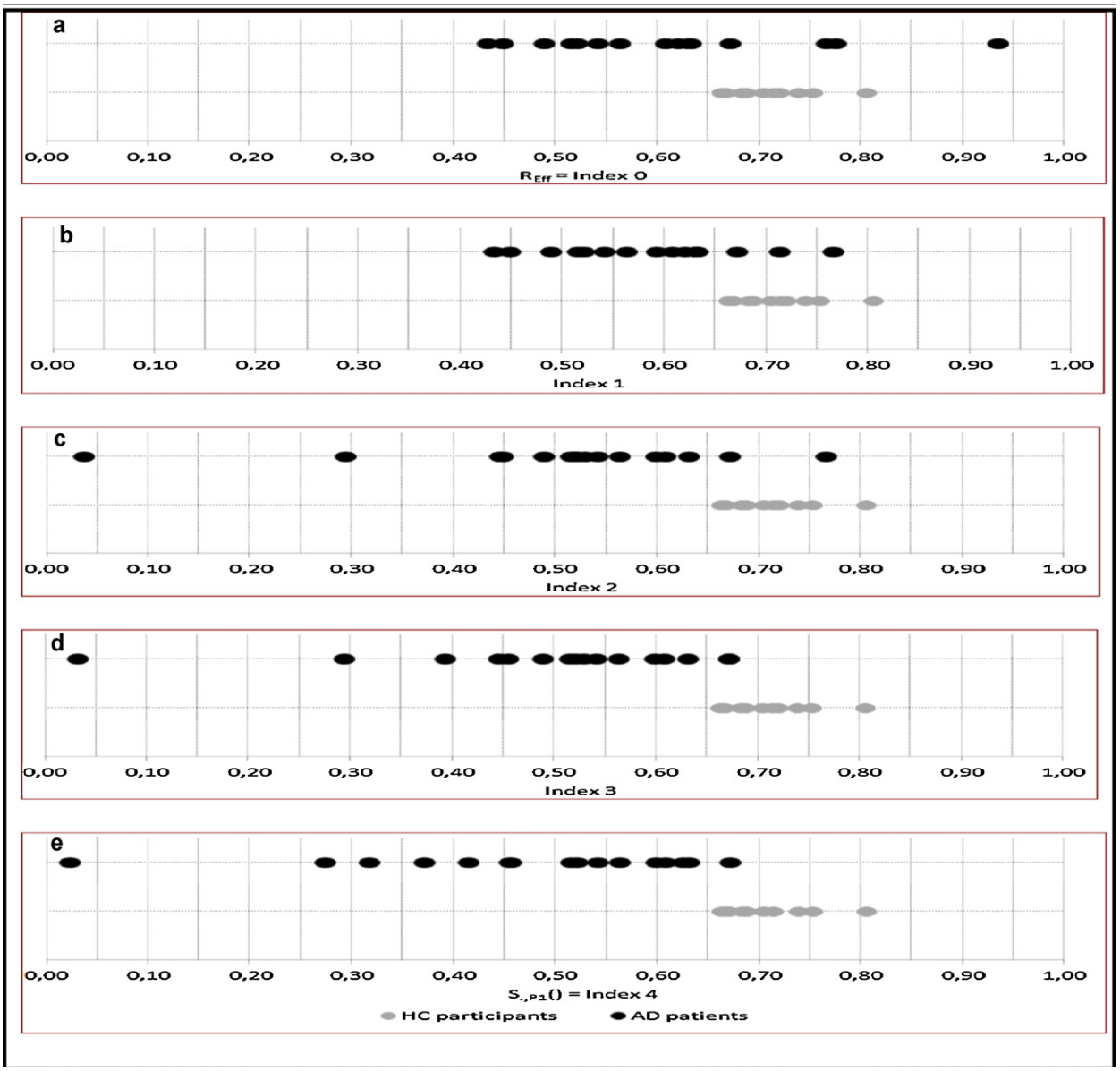

Fig. 2. Scores for Alzheimer disease (AD) patients and healthy controls participants during the semi-directed activities part of the assessment. Measurements represented for each participant j: a: REff = $Index_0$, P_1 (j) (percentage of time spent in the room to behave directed to perform a listed activities); b: $Index_1$, P_1 (j) = [REff (j)] × (impact of omission mistakes on the REff); c: $Index_2$, P_1 (j) = [REff (j)] × (cumulative impact of omission and repetition mistakes on the REff); d: $Index_3$, P_1 (j) = [REff (j)] × (cumulative impact of omission, repetition and order mistakes on the REff); e: final DAS score Sj, P_1 (k_1, P_1, k_2, P_1, k_3, P_1, k_4, P_1) (j) = [REff(j)] × (cumulative impact of omission, repetition, order mistakes and bad completion at the first attempt on the REff.

2. Results

2.1. Indoor and outdoor directed activities

The proposed system uses a constraint-based ontology to model and detect events based on different sensors readings (e.g., 2D video stream data is converted to 3D geometric information that is combined with a priori semantic information, like defined spatial zones or posture estimations given by accelerometer). The ontology language is declarative and intuitive (as it uses natural terminology), allowing medical experts to define and modify the IADL models. The proposed system was tested with 44 participants (healthy = 21, AD = 23). A stride detection algorithm was developed by the Taiwanese team for the automatic acquisition of patients gait parameters (e.g., stride length, stride frequency) using a tri-axial accelerometer embedded in a wearable device. It was tested with 33 participants (healthy = 17, Alzheimer = 16) during a 40-m walking test. The proposed system detected the full set of directed activities of the first part of our clinical protocol (e.g., repeated transfer test, walking test) with a true positive rate of 96.9% to 100% (Fig. 1).

2.2. Semi-directed activities

Sixteen participants with mild-to-moderate AD and 10 age- and gender-matched Healthy Control (HC) participants from the Nice Memory Center were evaluated clinically, cognitively, and functionally (Using the Instrumental Activity of Daily Living Evaluation [IADL-E]). During the semi-directed activity part of the scenario a measurement instrument of functional impairment was computed from quantitative and qualitative parameters collected from video recordings manually annotated by two independent clinicians (blind to the participants' clinical state).

Using data from the video monitoring system (VMS), A VMS-functional index (derived from a ratio of efficacy in ADLs [= k × time spent to correctly do the list of activities/total time in the observation room]) was validated and found to correlate strongly with cognitive (MMSE, Rho = 0.81) and IADL-E scores (Rho = −0.65), thus accurately differentiating AD (age = 76.7 ± 4.0, MMSE = 20.7 ± 2.0) from HC participants (age = 73.9 ± 4.5, MMSE = 28.1 ± 1.3). Fig. 2 shows the different functional impairment scores according to the number of qualitative parameters used to adjust the weighted ratio of efficacy RE_{ff} ($Index_0$). The differentiation between the AD and the healthy control groups increased progressively when the cumulative impact of weights k_1 (weight related to the omission, $Index_1$), k_2 (weight related to the repetition, $Index_2$), k_3 (weight related to the realization in the correct order, $Index_3$) and k_4 (weight related to the number of attempts before completing one activity, S [k_1, k_2, k_3, k_4]) were taken into account. Each of the functional impairment scores differed significantly between the two groups ($P < 0.05$).

2.3. Feasibility survey

All the 64 French participants (22 healthy controls, 30 MCI, 12 AD) who accepted to be tested using the system indicated that the assessment has been perceived as pleasant (83%). The duration and level of difficulty of the assessment has been perceived as adapted respectively by 98% and 96% of the participants. Finally, 67% of the participants were ready to accept such assessment using multiple sensors in a room of their own home but only for a limited time during the day.

3. Conclusion

The first result of the SWEET-HOME project has been the installation in France and in Taiwan of specific rooms equipped with audio and video sensors. This leads to the following results: firstly, it is possible to recognize physical activities performed by patients. The monitoring system is able to detect the full set of activities with a detection rate varying from 96.9% to 100%; secondly, using a VMS-functional score it is possible to differentiate AD patients from healthy controls. This VMS score has the potential to automatically provide a pragmatic, objective and continuous measure of cognitive and functional ability which may be useful in clinical assessments of AD patients [10] as well as for MCI patients as well as having a role as an outcome measure in clinical trials; thirdly, results of the survey indicate that the assessment has been perceived as pleasant (83%).

Disclosure of interest

P. Robert, F. Bremond declare to be involved in another European project (FP7) related to the same topic. The other authors declare that they have no conflicts of interest concerning this article.

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