# Measurement instrument for assessing functional abilities of elderly people with and without dementia using a video monitoring system

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*Abstract*— **This study presents the application of computer vision to health monitoring elderly people, improving the valuable diagnostic of person suffering from dementia symptoms. We propose a framework based on a video monitoring system (VMS) for assessing physical and cognitive abilities of elderly people during a clinical experiment. Recording sessions were divided into two steps: the first for assessing the gait, and the second for assessing cognitive abilities in daily life situations. Results of gait assessment show that patients with Alzheimer Disease (n=16, age =76.7years±4.0, %/W=11(68.75%)) had lower both walking speed and step length than Healthy Control (HC) participants (n=10, age=73.9years±4.5, %/W=5(50%)). From quantitative and qualitative data extracted from the VMS during the second step, a VMS-functional index was computed, validated and compared with current clinical rating scales. Results show that VMS-functional index was correlated strongly with standard cognitive and functional measurements (MMSE, Rho=.81, and IADL-E scores, Rho=-.65), thus accurately differentiating from healthy control (HC) participants. Results of this pilot study are promising, and need to be substantiated with a larger sample, and in another assessment room for assessing their reproducibility.**

***Keywords- Gerontechnology; Alzheimer Disease; Evaluation tool.***

## I. INTRODUCTION

Functional assessments that form part of a dementia work-up are designed to ascertain a person's ability to perform activities of daily living (ADL). Currently, functional abilities are assessed using clinical rating scales, yet scales are often limited in their ability to provide objective, sensitive and reproducible information over time. In contrast, information and communication technologies (ICT) may overcome these limitations using real-time processes though capturing behavioral and cognitive disturbances in a more detailed manner. Thus enabling clinicians to assess more objectively clinical situations and intervene appropriately by providing relevant information according to the patient's daily practice [1]-[5].

We propose a framework to assess objectively functional impairment of elderly people through an ecological and clinical experiment recorded by a video system.

## II. METHODS

### A. Recording sessions

Sixteen participants with mild- to-moderate Alzheimer's Disease 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) [6], [7]. For the first step of clinical experiment, gait parameters were assessed through a 4-meter walking test performed twice by the participants. For the second step, each participant was then asked to undertake a set of daily tasks in a smart-home setting fully equipped with everyday objects. The aim was to determine the extent to which the participant could undertake a list of daily activities in a given order, after having been guided with a set of instructions for each task of a realistic functional scenario. Before leaving the patient alone in the room, the examiner described each of the activities and the location and use of various objects needed to undertake the tasks. The examiner left the room only after being certain that the participant understood the tasks. The participant had an instructions memo at hand available anytime during the assessment. The participant could leave the room when they felt that they had completed the required tasks, though the maximum time allowed for the scenario was 20 minutes. During the completion of the scenario a video system of two video cameras (frame rate: 8fps) recorded all activities undertaken by the participant in the room.

### B. Gait parameters assessment

Gait parameters of elderly people were computed using the VMS providing the 3D geometric information of the person tracked in the scene [8]. Walking speed data computed from VMS were compared with the one provided by an ambulatory actigraph worn by participants during the clinical assessment.

### C. Functional impairment assessment

*Video annotation*

Following each recording session, two independent clinicians who were kept blind to participant's cognitive and clinical status annotated separately the video of the second step. Each clinician viewed each video at least twice to analyze each participant's gait, posture, positions in the room, and interactions with specific objects in order to ascertain the *ground truth* about each of the performed activities.

*VMS-functional index*

A measurement instrument of functional impairment (VMS-functional index) was computed from all information collected from video recordings annotated. At first, a simple quantitative ratio of efficacy was computed: $RE_{ff}$= [total time (in sec) spent by the participant in performing the listed activities / total time spent in the room]. Then, four activity parameters with a high likelihood of corresponding to functional decline were also identified and collected. Five independent clinicians (2 psychiatrists, 1 neurologist, 2 geriatricians) were asked to rate these parameters in order of increasing clinical importance (from the most to the least important: (1) omission of one of the activities; (2) repetition of the same activity; (3) incorrect order in performing the activities; (4) number of attempts before completing a given activity). The first quantitative ratio of efficacy $RE_{ff}$ was then adjusted by these parameters. This led to a functional impairment score according to the following formula, where j is a given participant:

$$S(k_1,k_2,k_3,k_4)\,(j) = [RE_{ff}(j)]\times[\,k_1^{a1(j)} \times k_2^{a2(j)} \times k_3^{1-a3(j)} \times k_4^{a4(j)}\,]$$

And *a1(j)* is the number of omissions, *a2(j)* is the number of repetitions, *a3(j)*is a binary value equal to 1 if the participant undertook all activities in the correct order, or 0 if not, and *a4(j)* is the total number of attempts before completing one activity. The model parameter set was ($k_1$, $k_2$, $k_3$, $k_4$) where the weights $k_1$, $k_2$, $k_3$ and $k_4$ verified the following relationship $0 < k_1 < k_2 < k_3 < k_4 < 1$. In the analyses, we defined the different indices of functional impairment as follows:

$$\text{Index}_0\,(j) = RE_{ff}(j)$$

$$\text{Index}_1\,(k_1)\,(j) = RE_{ff}(j) \times[\,k_1^{a1(j)}]$$

$$\text{Index}_2\,(k_1, k_2)\,(j) = RE_{ff}(j) \times[\,k_1^{a1(j)} \times k_2^{a2(j)}\,]$$

$$\text{Index}_3\,((k_1, k_2, k_3)\,(j) = RE_{ff}(j) \times[\,k_1^{a1(j)} \times k_2^{a2(j)} \times k_3^{1-a3(j)}\,]$$

To determine values of the model parameter set ($k_1$, $k_2$, $k_3$, $k_4$), the fitting procedure was divided into two steps. Firstly, 50,000 different combinations of parameter values, consistent with constraints of order defined by the independent clinicians, were drawn up using a random number generator. Secondly, multiple model parameter sets ($k_1$, $k_2$, $k_3$, $k_4$) to produce a "good fit" were selected if their associated score was both strongly and positively correlated with MMSE score, as well as being strongly and negatively correlated with IADL score using a non-parametric Spearman correlation coefficient as the criterion distance of good fit. For our analyses, the final functional impairment score S ($\kappa_1$, $\kappa_2$, $\kappa_3$, $\kappa_4$) was calibrated by using the combination of the mean of the parameters which were selected as the model parameter set during the second step of fitting procedure.

### D. Statistical analyses

Results are presented as means and its standard deviation (mean ± SD) for continuous variables, and as the number value and its associated proportion (n, %) for categorical variables. For continuous variables, intergroup comparisons were undertaken using non-parametric Mann-Whitney test, and Wilcoxon test was used to compare two paired groups. Analyses of associations were undertaken using Spearman rank correlation. The significance level was set at an alpha risk of 5% ($p < .05$). All calculations were performed using SPSS software (version 19.0).

## III. EXPERIMENTAL RESULTS

### A. Characteristics of study population

The mean age of the entire study sample was 76.5 (±7.1) years and 15 participants (40.5 %) were male. Significant intergroup difference in demographic factors (gender and age) was not found (AD group: age=76.7 ± 4.0, %/Women=11 (68.75%)); HC participants: age=73.9±4.5, %Women=5(50%)). The mean MMSE for the AD group was 20.7 (±2.0) and 28.1 (±1.3) for the healthy control group (*p<.001*). The mean IADL-E scores also differed between groups, with the AD group (14. ±1.08) having a significantly higher score compared to the Healthy Control group (10.5 ±5.9) (*p=.01*).

### B. Gait assessment

No statistical difference was seen between walking speed performed by the VMS and the one obtained by the ambulatory actigraph (*p*>.05). Table I shows that HC participants had a higher gait parameters than AD patients, for the two attempts, with a significant differences for the walking speed. Both groups had also higher gait parameters value on the second attempt than on the first attempt. Significant statistical difference between the first and the second attempt was found in AD patients for the walking speed parameter (*p<.05*).

TABLE I. GAIT PARAMETERS

| ***Mean ± SD*** | ***AD patients*** | ***NC participants*** |
|---|---|---|
| Walking speed, (m/s) | | |
| *First attempt (*)* | 0.77 ± 0.20 | 0.96 ± 0.23 |
| *Second attempt* | 0.92 ± 0.19 | 1.12 ± 0.31 |
| Step length (cm) | | |
| *First attempt* | 55.7 ± 13.6 | 62.8 ± 11.8 |
| *Second attempt* | 59.1 ± 12.5 | 67.3 ± 14.7 |

(*) Represent a significant statistical differences intergroup (AD patients vs HC participants) (p<.05).

### C. *Functional impairment assessment*

Validation of model defining the functional impairment score was done by a leave-one-out cross-validation given the small sample size (n=26). Criteria used for performed the good-fit of our model was both the Spearman coefficient correlation with MMSE and IADL-E, and the percentages of AD patients (respectively HC participants) overlapping with HC participants (respectively AD patients). Table. I shows results of validation: VMS-functional score ($S(k_1,k_2,k_3,k_4)$) is highly positively correlated with MMSE (Rho= 0.81 ± 0.02), and negatively correlated with IADL-E (Rho=-0.64 ± 0.02). These results provide satisfying reliability and stability of the functional impairment score. Only VMS-functional score of one AD patient was higher than the one of three HC participants maximum.

Table.III shows the correlation between the fitted VMS-functional score and the MMSE (respectively IADL-E) scores based on the data of the total study sample (n=26). The indexes were positively correlated with MMSE (progressive increase from .55 to .81 for the functional impairment score) and negatively correlated with IADL-E (from -.53 to -.65, for the functional impairment score). These results are consistent with our aim to develop an objective evaluation tool for functional impairment.

Figure.1 shows the 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 HC 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 ($\kappa_1$, $\kappa_2$, $\kappa_3$, $\kappa_4$)) were taken into account. Functional impairment score overlap between one AD patient (1/16) and two HC participants (2/10). Each of the functional impairment scores differed significantly between the two groups ($p$<.05).

TABLE II. LEAVE-ONE-OUT CROSS-VALIDATION

| **VMS-functional score evaluation** | |
|---|---|
| | ***Mean ±SD*** |
| Sperman's correlation between VMS-functional score and MMSE | 0.81±0.02 |
| Spearman's correlation between VMS-functional score and IADL-E | -0.64±0.02 |
| %AD overlapping with HC | 6% (min:0, max:1/16) |
| %HC overlaping with AD | 26% (min:0, max:3/10) |

TABLE III. VMS-FUNCTIONAL SCORE VALIDITY COMPARED WITH CURRENT CLINICAL RATING SCALES

| **Fitted VMS-functional score** | | |
|---|---|---|
| ***Spearman's rho*** | ***MMSE*** | ***IADL-E*** |
| $Index_0$ | 0.55 (*) | -0.53 (*) |
| $Index_1$ | 0.59 (*) | -0.62 (*) |
| $Index_2$ | 0.70 (*) | -0.64 (*) |
| $Index_3$ | 0.77 (*) | -0.65 (*) |
| S ($\kappa_1$, $\kappa_2$, $\kappa_3$, $\kappa_4$) | 0.81 (*) | -0.65 (*) |

(*) Represent a significant correlation between the functional impairment score considered and the medical evaluation tool.


Figure 1. - Functional impairment scores for AD patients and HC participantss. Measures represented for each participant *j* : a) $Index_0(j)$ =Ratio of efficacy(j); b) $Index_1(j)$ Ratio of efficacy(j)× $k_1^{a1(j)}$ ; c) $Index_2(j)$ = Ratio of efficacy(j)× $k_1^{a1(j)}$× $k_2^{a2(j)}$ ; d) $Index_3(j)$ = Ratio of efficacy(j)× $k_1^{a1(j)}$× $k_2^{a2(j)}$ × $k_3^{1-a3(j)}$; e) Final functional impairment score: S ($\kappa_1$, $\kappa_2$, $\kappa_3$, $\kappa_4$)(j) = Ratio of efficacy(j)×$k_1^{a1(j)}$ × $k_2^{a2(j)}$ × $k_3^{1-a3(j)}$ × $k_4^{a4(j)}$

## IV. CONCLUSION

This study demonstrated the application of a VMS in the assessment of different dimensions of functional abilities in elderly people. We sought to use the VMS to evaluate participants' functional impairment, thereby validating a method of quantitative evaluation that could significantly enhance the objectivity of functional assessments in dementia. The clinical phenomenology of AD encompasses symptoms that extend into various domains, including cognition, behaviour and daily functioning. VMS allows the interaction between these different domains to be assessed during participants' performance of a pre-determined clinical scenario. The VMS method also made it possible to define an objective and continuous measures of functional impairment disturbances, which could be reproducible over time.

One of the current limitations of the VMS system was that only part (the relative position of the participant in the room) of the evaluation of the video was automated. The majority of the

*ground truth* ascertainment was undertaken using manual annotation. This process was laborious and time-consuming but it was a necessary first step in order to create a standardized template from which automated annotation software is being developed. This method is promising but needs to be refined in order to become a fully automated activity recognition process. Secondly, our results need to be replicated in larger samples and in other experimental conditions (assessment room).

In summary, this pilot study outlines a novel and unique application of a video monitoring system for use in dementia. This system has the potential to provide the first automated pragmatic tool for both an objective and continuous measure of cognitive and functional ability for the assessment.

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