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Psychometric Evaluation Supported by a Social Robot: Personality Factors and Technology Acceptance

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***Abstract*— Robotic psychological assessment is a novel field of research that explores social robots as psychometric tools for providing quick and reliable screening exams. In this study, we involved elderly participants to compare the prototype of a robotic cognitive test with a traditional paper-and-pencil psychometric tool. Moreover, we explored the influence of personality factors and technology acceptance on the testing. Results demonstrate the validity of the robotic assessment conducted under professional supervision. Additionally, results show the positive influence of Openness to experience on the interaction with robot's interfaces, and that some factors influencing technology acceptance, such as Anxiety, Trust, and Intention to use, correlate with the performance in the psychometric tests. Technical feasibility and user acceptance of the robotic platform are also discussed.**

I. Introduction

Social humanoid robots have been successfully integrated into health-care to provide specialized treatments and services [1], but very few studies have been exploring the application of robotics in the diagnostic process. As shown in a previous work [2], a robot-assisted cognitive assessment could guarantee many advantages, in fact by design robots can guarantee test standardization and assessor neutrality. The use of humanoid social robots appears to be particularly useful in assisting professionals to detect initial signs of impairment by allowing large-scale screenings as robots can be deployed also outside the clinic. Indeed, various studies began to investigate this new field of research, collecting initial promising data. For example, humanoid social robots have been used to administer Patient Reported Outcome Measurement questionnaires to elderly persons [3] and to improve Autistic Spectrum Disorder diagnosis [4].

Further support to this approach is given by the preference of interacting with a humanoid social robot rather than with a non-embodied computer screen, shown by both young and senior users [5], [6]. When a person interacts with an embodied physical agent, he/she is typically more engaged and influenced by the interaction with respect to other technologies [7] and it has been shown that subjects are more likely to value their experience as more satisfying when confronting with human-like interfaces [6], so making them a viable solution to automatic psychometric evaluation.

First results, presented in [8], showed the viability of robotic cognitive assessment by comparing the Montreal Cognitive Assessment (MoCA) test to a prototype of a MoCA-inspired robotic cognitive exam, administered by the SoftBank humanoid robot Pepper. Although the findings were encouraging, further investigation with senior participants and another test as an external criterion were needed.

Moreover, to fully exploit the use of a social robot as a clinical tool, it is necessary to measure its psychometric properties, but also to define all the factors that might influence Human-Robot Interaction (HRI) and user performance. When evaluating people's responses towards the interaction with a robot, it is important to consider their personal characteristics since they could be predisposed to like or dislike robots in general. Indeed, in this work, we also explore the influence of personality factors and technology acceptance on the cognitive test performance, as previous literature had shown the effect of factors like personal innovativeness [9] and openness to experience [10] in the use and evaluation of new technologies.

Objectives of the study are: i) to evaluate the feasibility or external validity of the robotic test by a correlation between score from robot test and score from a similar paper and pencil cognitive test; ii) to explore the influence of personality factors on psychometric assessments; iii) to collect data on the acceptance of the robotic platform by senior users. To achieve our objectives, we administered an upgraded version of the MoCA-inspired robotic cognitive test to a sample of elderly people, who were also tested with the traditional paper-and-pencil Addenbrooke's Cognitive Examination Revised (ACE-R) test [11]. NEO Personality Inventory-3 (NEO-PI-3) [12] and an Italian version of the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire [13] were used respectively to evaluate personality traits and technology acceptance.

Results showed that a social robot can be a viable solution to the psychometric assessment of elderly. Additionally, we observed a positive influence of the Openness to experience factor on the interaction with the robot. The Anxiety has a moderate correlation with the participants Visuo-spatial capabilities, and there is a negative correlation between Trust on technology and Attention score. Moreover, we found an association between Intention to use and Delayed Recall. These findings contribute to our understanding of how to

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design HRI in the case of using the robot as a psychometric evaluation tool. They also contribute to understanding how elderly users accept assistive social agents and who are the subjects that can potentially positively respond to a robot-based assessment procedure.

II. Materials and Methods

A. The Traditional Cognitive and Personality Assessment

The traditional assessment of cognitive status and personality was conducted by neuropsychologists through the Addenbrookes Cognitive Examination Revised (ACE-R) and the NEO Personality Inventory-3 (NEO-PI-3) tests.

The ACE-R is a rapid screening battery assessing several cognitive domains; it includes 11 items of Mini Mental State Examination plus other 15 tasks whose combination produces five sub-scores exploring cognitive domains similar to those evaluated in the Montreal Cognitive Assessment (MoCA): attention/orientation (score range: 0-18); memory (score range: 0-26); fluency (score range: 0-14); language (score range: 0-26); visuospatial (score range: 0-16). The ACE-R maximum score is 100.

The NEO Personality Inventory is internationally recognized as the *gold standard* instrument to measure personality. It consists of 240 items and measures five dimensions of the personality according to Big Five Model: Neuroticism (score range: 47-315), Extraversion (score range: 46-230), Openness (score range: 48-240), Agreeableness (score range: 48-240), and Conscientiousness (score range: 48-240).

B. The Robotic Cognitive Assessment

The robotic assessment was conducted by a social humanoid robot, which was programmed to administer and score some cognitive tasks inspired by the Montreal Cognitive Assessment test (MoCA), a brief screening tool for Mild Cognitive Impairment [14] freely available from the official website, used in 100 countries around the world and translated into 46 languages. Our robotic cognitive test assesses the same areas of the MoCAs, therefore we have the same eight subtests that for simplicity have the same names: Visuospatial/executive (alternating trail making, copying a cube, drawing of the clock), Naming, Memory, Attention (digit span, vigilance, serial), Language (sentence repetition, fluency), Abstraction, Delayed Recall, and Orientation. The maximum global score is 30.

As a result of the cognitive assessment, the robot will provide: i) an automatic score registered by the robot, with verbal transcriptions and audio/video recordings of the administration; and ii) a supervised score calculated by a psychologist through the recordings available, to obtain the actual score achieved by the user. Details on the development process can be found in [2].

The prototype used in the experiment presented in this article has been further developed: after the pilot test [2] the user feedback was used to improve the interaction and reliability; the multi-modal interface was translated in Italian, including a more expressive movement of the robot to provide additional cues for a more intuitive interaction, the sensitivity of the automatic score was tuned, and a sound was added to confirm the correct registration of user's answers.

During the administration, the robot gave all the instructions using the text-to-speech and used its sensors to receive people's input and track behaviors: speech recognition, visual recognition, face tracking, pressure sensors, and tablet. Each session was audio and video recorded by both the robot and an external camera.

C. The Unified Theory of Acceptance and Use of Technology

To determine the strength of predictors for elderly participants' intention to accept and use the humanoid robot as a psychometric tool, we adopted the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire [15], that represents an instrument to measure the variety of perceptions of information technology innovations. We adopted the version of the UTAUT questionnaire proposed by [16] because it was already adapted and validated in the similar context of assistive robotics applied to elderly users. This UTAUT questionnaire consists of 41 items and explores 12 constructs: Anxiety (ANX), Attitude (ATT), Facilitating conditions (FC), Intention to use (ITU), Perceived adaptability (PAD), Perceived enjoyment (PENJ), Perceived ease of use (PEOU), Perceived sociability (PS), Perceived usefulness (PU), Social influence (SI), Social Presence (SP) and Trust. Subjects are required to reply to each item on a Likert type scale (range: 1-5). The questionnaire was translated from English to Italian by two psychologists and an engineer, that were proficient in English and Italian and familiar with HRI. The translation was examined at a consensus meeting, back-translated, and approved at a second consensus meeting. A comprehension test was carried out in a subgroup of 15 individuals aged 18 years. This consisted of a face-to-face interview during which the interviewer inquired whether the subject had any difficulty in understanding the questions and the pre-coded answers. A comprehension rate was obtained as the percentage of questions and pre-coded answers of all items correctly understood by subjects. In the test, more than 90% of subjects found the questions easy to understand and had no difficulty in interpreting the answer modes. The final Italian version of the questionnaire is available from the authors upon request.

III. Experiments

A. Pepper Robot

The robotic platform used in our experiments is the Softbank Pepper robot. Table I presents the robot interfaces and how these are used to implement the test sub-components.

Similarly to the MoCA, the administration included two more tasks, one at the beginning of the test (the *welcome task*) and one at the end (the *thank you task*). In the welcome task, Pepper introduced itself and asked the participant to provide his/her age, gender and years of education. This was meant both to collect important information about the person, as well as to train him/her on HRI. The robot could recognize and follow the face in front of it for to better engaging the

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TABLE I
ROBOTIC TEST SUB-COMPONENTS AND CORRESPONDING INTERFACES USED

	Speech prod.	Speech recogn.	Tablet	Pressure sensors	Visual recogn.
Visuo-spatial Executive	Instructions	None	Characters to connect, image to copy additional cue (clock)	None	User's drawings
Naming	Instructions	User Answers	Images to recognize	None	None
Memory	Instructions, words to learn	User Answers	None	None	None
Attention	Instructions, numbers to recall	User Answers	Additional cue (vigilance)	Head (vigilance)	None
Language	Instructions, sentences to repeat	User Answers	None	None	None
Abstraction	Instructions, objects to categorize	User Answers	None	None	None
Delayed Recall	Instructions	User Answers	None	None	None
Orientation	Instructions	User Answers	None	None	None

participant, and it moved its arms and hands as suggested in the literature in the case of HRI with adults [17].

The timing of the administration was regulated by internal timers that were set empirically. Therefore, if the participant did not complete a task, the session continued when those internal timers expired. Pepper audio-recorded the whole session and took photos of the second and third tasks' drawings; moreover, it produced a *Dialogue file* with the transcription of the verbal conversation with the participant and a *Log file* containing the automatic score achieved. This way, a clinical psychologist was able to fully review the administration and re-evaluate.

B. Participants

An initial sample of 21 native-speaker Italian elderly participants was enrolled by the Department of Psychology of the University of Campania "Luigi Vanvitelli". Among these, 19 subjects (Males = 11, Females = 8) completed both the robotic cognitive assessment and the traditional paper-and-pencil cognitive and personality evaluation. As important variables, we considered their age (range = 53-82, M = 61.16, SD = 7.819) and years of education (range = 8-18, M = 12.16, SD = 3.56).

C. Procedure

Tests were performed in February 2018 at the University of Naples Federico II, where a large laboratory area has been transformed into a small furnished house, trying to simulate as hard as possible a perfect daily environment. After being welcomed, informed about the procedure and having signed a consent form, the elderly participants were led to a first room, where they completed Neo-PI-3 under the supervision of a psychologist and also underwent ACE-R, performed by neuropsychologists.

After this first phase, the participants were conducted in the laboratory and left alone with the robot. The robotic session was entirely run by Pepper: it gave the instructions, registered the answers and calculated the scoring. The experimenter did not interfere with the interaction and monitored the tests from another room. The session was video-recorded and timed. In order to have as spontaneous behavior as possible, the participants were not aware of being recorded by cameras during the activities.

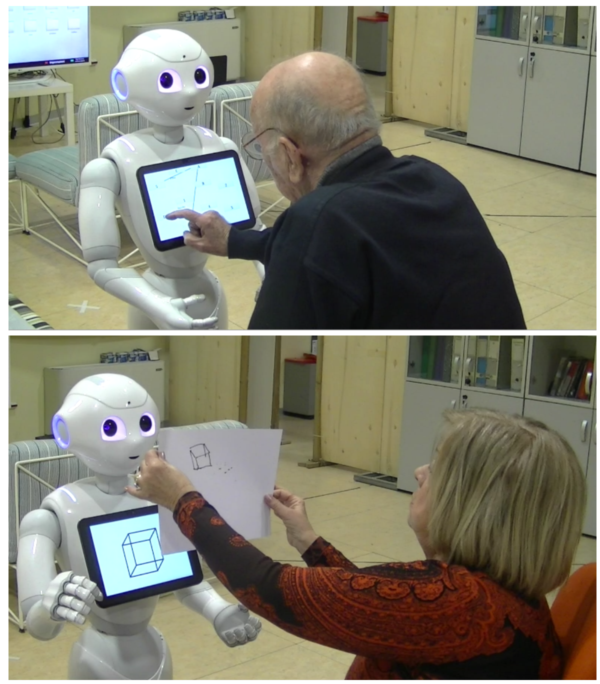

Fig. 1. Screen-shots from the testing phases

At the end of the interaction with the robot, the UTAUT questionnaire was administrated by the psychologists to evaluate the level of technology acceptance by the participants after the physical and social interaction with the robot. Each test session lasted for approximately 45 minutes.

As the order of presentation and administration of the tests could affect the performance in the cognitive tests, the order of presentation of the tools used in the tests was always the same for all subjects. In particular, the most complex cognitive tests were administered for first in order to avoid a possible effect of fatigue and emotional involvement. In Figure 1, few screen-shots of the testing phase are shown.

D. Statistical Analysis

The data were analyzed with the SPSS software (version 24). First, descriptive statistics were calculated: average scores, minimum, maximum, standard deviation. Then, Spearman and Pearson correlations - chosen according to the shape of the distribution and the typology of data -

were calculated to check the validity of the robotic system comparing automatic and supervised scores; and to explore the relationship between personality factors, technology acceptance, and cognitive assessment. Regression analysis, finally, was used to confirm the predictive role of a specific personality factor towards the automatic robotic score.

IV. RESULTS

A. *Descriptive statistics: ACE-R, NEO-PI-3, Robotic and UTAUT Scores*

With regards to the paper and pencil psychometric instruments, the participants achieved a mean total score of 90.42 for ACE-R (range=78-96; SD=4.17).

NEO-PI-3 personality factors' average global scores were as follows: Neuroticism=128.32 (range=94-174; SD=23.09), Extraversion=144.32 (range=111-197; SD=21.51), Openness to experience=146.68 (range=114-198; SD=22.35), Agreeableness=166.2 (range=129-208; SD=18.17) and Conscientiousness=175 (range=132-208; SD=20.86).

The average of the automatic global score for the robotic test is 13.74 (range=7-20; SD=3.43), while after the professional revision, the supervised average of the global score for the robotic test is 21.26 (range=13-27; SD=3.98). The subset results respectively of the supervised and automatic subsets scores are shown in Table II.

TABLE II

SUPERVISED AND AUTOMATIC SUBSETS SCORES

	Automatic				Supervised			
subset	**avg**	**min**	**max**	**std**	**avg**	**min**	**max**	**std**
Visuo-spatial	0.53	0	1	0.51	3.42	0	5	1.43
Naming	2.68	1	3	0.67	3	1	3	0
Attention	1.42	0	3	1.07	4.16	1	6	1.34
Language	1.74	0	3	0.93	2.05	1	3	0.78
Abstraction	1.37	0	2	0.68	1.16	0	2	0.77
Delayed Recall	2.74	0	5	1.49	2.68	0	5	1.73
Orientation	3.26	2	5	0.93	4.79	3	6	0.92

Finally, UTAUT average construct scores are shown in Table III. The reliability of the UTAUT questionnaire was established by calculating Cronbach's alpha for each of the 12 constructs (each one consisting of different questions). Results showed a value of 0.868 that indicated an high level of internal consistency (Cronbach's alpha minimum value in the case of a deleted construct is 0.838). For each construct, the result has been divided with respect to the number of questions characterizing the construct.

B. *Correlations among Cognitive Scores*

Table IV reports bivariate Spearman correlations between the average global scores of the ACE-R, the robotic automatic and supervised scores. There is a quite high and significant relationship between the robotic supervised score and the ACE-R (ρ=0.46; $p < .05$), which confirms the concurrent external validity of the robotic assessment after expert revision. However, the correlation between the automatic robotic score and the ACE-R is not significant, but still above the medium effect-size according to Cohen's criteria [18] (ρ=0.42).

TABLE III

UTAUT RESULTS

Code	Construct	Max	Min	Avg	Std
ANX	Anxiety	4.75	2.5	3.76	0.66
ATT	Attitude	5	1	4.02	1.02
FC	Facilitating conditions	4.5	1	2.92	0.98
ITU	Intention to use	5	1	2.77	1.21
PAD	Perceived adaptability	5	1	3.68	0.99
PENJ	Perceived enjoyment	5	1.4	4.15	0.82
PEOU	Perceived ease of use	4.6	2.4	3.59	0.65
PS	Perceived sociability	5	1.25	3.72	0.96
PU	Perceived usefulness	5	1.33	3.91	0.99
SI	Social influence	5	2	3.39	0.74
SP	Social presence	5	1.2	3.04	0.96
TR	Trust	5	1	3.18	1.30

TABLE IV

SPEARMAN CORRELATIONS AMONG GLOBAL SCORES

	ACE-R	Automatic score	Supervised score
ACE-R	1		
Automatic score	0.42	1	
Supervised score	0.46*	0.45	1

*$p < .05$

Considering the sub-components of each psychometric tool, we found out that ACE-R's fluency strongly and significantly correlates with the robotic automatic language subtest (r=0.69; $p < .01$) and with the robotic supervised language subtest (r=0.48; $p < .05$).

C. *Correlations Among Personality Factors and Cognitive Scores*

Spearman correlations were calculated to investigate the relationship between the traditional and robotic cognitive assessments and NEO-PI-3 personality factors (see Table V). Results showed that the only strong and significant relationship was between the robotic automatic score and *Openness to experience* dimension (ρ=0.58; $p < .01$).

TABLE V

SPEARMAN CORRELATIONS AMONG GLOBAL SCORES AND NEO-PI-3 PERSONALITY FACTORS

	Automatic score	Supervised score	ACE-R
Neuroticism	-0.32	-0.22	-0.21
Extraversion	0.37	-0.02	0.09
Openness	0.58**	0.44	0.34
Agreeableness	0.12	0.15	-0.14
Conscientiousness	-0.08	-0.32	-0.08

**$p < .01$

In more detail, the robotic *automatic Attention* subtest strongly and significantly correlates with *Extraversion* (r=0.63; $p < .01$), the robotic *automatic Language* subtest with *Openness to experience* (r=0.52; $p < .05$) and the robotic *automatic Naming* subtest with *Neuroticism* (r=0.47; $p < .05$). No other significant correlations involving personality factors were found.

D. *Correlations Among Cognitive Scores and UTAUT*

Results in Table VI showed that the *Anxiety* has a moderate correlation with the supervised evaluation of *Visuospatial* capabilities, while the *Social Presence* was inversely correlated

TABLE VI

SPEARMAN SIGNIFICANT CORRELATIONS AMONG UTAUT RESULTS AND COGNITIVE AUTOMATIC SCORES (A) AND SUPERVISED (S)

UTAUT	Visuo-spatial(S)	Visuo-spatial(A)	Attention (S)	Delayed/ Recall(S)
ANX	.470*			
SP		-.551*		
ITU				.474*
TRUST			-.489*	

$*p < .05$

with the automatic one. We found also an inverse correlation of *Trust* with the supervised evaluation of *Attention*. Finally, a moderate correlation of *Delayed Recall* with the supervised evaluation of *Intention of Use* has been observed.

E. Linear Regression

To further investigate the relationship between personality and robotic automatic score, we performed a linear regression analysis. On the basis of the correlation results shown in Table VII, *Openness to experience* is the only factor that could significantly contribute to the robotic automatic score, therefore, we considered this as the only independent variable.

TABLE VII

LINEAR REGRESSION ANALYSIS - PREDICTORS: PERSONALITY FACTORS; DEPENDENT VARIABLE: AUTOMATIC SCORE

	Automatic score R^2=.394		
Personality factor	β	**t**	***p***
Openness to Experience	0.63	3.33	$< .01$

The regression analysis confirms that the *Openness to experience* facilitates the interaction with the robot and therefore improves the automatic scoring.

V. DISCUSSION

Our finding of an association between the cognitive test performance on robot-assisted MoCA and Openness to experience might indicate that this specific trait plays a relevant contribution to performance in elderly people when a neuropsychological test is proposed by a humanoid robot. This finding could be explained bearing in mind that Openness is a personality trait related to the tendency to be receptive to new ideas and experiences, thus the physical/social interaction with a robot may represent a novel experience for elderly people. The relation between the Openness to experience and the automatic scoring only suggests that the attitude toward the novel technology can facilitate the unsupervised application of the robotic instrument for cognitive assessment. On the other hand, this underlines the importance to properly design the multimodal interfaces of the robot in such a way that the interaction is facilitated and effective also for those not inclined to use the social robot.

For the UTAUT, we consider a positive perception of a participant when the construct score is greater than 3, while a negative perception is when average score is lower than 3. Starting from these results, we can assess that participants had a fairly positive perception of the main characteristics of the robot, such as adaptability, sociability, and usefulness. Furthermore, they have been positively influenced by the social aspects of the interaction.

The observation of an association between Anxiety of UTAUT and supervised Visuospatial score indicates that a high level of anxiety experienced when using a novel system could help cognitive test performance. This finding is supported by evidence which shows that the state of anxiety has not a negative impact on cognition in elderly people [19], but rather it can improve the selectivity of attention [20], thus leading to an enhancement of the cognitive test performances. Taking into account this previous evidence, our finding could be explained by the fact that the interaction with a robot, being an unusual and novel situation for elderly participants, can have determined a state of anxiety, particularly during the first MoCA subtasks. This anxiety state could also have facilitated the selectivity of attention [21] on visuo-spatial tasks.

The negative correlation between Trust of UTAUT and supervised Attention score might indicate that elderly with a high level of attention may believe to not need to follow suggestions or advises provided by a robot. Moreover, the association between a high score on ITU of UTAUT questionnaire and high supervised Delayed Recall score might suggest that elderly people with higher memory performance seemed to be more willing to use the system over a longer period. This positive intention might be associated with the idea that the technology can improve the memory, stimulate learning of new things or facts and help people to preserve their memory against age-dependent decline as previously demonstrated [22].

Results of the correlation analysis were not statistically significant with regards to the automatic robotic assessment score. This divergence might depend only on the different methodology used to score the user performance, which was biased by the limitations of speech and visual recognition. Even, the negative correlation between the Social presence of UTAUT and the automatic Visuospatial score should be interpreted cautiously since it is shown only in the automatic evaluation. This divergence might depend again on the different methodology used to score the participants' performance in the two visuospatial subtests: in supervised evaluation, the scoring was performed directly on participant's outcome on the paper sheet, whereas in automatic scoring method, when each participant finished the drawing task, he/she had to put the outcome in front of Pepper's head to allow Pepper to record it; therefore, it might be that our elderly participants did not correctly position their drawings and, thus, Pepper was not able of recording the outcome.

This study may have some limitations, as the small number of participants, the difference between instruments MoCA and ACE-R, and the Hawthorne Effect, also known as the observer effect, which supposes the alteration of subjects conduct because of their awareness of being observed. The results and limitations of the present study will be feedback future work where we aim to design a new trial with a larger sample to provide further evidence. In future work, we will also firther explore the use of the most advanced AI Cloud services that demonstrated to be beneficial to improve the automatic scoring of the tests [23].

VI. Conclusions

This paper explores the viability of social robots as psychometric tools for quick and reliable screening of a person's cognitive level. To this end, we involved 21 elderly participants into a comparative study, where a robotic cognitive test prototype was compared to standard and supervised psychometric assessment procedures. In order to evaluate the acceptance of such a robot prototype by the participants and to analyze to what extent this may have been influenced by their particular personality traits, elderly participants were administered other tests for traditional cognitive and personality assessment performed by neuropsychologists. They were also asked to fill a questionnaire based on the UTAUT model after interacting with the robot to register the level of usability and acceptance of the technology.

The results show that the Openness to experience of the participants has a positive influence on the automatic scoring performed via the robot's AI software (mainly speech and object recognition). This may be explained by the limitations of the robot interfaces, especially the speech recognition, which requires some adaptation from the user for best performance. This finding may be of paramount importance in the design of psychometric assessment tools that are administered by artificial agents like robots. In fact, the final score may be affected by the personality of the subject and, therefore, roboticists should better understand how to adapt the robot behavior in order to provide a more familiar interaction also to those that are close to innovation. However, after expert revision of the results, the supervised scores are not affected by this bias. This result suggests the viability of the robotic cognitive assessment, after the appropriate development of the technology, which should reach a human-like reliability.

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