BRAININFO 2019

The Fourth International Conference on Neuroscience and Cognitive Brain Information

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BRAININFO 2019 Editors

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BRAININFO 2019

Foreword

The Fourth International Conference on Neuroscience and Cognitive Brain Information (BRAININFO 2019), held between June 30 – July 4, 2019 - Rome, Italy was dedicated to evaluate current achievements and identify potential ways of making use of the acquired knowledge, covering, the neuroscience, brain connectivity, brain intelligence paradigms, cognitive information, and specific applications.

Complexity of the human brain and its cognitive actions stimulated many researches for decades. Most of the findings were adapted in virtual/artificial systems in the idea of brain-like modeling them and used in human-centered medical cures, especially for neurotechnologies. Information representation, retrieval, and internal data connections still constitutes a domain where solutions are either missing or in a very early stage.

We take here the opportunity to warmly thank all the members of the BRAININFO 2019 Technical Program Committee, as well as the numerous reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to BRAININFO 2019. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the BRAININFO 2019 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that BRAININFO 2019 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the area of neuroscience and cognitive brain information.

We are convinced that the participants found the event useful and communications very open. We also hope that Rome provided a pleasant environment during the conference and everyone saved some time for exploring this beautiful city.

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Why Do Seniors Accept or Reject New Technologies? Towards Developing a Seniors Oriented Technology Acceptance Model

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***Abstract*— On the background of literature review and field-research, this article proposes a new conceptual model for understanding why seniors accept or reject new technologies and gerontechnologies. This framework bears a special focus on the relation between TV and seniors because it has been developed in the context of a new gerontechnological TV device, Senior-TV. The already existent technology acceptance models are focusing on youth and people on the job, and little research has been carried out in the area of elderly people. Hence, we inquire into the seniors' behavioral intention towards the use of new technologies, aiming to develop a multiple-perspective conceptual model: 1) by employing a gerontographics approach, which gives a more complex data disaggregation in order to better understand the needs of the seniors; 2) by overcoming the classic TAM and UTAUT models and refining the existent models of technology acceptance tailored to seniors' market, and to incorporate other potential relevant explanatory variables; 3) by a more in-depth understanding of the relevance of technology attributed by seniors in their life; 4) by diversifying the key informers in order to have a multifaceted perspective, such as formal and informal caregivers and to better understand how do they relate to the relation between seniors and technology. The data for the analysis came from purpose sample of 148 seniors, a survey conducted over 2017-18 in Slovenia, Romania and Cyprus and a follow-up survey conducted from February to April 2019 in the same countries, with a sample of 105 seniors, which informs on the new framework proposed here. Our research show that based on a gerontographics segmentation, scholars and practitioners alike may understand, on the one hand, the influences of seniors' technology experimentation and acceptance, and, on the other hand, seniors' openness towards specific types of technologies. In order to account for the seniors' perspective on the relevance of technologies in their life, based on the gerontographics segmentation, we mapped their interests and predisposition towards the attributes of technologies. The degree to which developers meet these interest and predispositions of the seniors, give the ascendance of the new product or service of the seniors' market.**

Keywords- technology adoption; gerontechnology; gerontographics; technology acceptance model.

I. BENEFITS OF NEW TECHNOLOGIES AND GERONTECHNOLOGIES

The population is ageing. It is widely believed that the development of new technologies and gerontechnologies can tremendously help societies in facing the challenges posed by the ageing population. The increasing number of seniors in our societies build a demand for entertainment, communication, education and health and open new markets for the new technology developers [1]-[3]. Though little is known of the seniors' behavioral intention and preferences toward new technologies. Technology is of special focus due to the widespread and unchallenged societal acceptance that technology may improve the quality of elderly people not only in terms of their healthiness [4], but also in psychological and social terms, such as reducing loneliness, anxiety, social isolation [5], and lowering self-esteem, which impacts dramatically on the poor cognitive functioning [6]-[8], mortality [9][10], impaired sleep [11], impaired mental health and Alzheimer's disease [12]. The benefits brought by ICT for seniors are also discussed in the literature [13]-[15] and some research show that seniors benefit from ICT through perceiving the life stress much lower, due to the fact that via ICT the seniors improve their connection to outside world and so their life quality increases [16]-[18]. If technology advancement improves the ways of communication, information and entertainment while staying at home, this potential is highly appreciated for the beneficial improvements technology has made for the people aged over 65.

II. CURRENT BARRIERS IN TECHNOLOGY ADOPTION BY SENIORS

There are two types of recurrent barriers which occur when developing new technologies for seniors. The first refers to assuming a relative homogeneous market of people aged over 65 and, the second refers to overlooking the social influences of formal and informal carers and of the relevance and meaning attributed to new technologies and gerontechnologies by the seniors.

Delello and McWhorter [19] emphasize that the obstacles

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for the adoption of technology by elderly include: costs [20], inappropriate design, experience, awareness [21], attitude [22], self-efficacy [23], and a general lack of interest [24]. Demiris et al [25] address the psychological barriers identified as the privacy violations from the cameras, the replacement of human assistance by technology, the user-friendliness of technology. The specific needs of the older persons are not taking into consideration when developing technology and, moreover, those who design and develop technology are young, who hold different needs and abilities [26]. Therefore, elderly people adopts with difficulty new technologies because of the age-related impairments, vision, hearing and memory loss, and loss of mobility, which lead to less of confidence and difficulties. Hence, Boulton-Lewis et al add embarrassment with lack of abilities, reduced dexterity and visual acuity and memory loss.

Mitzner et al [27] found that the openness towards adopting new technology is related to the support offered by technology to everyday tasks, convenience and useful characteristics, while the reluctance is related to the inconveniences created, unhelpful characteristics, and security and reliability concerns. Oestlund [28] points out to the perception of a limited future, the increased feeling of fatigue and circumspection, which all significantly reduce the appetite for new technology.

Bringing together older adults and technology, gerontechnology is a fast growing interdisciplinary domain [19]. The differentiation between the adoption of gerontechnology and of the new technology by seniors is also of crucial importance. Gerontechnology refers to inquiring into human-computer interaction for seniors and it requires an interdisciplinary journey into nursing, gerontology and social work, while new technologies adoption by seniors does not employ the nursing perspective. However, the gerontologists draw attention to the phenomenon of the too fast growing technology while the implications can be understood in time.

III. TOWARDS A NOVEL MODEL OF TECHNOLOGY ACCEPTANCE BY SENIORS

The first two pilot cycles employed by our research were aimed to adapt and test the most frequent used theoretical models on technology acceptance. The first field reseach cycle was based on Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) models, but they proved insufficiently explanatory when applied to the seniors due to the fact that these frameworks are constructed and tailored on students and people on the job. Therefore, most of the items were irrelevant for the older people and they failed to offer a conceptual understanding of how technology can be integrating with aging [29].

In the last years, new research started to be developed to overcome TAM model and for developing a more in-depth understanding of gerontechnology. Technology Acceptance Model (TAM) was proposed by Davis [30] and it was at the center of an overwhelmingly high number of researches regarding technology adoption but, among all, just a few studies focused on senior citizens [3]. Afterwards, Davis proposed TAM2, adding subjective norms into the model. Because the research on seniors is quite rare, more research is needed for conclusive results for this specific target group. TAM model proves to be easy replicable and consistent across technologies [31] but, along Legris et al [32], researchers advice for a more systematic study of external variables. After about 20 years since the TAM model was proposed, Venkatesh et al. [33] discuss the fu

ture of this model for research and emphasize that the model has been widely replicated because of its simplicity and easiness of generalizability, though its relevance is limited. Substantial changes have been introduced in The Unified Theory of Acceptance and the Use of Technology Model, UTAUT1 and UTAUT 2 models. Legris et al [32] suggest to integrate the model into broader frameworks which include human and social factors and the adoption of innovation model.

For the third pilot cylce, we included the lessons learned from the first two cycles and tested two conceptual models in order to assess their explanatory power: the Senior Technology Acceptance Model (STAM), which was proposed by Renaud and Biljon [34] and the Gerontechnology Acceptance Model proposed by Chen and Chan [35]. The first stays as the earliest effort for conceptual theorization of predicting technology acceptance and adoption by seniors and it was designed to predict older adults' mobile phone adoption. The model proposed by Chen and Chan [35] is built on the inquiry into gerontechnology acceptance by elderly from Hong Kong. Both models are based on TAM and UTAUT classic models. We complemented the findings with a qualitative inquiry into the contextual factors that shape technology adoption. Hence, we build up a conceptual framework to integrate both various models tested in quantitative studies and the qualitative research related to our topic.

A. Methodology

There are two field-research stages employed in our analysis which had been carried out under the Active and Assistive Living (AAL) Program with funding by the European Union. The data for the first analysis came from purpose sample of 148 seniors, two surveys conducted over 2017-18 in Slovenia, Romania and Cyprus and the second analysis consists of a follow-up survey conducted from February to April 2019 in the same countries and having a sample of 105 senior respondents. The primary goal of the overall research was to explore the levels of adoption by senior consumers of a new emerging technology, Senior-TV. In order to recruit participants, the project coordinator of each country contacted the administrators of nursing homes, daily centers, hospitals and retirement houses, and independent seniors at home and asked for their permission to test the Senior TV product. To assure protection of human subjects,

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the research did not employed any identifying details (including e-mails, phone numbers, addresses, etc.). It was not mandatory to answer all the questions, and if any question caused the participants even the mildest inconvenience, they could choose not to answer it. They were free to withdraw from the study at any time and for any reason. We have included the "Verbal Fluency Test" (VFT) which is an instrument for cognitive assessment and it has been also used in the previous two pilots and the short version of the Health Survey SF12, a scale which has been included to indicate the physical and psychological state of the respondents.

B. Research Findings

By developing a novel seniors' oriented technology acceptance model, we aim to support the advancing research on technology adoption by seniors. Our research shows relevant aspects which need to be considered when discussing the relation between seniors and new technology.

a) Gerontographics segmentation

Seniors are internally a very diverse group in terms of age, culture, emotional state of health, cognitive abilities, social needs and preferences. Seniors' heterogeneity and their attitudes towards engagement with new technologies and gerontechnologies shall be assessed through gerontographics approach [36]. The classic differences of young and old seniors is insufficient in tackling on the specificities of the seniors target groups. Our findings demonstrate that age, physical state of health and cognitive abilities do not have a direct and unmediated impact on the seniors' performance with technology and on their behavioral intention to utilize technologies, validating the recommendations of going beyond the trite understanding of the concepts of biological and cognitive age [37]. Gerontographics segmentation is a useful tool in analyzing and targeting adult market [38]-[40] and it is based on the assumption that elderly manifest similar behavior as long as they had encountered similar circumstances, experiences and past events. Four segments of the elderly are considered: healthy indulgers, ailing outgoers, healthy hermits and frail recluses. Healthy indulgers experience good psychological physical and social aging; ailing outgoers in spite of a decline in the physical well-being manifest high level of psychological being and stay socially integrated; healthy hermits keep a good physical being but a low psychological well-being and stay isolated from society; the frail recluses have chronic health conditions and low psychological well-being.

Chen and Chan [35] show that external variables, such as health and ability characteristics, have a direct and unmediated influence on usage behavior. Henceforth, the gerontographics segmentation, which are the lens through which we chose to look to our data, are in line with Chen and Chan [35] research findings and with the first model which refers to the 'user context'.

The fact that the framework proposed by Chen and Chan [35] emphasizes the relevance of contextual factors rather than of the product experience, is also confirmed by our field-research: seniors habits, activities, interests and curiosities are a results of their life long experiences and, therefore, their adoption on new technologies depend on contextual factors and not on new technology products' attributes. Moreover, the data from the first field-research cycle show that technologies cannot actively engage seniors per se, but the attitudes of the seniors towards the new technologies determine seniors' engagement with new technologies and gerontechnologies. This attitude of the seniors is determined by the state of health of the respondents and by their current life style, which may be assessed through a gerontographics approach.

b) Social influences versus 'perceived usefulness'

Social influences or its lacking foster seniors' acceptance or rejection of gerontechnologies and new technologies. In the case of dependent seniors, which are integrated into the category of frail recluses, the social influences of the nursing professionals and informal carers are key in the processes of experimentation and acceptance of new technologies or gerontechnologies. Social influence replace the variable of 'perceived usefulness' for the categories of frail recluses and healthy hermits, the categories which have a certain degree of dependency and are isolated and/or self-isolated from society. A top-down approach is present in developing and promoting gerontechnologies by not considering seniors' habits, values and desires and the same top-down approach is advanced when designing new technologies products or services and expect seniors to engage with them.

'Perceived usefulness' is relevant for the two categories of healthy indulgers and ailing outgoers, which confirms the results presented by Selwin et al. [41] who show that independent seniors avoid ICT because of the perceived irrelevance in their lives. Therefore, instead of opting for gerontechnologies and any technology services which age-stigmatize and are focused on health improvements, if the case, they prefer to opt for universal technologies. Our findings are also consistent with those of Boulton-Lewis et al. [26] who present the importance of promoting technological models within ethical frameworks, which see users as independent decision-makers, only as long as we target the healthy indulgers and ailing outgoers.

The technologies tailored for senior users tend to focus on health improvements and supportive services, while independent seniors do not perceive themselves as dependent and in-need of health technologies. Moreover, those seniors opened towards the adoption of new technologies perceive themselves younger than their biological age. Therefore, our findings go in line with the research which shows that the main reason expressed by an overwhelming majority for the non-use of ICT is actually the perceived irrelevance of ICT in their lives [41].

c) Seniors' predispositions and interests

Our research findings show that watching TV does not have many symbolic associations for the healthy indulgers and ailing outgoers, while there are plenty of mentally

associations attributed to TV watching by healthy hermits and frail recluses. Healthy indulgers look for information (62.5%) and social integration (42.9%) and ailing outgoers look for information (66.7%), enjoyment (66.7%) and social integration (50%) when experimenting new technologies. In conclusion, gerontechnologies and other age-stigmatizing services such as those designed for health utility, fail to meet the needs of the socially integrated seniors. By contrast, the healthy hermits and frail recluses, who are not socially integrated, associate TV watching with decreasing loneliness and companionship to a high degree. 83. 6% of the healthy hermits associate TV watching with decreasing loneliness, 80.3% with information and 61.5% declares that it sets their daily rhythm. Frail recluses prove to be the most dependent group of gerontechnology and new technologies. 89.5% of frail recluses associate TV watching with enjoyment, 76.5% with decreasing loneliness and 75% with companionship. Nevertheless, TV watching is largely associated with social integration, which matters for all four categories, though for a higher degree for the last two, as being one of a very few vehicles for their sense of belonging to society (60.6% for frail recluses, 57.7% for healthy hermits, 50% for ailing outgoers, and 42.9% for healthy indulgers).

IV. CONCLUSIONS AND FUTURE WORK

This analysis proposes a framework for analyzing the seniors' relation with new technologies and gerontechnologies and it aims to increase the understanding about the factors affecting seniors' acceptance or rejection of newly developed technologies. It was found that gerontographics segmentation can tremendously inform on the openness of the seniors towards certain products or services. Seniors who are independent and socially active, namely the categories of healthy indulgers and ailing outgoers, are open only towards new technologies and avoid age stigmatized gerontechnologies and health oriented products and services, while the categories of frail recluses and healthy hermits, who are more self-isolated and dependent, are more open towards new technologies and gerontechnologies alike.

Frail recluses and healthy hermits, or in other words, seniors who are not socially integrated and feel psychologically ill, adopt technologies under the influences of their formal or informal caregivers. Hence, 'perceived usefulness' and 'perceived ease of use' of the technologies, factors which play a key role in the classic technology acceptance models, are replaced with social influences factors. These findings are consistent with the senior technology adoption framework developed by Chen and Chan [35]. Moreover, we found that a major key factor in the acceptance of technology by seniors is played by their predisposition in choosing technologies which carry out a specific role for them. Seniors who are socially isolated adopt technologies for decreasing loneliness and setting up a rhythm of the day, while those socially integrated accept technologies only for information and enjoyment. More research is needed in order to test the model proposed here on a wider range of technologies and in different cultural settings.

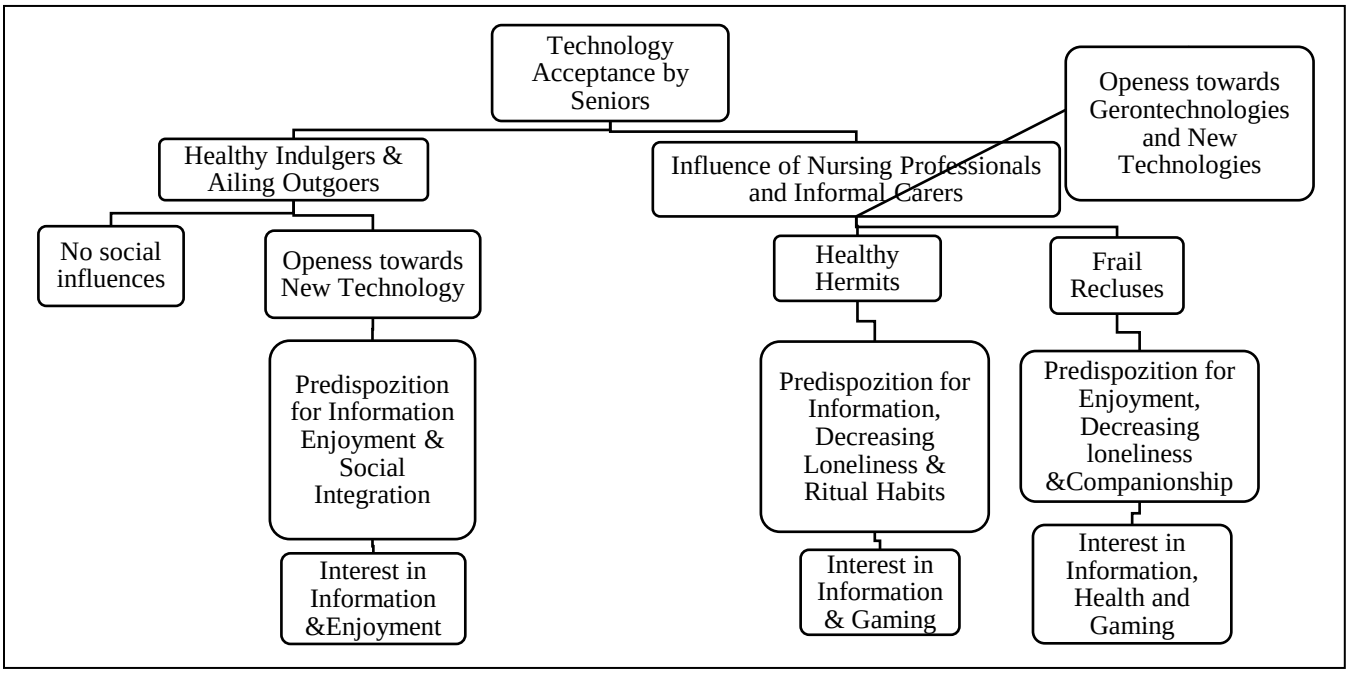

Fig. 1 A novel framework for understanding seniors' technology acceptance

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The Impact and Benefits of Innovative, Intelligent Assistive Lightening for The Cognitive Decline of the MCI Independent Seniors

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***Abstract*— The Personalizable assisTive Ambient monitoring and Lighting (PETAL) Project represents a unique and innovative solution that aims to reduce the cognitive decline among Mild Cognitive Impairment patients through an assisted ambient environment, as well as through the use of neurocognitive stimulation applications. The functioning of the system is based on an online platform named "Rule Editor" that will act as both receptor for the information coming from the environment and transmitter of the information which will eventually materialize through the peripheral devices connected. One of the most important parts of the system is the Human Centric Lighting (the term was coined in 2013 and refers to lighting that induces positive health effects in human beings), which supports the following functions: sleep-wake rhythm, directs attention in a timely manner, supports structure of daily activities and spatial-temporal orientation. The system will also integrate motion and proximity sensors that will continuously monitor the presence of the patient inside the home through a smartwatch worn by the elderly. Using the same smartwatch, the platform can send warnings to different numbers prior set in the case the patient falls. Moreover, regarding the neurocognitive stimulation applications, the patients will perform exercises for maximum an hour, 3 times a week. Using this platform, we can monitor changes that might appear in some particular contexts – aspects regarding the user, time, environment, etc. Thus, the necessary adjustments that should respond to the patient's requirements could be performed. The platform will allow the caregivers to personalize the way in which the platform as well as the Lighting System and other connected devices and appliances will act using a set of "rules".**

Keywords – *MCI; elderly; light; cognitive functions; technology.*

I. INTRODUCTION

Lately, ageing and dementia have represented a main focus among both clinicians and researchers in terms of early diagnosis and interventions through predictive biomarkers. The term Mild Cognitive Impairment (MCI) was firstly introduced in 1988 [1] to describe a transitional state between the cognition of normal aging and mild dementia – the subjects were identified based on the Global Deterioration Scale when Stage 3 criteria were fulfilled.

In section II we will present the concept of MCI in detail by providing evidence-based information regarding clinical presentation, assessment and diagnostic criteria. In the `third section, the operating system of the PETAL project is explained while in the last sections – Conclusions, all the achievements are going to be summarized and the future work will be presented as well.

II. RELATED WORKS

The first clinical criteria for MCI were proposed by a group of investigators from the Mayo Clinic in the late 90's; In 1999 the concept of MCI has further been developed [2][3] and in order to reach an agreement on the clinical features of MCI, an international conference was held in 2003 (Key Symposium) that materialized in a revised criteria for this condition [4]. More recently, the National Institute on Aging and Alzheimer's Association (NIA-AA) put together a group in order to once again evaluate MCI clinical criteria along Alzheimer's Disease Spectrum [5] – the core criteria overlap with those proposed by the Key Symposium. The American Psychiatric Association has recently published new criteria for dementia in the fifth edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-5), which recognize the pre-dementia stage of cognitive impairment. The condition, which has many of the features of MCI, is termed mild neurocognitive disorder (NCD) [6]; see Table1.

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TABLE I. EVOLUTION OF MCI CRITERIA

Criteria	Mayo Clinic	Key Symposium	NIA-AA	DSM-5
Self- or informant-reported memory complaint	X			
Self- or informant-reported cognitive complaint		X	X	X
Objective memory impairment	X			
Objective cognitive impairment		X	X	X
Essentially preserved general cognitive functioning	X			
Preserved independence in functional abilities	X	X	X	X
No dementia	X	X	X	X

The prevalence of MCI can highly vary depending on the population. Using Winblad's 2004 diagnostic criteria [4], the prevalence of MCI was 28.3% in the U.S.[7], 24.3% in Austria[8], 17.2% in Germany [9] and 12.7% in China [10]. According to a recent review of population and community-based studies, the annual incidence rate of MCI ranged from 51 to 77 per 1,000 persons in those 60 years or older [11].

As seen in Table 1, MCI patients present cognitive disfunctions which do not fulfill the diagnostic criteria for dementia. Typically, **executive functions**, **attention**, **language** and **visuospatial skills** are the main domains in which MCI develops [12]. Clinical data suggesting a change in cognitive abilities is necessary for being classified as MCI. This information is generally gathered by using questionnaires addressed to the patient and or caregiver. People diagnosed with MCI have greater difficulty or need a longer period of time, compared to healthy individuals of the same age category, to complete daily activities that require greater use of cognitive functions - use of the phone, finding and organizing personal things, shopping, treatment compliance, moving and guiding or managing their own finances. In spite of these disorders, patients with MCI are in most cases independent - the accusations they invoke do not interfere with the abilities and the possibility of social activities within the family or the workplace [13]. The subjective cognitive complaint then needs to be confirmed by objective cognitive measures such as neuropsychological test batteries. Objective cognitive impairment is defined as a poor performance in one or more cognitive measures, which suggests deficits in one or more cognitive areas or domains. There is no gold standard to specify which neuropsychological test battery to use, but it is important that all the main cognitive areas are examined [12].

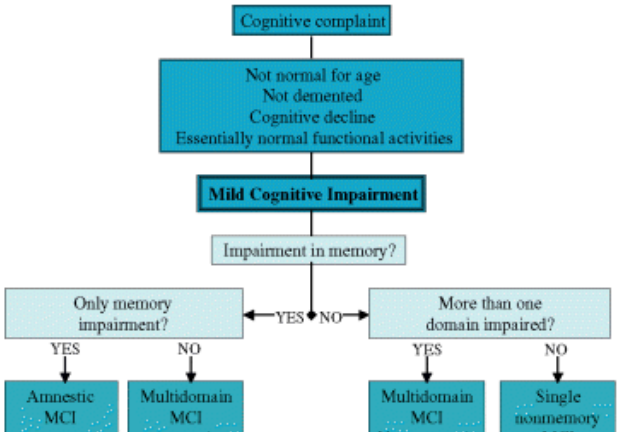

Figure 1. MCI Subtypes Classification (adapted with permission from Lippincott-Raven Publishers, Williams & Wilkins)

Considering impairment in the memory domain as well as in a single domain or multiple ones, MCI can be classified in 4 major subtypes – amnestic MCI (aMCI) and non amnestic MCI (naMCI), single or multiple domain as follows: **aMCI – single domain** (impairment only in memory), **aMCI – multiple domain** (impairment in memory and other cognitive domain**), naMCI – single domain** (impairment in a single cognitive domain, but not memory), **naMCI – multiple domain** (impairment in at least two cognitive domains, but not memory).

Risk factors are a subject relatively new to research, the current information being gathered in the last ten years. The most important risk factors are: *old age, low level of education, male gender, presence of Ɛ4 allele on APOE gene, comorbidities* – cardiovascular diseases and diabetes having a more impact, *depression*. **Physical activity** as well as **social and cognitive stimulation** can both contribute to postponing or preventing MCI [12]. A review of 41 cohort studies with a ten-year maximum follow-up was conducted and revealed that, on average, a **32%** of people with MCI progress to dementia [14]. In a multiethnic community-based study of 2,364 participants, the investigators specifically examined the reversion rate of MCI, the results being as follow: **47%** remained unchanged and **31%** reverted to normal within an average of **4.7 years** follow-up [15]. While the reasons for these different outcomes remain unknown, additionally, the risk of mortality increased by 50% to 150% in persons with MCI compared to those without MCI [16][17][18].

In terms of MCI interventions that aim to prevent, slow down or even reverse the progression of this pathology can be grouped in the following categories: **pharmacological**, **physical training / exercise**, **cognitive interventions** and **psychotherapy** [19]. Recommendations focus more on non-pharmacological interventions, one of the main reasons being that they produce no adverse effects. Among the non-pharmacological interventions, **cognitive training** and **physical exercise** (specifically aerobic exercise) may attenuate the cognitive impairment. A recent review showed how the efficacy of cognitive training in MCI measured as improvements in tests of global cognitive

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functioning, memory and meta-memory [20][21]. A limitation of these findings is the small samples of the individual studies. Only seven RCTs (randomized controlled trials) were identified by a systematic review [20], with a total of 296 MCI subjects who were cognitively treated. Most of these studies in fact included samples of fewer than 50 individuals; therefore, replication of the findings in larger RCTs is warranted.

To conclude, MCI is by all means a heterogenous entity limited by inconsistent findings. In many ways, the rapid transition from research to clinical setting has been premature. However, this does highly reflect the clinical need of standardized criteria and diagnostic algorithms given the high level of awareness of cognitive disorders in population. The major controversial issues for MCI research are centered on the **subjects** – source (memory clinics or general population) and age (middle aged or elderly), **implementation of the criteria** – test batteries, cut-offs and norms, **data collection** – prospective vs retrospective case findings as well as **classification** – standardized algorithm vs clinical judgement, **blindness** – awareness vs blindness (to clinical history) and **follow-up** (short-term vs long-term predictivity)[12].

III. PETAL PROJECT

As previously mentioned, the current focus regarding MCI interventions is directed more towards the non-pharmacological interventions.

PETAL Project - PErsonalizable assisTive Ambient monitoring and Lighting aims to extend the time older people can live in their home environment by increasing their autonomy and assisting them in carrying out activities of daily living. In particular, the goals are to provide older adults affected by MCI with useful and usable means to increase their awareness and control of their current lifestyle by providing them with relevant and tailored information in an intuitive and natural manner. The PETAL system is comprised of 2 main components – **the Lighting system** and a **cognitive-stimulation exercises mobile app**. The lighting system will be in charge of the non-visual light effects as well as the photometric factors (triggers of the non-visual light effects) whereas the cognitive stimulation app will focus directly on the cognitive improvements.

The current definition of light is based on its physical explanation as being the visible part of the electromagnetic spectrum. However, the human eye cannot see a spectrum, it is rather the photoreceptors – rods and cones, which collect, decipher and transpose the emission or reflectance of electromagnetic waves in a specific range or photons into meaningful visual signs in our brains. It is only two decades since the entraining and phase-shifting capacity of light on human circadian rhythms was discovered. Relatively little attention has been paid to other light effects on human brain, such as its alerting properties. As of 1995, only a handful of studies had directly or indirectly examined the immediate activating effects of light on alertness, performance and/or mood [22][23]. This has recently changed since a novel, third type of photoreceptor in the retina of mammals has been detected [24]. This novel photoreceptor cell type, an intrinsic photosensitive retinal ganglion cell, is considered to play a crucial role in many of the non-visual biological effects of light also in humans. The existence of such a photoreceptor can explain why pupil constriction, melatonin suppression and circadian entrainment are still possible in rodless and coneless transgenic mice [25][26].

Personalizable Lighting is a term that has become more and more popular in the lighting industry during the last years. Although the term is used on a large scale, there is no precise definition of this term. In the Human-Computer Interaction area, two main approaches are considered for personalization: **adaptive interfaces** - which dynamically adjust the interface in a way that is intended to support the user and **adaptable interfaces** - which provide customization mechanisms but rely on the user to use those mechanisms to do the adaptation [27]. Thus, these approaches differ with respect to who is in control of the personalization: **adaptive interfaces are system-controlled whereas adaptable interfaces are user-controlled.**

PETAL System aims to trigger the non-visual lighting effects - **regulation of sleep-wake cycle, regulation of appetite, impact on mood, impact on activity-rest-pattern, impact on behaviour** by exploiting and modulating the photometric light parameters, such as *light intensity, light spectrum – colour temperature, time and duration of the exposure as well as light history*. Thus, the project is a classic exponent of the Human Centric Lighting (term introduced in 2013 into the lighting industry that describes all kinds of lighting that positively affect human being's mood, alertness, performance, health and well-being).

The lighting system is composed of hue bulbs, hue light stripes for guidance and a central luminaire which consists of 3 lighting components: up-light (indirect light for ambient room illumination), down-light (diffuse task-light for facial brightening) and flexible spot (direct task-light for high visual requirements in the task area). The system will also integrate a set of sensors – proximity and motion sensors, temperature, humidity pressure, smoke and gas sensors, as well as door and window sensors; all this equipment will be integrated through an online platform that allows the user to program and control the system according to the subject needs, preferences and schedule. Moreover, monitoring the presence of the subject inside the home is possible, through a smartwatch worn by the elderly. Using the same smartwatch, the platform can send warnings to different numbers prior set in the case of a fall.

In conclusion, the PETAL - Lighting System is an adaptable lighting system that represents a first step towards

an adaptive lighting solution in private homes for elderly with MCI. In connection with the PETAL platform, a flexible solution was created that is adaptable to a great variety of requirements that can occur in this setting. Further development that integrates automatic algorithms that produces necessary lighting rules because of gathered information from sensors can be the next step towards an optimized, adaptive lighting solution.

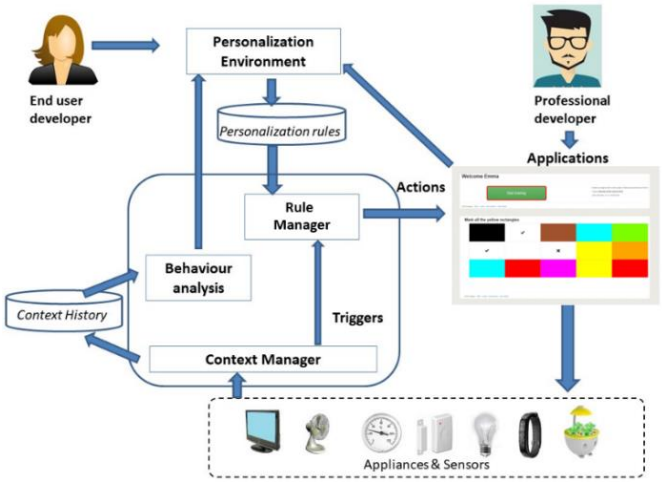

Figure 2. Integration of Applications with the Personalization Platform

IV. CONCLUSIONS

To sum up, PETAL System is part of the cognitive interventions among MCI patients that aims to prevent, slow down or even reverse the progression of this pathology. Through its personalizing lighting system and adaptive interface it is going to extend the time older people can live in their home environment by assisting them during the activities of daily living as well as increase their autonomy by triggering the non-visual effects of light.

Until now all the components of the PETAL system have been tested and integrated with each other in order to be fully operable and a mock-up trial has been successfully performed. Thus, the system is ready to be installed in our patient's homes so that it can be evaluated whether it is able to reduce the neurocognitive progression. In order to objectify this hypothesis, we performed neuropsychiatric tests on our patients (Neuropsychiatric inventory, Mini Mental State Examination, Activities of Daily Living and Instrumental Activities of Daily Living Questionnaires, Quality of Life Questionnaire, Rey Auditory and Verbal Fluency Test, as well as Raven Matrices, Wisconsin Card Sorting Test and Stroop Test) prior to the field trial of the system and it will be performed once again after the end of the testing phase. What is more, using the Zarit Burden interview we will be able to measure the impact PETAL System has on caregivers as well.

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Virtual Assistant for Healthy Aging: Benefits Perceived by Elders

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***Abstract* — We advocate for developing innovative products that help elderly people maintain their mental and physical health while aging, by enhancing their user experience. This article presents findings from our applied research activities which involve senior users throughout the development of elder-friendly virtual technologies. We describe Ella4Life, an innovative solution that supports elderly people in improving their healthy aging and emphasizing the virtual assistant role for communication, interaction, staying informed, etc. The methodological approach is based on assessing the elderly requirements in terms of perceptions and their own representation of virtual assistance. We used a qualitative method for data collection, through focus group and in-depth interviews for identifying the requirements of the elders when facing a virtual assistant. Challenged with an innovative application including a virtual assistance, the elders gave us useful information about their expectations, the main findings being presented here. The involvement of elderly users living in different countries adds further value to our work with regard to the universal benefits gained from interacting with a virtual assistant and also offers useful insights for a better adaptation/ customization of the solutions for addressing their particular needs.**

Keywords- healthy and active aging, elderly user requirement, virtual assistant

I. INTRODUCTION

In the upcoming years, the healthy brain aging needs to be considered from an interdisciplinary theoretical and practical perspective in order to understand the complex nature of processes of cognitive aging and to improve the quality of life. While researchers [1] emphasize new approaches for integrating perspectives across disciplines in the research for better understanding cognition, health, and aging, the impact of new technologies on aging well should also be better investigated. We have to develop new solutions and products that can improve people's lives. For example, as new technologies emerge, the combination of appropriate online education and social communities could help patients cope better with Parkinson's disease, promoting social inclusion and greater support for their wellbeing [2].

In the case of the elderly, virtual reality experiences enhance their communication and interaction taking place within a simulated environment, with auditory and visual feedback [3]. Stimulating interaction and communication skills are important because of their role in stimulating cognitive abilities. Also, virtual reality has applications in some areas of neuropsychology, psychotherapy, surgical education, post-stroke intervention, musculoskeletal recovery, pain mitigation, Alzheimer's disease [4].

There are emerging new technologies that could increase the effectiveness and quality of healthcare services across the world. The common thread between all digital implementations is that they all require human-machine interfaces [5]. The challenge is to design interfaces which will best fit the targeted users and enable smooth interaction, especially for the elderly users [6]. For instance, the idea of combining assistive technologies and personal help involving the social environment of people with dementia was well received by people with this condition [7]. On the other hand, it is important to provide easy to use friendly products with respect to multicultural differences. Even if in various European regions we have a different innovation performance score, according to the Regional Innovation Scoreboard, we have to better capitalize regional strengths that generate smarter public services [8] and focus on strengths and comparative advantages.

A. The background and our contribution

From the perspective of the innovative solution, it is important what benefits the product i.e. virtual assistant should provide. From the perspective of the people i.e. users, we have to focus on their behaviours, needs, and motivations.

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User-research has to be mainly about defining problems not about creating solutions [9]. All user-research work aims to place the people at the centre of their solutions to-be-developed (user-centric approach). But beyond this, as products are increasingly being promoted internationally, the transnationally and intercultural usability issues become more important. Previous studies [10] evaluated the cross-cultural understanding of interface design and concluded that, for example, understanding of a website did indeed differ across people from various geographical regions i.e., North American, English, Japanese and Dutch users.

Studies about older adults' experiences [11] confirm that virtual reality was reviewed positively, yet modifications are necessary in order to facilitate an optimal user experience and provide a potential benefit for this population segment. The work on virtual assistants designed for interacting with multicultural environments is still in its pioneering stage.

This paper aims to highlight the benefits of using virtual assistance for healthy aging, tailored to multicultural environments, and to help remove barriers that potentially limit the benefits of great innovation. After the introduction, in Section 2, we present an innovative solution, Ella4Life including a virtual assistant, a cloud-centred platform supporting elderly persons to manage their health indicators, medication, chronic diseases, etc., combined with sensor-based technology. In order to improve the usability of the product, in Section 3, we focus on assessing elderly user requirements, needs, and perceived benefits. The research has an attitudinal dimension meant to understand and assess the elderly stated beliefs and requirements. The methodology describes the method, the used tools, the group of participants living in four European countries (Romania, Poland, Switzerland and the Netherlands). Qualitative insights and results are presented. In Section 4, the conclusion reveals the main representations of elderly users challenged with the innovative application including virtual assistance. Their positive attitude boosts future work aiming at developing technological products in order to improve healthy brain aging.

II. THE PROPOSED SOLUTION: A VIRTUAL ASSISTANT

The project Ella4Life (your Virtual Personal Assistant for home and on the road), co-funded by the European AAL Joint Program (2018-2021), aimed to offer an application to help elderly, healthy or with a chronic disease or mental condition, to stay healthier and live a more pleasant life, independent and safe. Working on the project are organizations from the Netherlands, Switzerland, Poland, and Romania.

Digital Ella4Life helps elders organize their daily structure, provides personalized entertainment and helps stimulating their mental condition. Professionals carers and informal caregivers and warned in case of emergency because Ella4Life is connected with them and will inform them when such situations occur. The application provides care and cure, both for when elders are on their way outdoors as well as at home, for health and wellbeing. Ella4Life is a virtual assistant, friendly and fun to use, obtained through the integration of three technologies, Emma, Anne and sensor technology. It is a speech-controlled system used in elder people's homes for care, medication and a healthy lifestyle. The proposed solution stimulates the elderly to communicate with the virtual assistant. Also, Ella interacts by voice recognition, in English and in local languages (upcoming work) and helps with daily activities and stimulates people mentally and physically as a ‘lifestyle-coach'. As a virtual assistant, it generates a human realistic presence, sounds and other sensations that simulate the elderly's brain through communication and interaction in a domestic environment.

III. ASSESSING ELDERLY USER REQUIREMENTS

The process of enhancing the elderly user experience is complex and starts from developing a positive attitude towards the virtual (assistance) product and focuses on benefits that can be both practical and emotional. Research on user requirements is built on the fundamental idea that the contribution of the elderly people in the design and development of the right product leads to a superior solution. User requirements analysis draws clearly articulated statements about what do users expect the virtual solution to do, and what they want, considering their needs, satisfaction, and acceptance. Furthermore, the involvement of users stimulates a positive attitude towards the acceptance of the virtual world. Country-specific requirements must be considered in order to achieve an overall acceptance, so involving people from different European countries assures the multicultural representativeness.

A. The methodology

To make sure that we are developing the right product that the elders would benefit from, we invited seniors who are (potential) beneficiaries of the integrated solution in order to express their opinion regarding the using of a virtual assistant in daily activities or to stay in contact with the healthcare professionals and with their informal caregivers. Participating users were persons who agreed to use new technologies and were willing to use virtual assistance and interaction.

The evaluation method was based on qualitative research for understanding seniors' requirements (satisfaction, opinion, needs, etc.) in a specified context and using appropriate tools for analysing facts with a measurable approach. In particular, we used a combination of both focus groups and in-depth interviews because we intended to get a comprehensive evaluation of the benefits and everyday experiences of individual users. One important aspect analysed was the multicultural insight. The period of data collection was September – November 2018. All the responses are considered relevant (there are no wrong responses) and studied by comparing with the rest of the data to establish analytical categories. First, we focused on understanding the specific context of peoples' daily activities and after that we investigated the dimension of these characteristics. Information was analysed in order to obtain qualitative insights or through numerical comparisons for quantitative estimations, both considered as being relevant tools for

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exploring new ideas and development of innovative ways for human-computer interaction.

The respondents were recruited on a voluntary basis, being persons who usually do not know each other but are able to share experiences and express their opinion. They were senior adults, potential beneficiaries of the integrated solution provided by Ella4Life, within the age category 55 years and older, male and female, healthy or with a chronic disease or mental condition. There were involved 8 persons in Romania, 7 persons in Poland, 8 persons in Switzerland and 5 persons in the Netherlands. All countries are considered developed economies, Romania and Poland being newer European Union (E.U.) member States, the Netherlands as an established member State, and Switzerland as non-member State. Only Romania is categorized as an upper-middle income, all others are high-income countries.

B. The results

a) Insights from **focus groups** revealed that Ella4Life solution including a virtual assistant was welcomed by elderly and seems to be very interesting because it is perceived as a real partner for elderly who need assistance and support. Elderly users were asked about the Ella4Life solution and particularly in relation to the idea of having a virtual assistant, monitoring certain health parameters and helping them with adapted suggestions and advice. About the interaction of the elderly with the virtual assistant, the perception is positive because all participants consider communication to be very important.

In Romania, elders were willing to share information and interact with others. Moreover, they valued the possibility to build a network and share information. Seniors valued the connections, the feeling of being involved and staying active. Also, they valued that it brings people together and facilitates the connection between elders, and doctors. The virtual environment can assure elderly the needed interaction. So, they agreed with the idea of interacting with a non-human assistant because interaction and communication are a fundamental need, and elderly valued connection with others, even being virtual.

Most participants from the Netherlands valued virtual assistant and believed that most people would first want to buy the voice recognition part of the proposed solution.

Oppositely, the elders from Switzerland considered that talking to an avatar can lead to loneliness. Because the elders are no longer required to deal with others, the ability to have a coherent conversation can be lost. In communication, it is important to get the direct emotions of the other person. The use of an avatar should be limited to some previously defined time intervals per day.

b) Findings from **in-depth interviews**. In order to quantify the elder's acceptance of using Ella4Life and to better collect the personal ideas about interacting with a virtual assistant, we collected data using an in-depth interview and analysed elders' responses. Findings on acceptance to use and interact with virtual are optimistic.

The question is "How do you think that interacting with your virtual assistant will be a benefit to you?" with multiple responses possibility.

Figure 1 shows how interacting with a virtual assistant would help them in specific ways, in their opinion. Respondents appreciated that it will offer useful information in real time, as stated by 6 persons in Romania, 5 persons in Netherlands, 3 persons in Poland and 7 persons in Switzerland. Also, elders considered that interacting with a virtual assistant allows them receiving advice and coaching when needed, as mentioned by 7 persons in Romania, 2 persons in the Netherlands, 1 person in Poland and 4 persons in Switzerland. The presence of a virtual assistant would be help seniors to improve their mood when they are feeling down, as answered by 3 persons in Romania, 4 persons in the Netherlands, 1 person in Poland and 8 persons in Switzerland. Also, 5 persons in Romania, 4 persons in the Netherlands, 5 persons in Poland and 3 persons in Switzerland considered that the virtual assistant would help them stay in contact with family members and friends. Others appreciated that it would

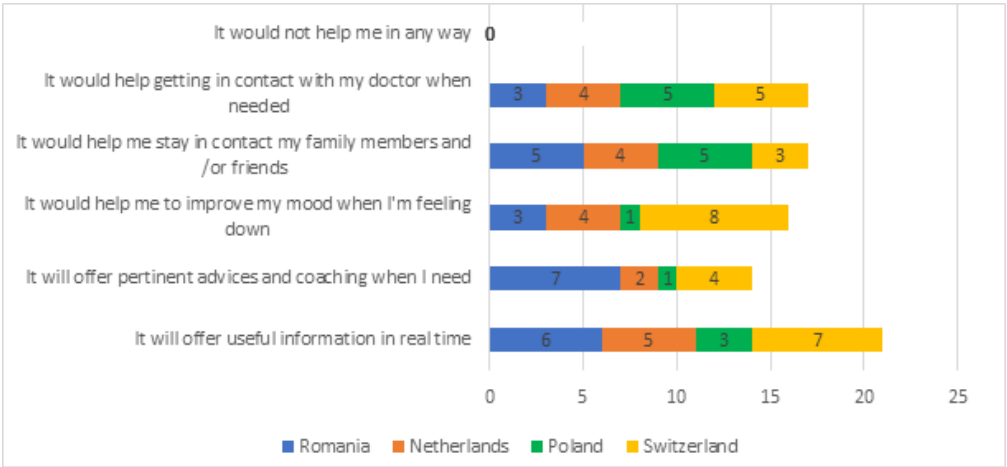

Figure 1. Interacting with a virtual assistant (multiple choices)

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help them get in contact with a doctor when needed. This was the opinion of 3 persons in Romania, 4 persons in the Netherlands, 5 persons in Poland and 5 persons in Switzerland.

Overall, the elders had a positive opinion in terms of attitudes and acceptance of using the Ella4Life solution for improving their lives. In general, many people appreciated the benefits of interaction and connection, receiving advice and useful information in real time.

IV. CONCLUSION

Ella4Life supports elders in maintaining a healthier lifestyle and aging well. This article focuses on the involvement of the elderly in the development of Ella4Life in order to facilitate their acceptance and build a positive attitude. Research on user requirements aims to bring together insights about what they (elderly users from different countries) require this innovative solution to do, and what are the benefits, from a multicultural perspective. The results will help the specialists to improve the prototype of a superior integrated solution and offer a more qualitative product that can be used by people living in different European countries. The product will be further tested with people within the category 55 years and older in the near future. The user research on multicultural differences is essential in order to design an innovative product as a key part of the development process.

Our insights reveal that the Ella4Life solution, based on a virtual assistant, was welcomed and appears to be very interesting because elders need to stay informed, to receive news and medical advice, and to network with others. They think interacting with a virtual assistant is a pleasant activity for them, sharing information in real time. In conclusion, elders have a positive opinion in terms of attitudes and acceptance for using Ella4Life to improve their lives. Elders are aware of their needs and want to mobilize their cognitive resources for their own benefit.

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Exploring a P300 Brain-Computer Interface Based on Three Different RSVP Paradigms

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***Abstract*— A BCI Speller is a typical Brain-Computer Interface (BCI) system for communication purpose. This technology can provide users with severe motor disability with an assistive device controlled by brain activity. In the present preliminary study we investigated, in five subjects, the performance and the Information Transfer Rate (ITR) based on three different Rapid Serial Visual Presentation (RSVP) paradigms to control a BCI speller. The variants of the three paradigms were the stimuli presented: letters, images and famous faces. These preliminary results showed that performance can increase when using an RSVP paradigm based on images, and ITR can improves when using the images and the famous faces paradigms.**

Keywords- Brain-Computer Interface (BCI); P300; speller; stimuli; RSVP Paradigm.

I. INTRODUCTION

A Brain-Computer Interface (BCI) is based on analysis of the brain activity recorded during certain mental activities in order to control an external device. It helps to establish a communication and control channel for people with serious motor function problems, but without cognitive function disorder [1]. Currently, the most commonly used BCI systems are those based on electroencephalographic (EEG) signals, mainly because they can be recorded in a non-invasive manner and show adequate temporal resolution.

A BCI Speller is a typical brain-computer interface system for communication purpose. This technology can provide users with severe motor disability as, for example, patients suffering Amyotrophic Lateral Sclerosis (ALS), with an assistive device controlled by brain activity.

Most of the BCI spellers are based on the P300 Event-Related Potential (ERP). The P300 signal is a positive deflection in voltage occurring about 300 ms after an infrequent or significant stimulus is perceived [1]. P300 wave amplitude is typically between 2μV and 5μV and is symmetrically distributed around central scalp areas, showing greater amplitude in occipital rather than frontal region [2]. Most of these spellers are based on the P300 speller first developed by Farwell and Donchin [3]. In this BCI, a 6 x 6 matrix of letters, arranged in rows and columns, is shown to the subject. The user focuses his/her attention on the matrix element he/she wishes to select as each row and column is flashed (i.e., intensified) randomly, one after the other. After a number of flashes, the symbol that the user has supposedly chosen is presented on screen. This paradigm is known as Row-Column Presentation (RCP) paradigm.

In order to increase the performance of a BCI Speller based on the RCP paradigm, numerous variations have been proposed. Some works have been focused on modifying the stimulus presentation, such as the use of different color [4] or, even, the nature of the stimuli. One of the stimuli which

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has result to better improve the BCI performance is the used of familiar faces [5] [6]. Specifically, in [5], the stimulus used was famous face. In [6], the use of green familiar faces improves the BCI performance compared to the famous face paradigm.

Besides, a preliminary study carried out by the research group of the University of Málaga – the UMA-BCI group – shows that the use of a set of varied different pictures (e.g., photographs of things, people or places) as flashing stimuli could also significantly improve the performance of a BCI-speller based on RCP [7].

The performance of a BCI-P300 speller based on the RCP paradigm depends, to some extend, on the user´s ability to gaze the different symbols of the matrix. Effectively, some studies have clearly demonstrated that the performance of the classical speller considerably decreases in cover attention mode [8] [9], that is, when subjects have to fixate the center of the screen while paying attention to the target using visual periphery. Unfortunately, some of the potential users of a BCI speller, that is, ALS patients, could have impaired in their visual function. For these users, a BCI speller based on the RCP paradigm is not useful.

Different solutions have been proposed to develop visual BCI spellers independent of the eye gaze. One of this solution is based on the Rapid Serial Visual Presentation (RSVP) paradigm, proposed by Acqualagna et al. [10]. In this paradigm, the different symbols (letters) were presented one by one, in a random order, in the center of the screen. In a recent study [11], in order to study if the characteristics of stimuli can have an influence on the performance, three different RSVP paradigms were studied: colored ball, grey dummy faces and colored dummy face. For each paradigm, six different stimuli were presented (6 colors and 6 face expressions). The obtained results showed that the combination of colors and face expressions could improve the bit rate.

As the use of stimuli based on famous face and pictures have been proven to improve BCI performance in a BCI speller based on RCP paradigm, the main objective of our study was to study if similar stimuli could improve the performance and the Information Transfer Rate (ITR) on a BCI speller based on the RSVP paradigm. To this end, three different stimuli sets were tested: letters, pictures and famous faces.

This paper is organized as follows: section 2 describes the experimental setup, and present details about the spelling paradigms. The results and discussion are presented in section 3, followed by the conclusion and future works in section 4.

II. MATERIAL AND METHODS

A. Participants

Five healthy French university students (S1-S5) participated in this study. None of them had previous experience using a BCI system. The study was approved by the Ethics Committee of the University of Malaga and met the ethical standards of the Helsinki Declaration. According to self-reports, all participants had no history of neurological or psychiatric illness, had normal or corrected-to-normal vision, and gave informed consent trough a protocol reviewed by the ENSC-IMS (Ecole Nationale Supérieur de Cognitique – Intégration du Matériau su Systéme) Cognitive and UMA-BCI teams.

B. Data acquisition and Signal Processing

The EEG was recorded using the electrode positions: Fz, Cz, Pz, Oz, P3, P4, PO7 and PO8, according to the 10/20 international system. All channels were referenced to the right earlobe, using FPz as ground.

The EEG was amplified through a 16 channel biosignal amplifier gUSBamp (Guger Technologies). The amplifier settings were from 0.5 Hz to 100 Hz for the band-pass filter, the notch (50 Hz) was on, and the sensitivity was 500 μV. The EEG was then digitized at a rate of 256 Hz. EEG data collection and processing were controlled by the *UMA-BCI Speller* software [12], a BCI speller application developed by the UMA-BCI group which provides end users with an easy to use open source P300 speller. This software is based on the widely used platform BCI2000 [13] so, it takes advantage of the reliability that such a platform offers. The *UMA-BCI Speller* wraps BCI2000 in such a way that its configuration and use is much more visual and easier. It supports two P300 stimulations: RCP and RSVP. Users can configure their speller more appropriately using characters, images or sound cues, and they can navigate through different layouts, thus opening the door to complex speller configurations. As with a P300 speller developed with BCI2000, a Stepwise Linear Discriminant Analysis (SWLDA) of the data was performed to obtain the weights for the P300 classifier and calculate the accuracy.

C. The RSVP Paradigms

As it was mentioned, three different RSVP paradigms were tested by participants. These paradigms were: i) Letters (L), ii) Pictures or Images (I) and iii) Famous Faces (FF), and are represented in Figure 1. Each RSVP paradigm consisted in 9 different stimuli. In the L paradigm, the used letters were A, B, C, E, L, M, O, R and S. Each image of the I paradigm was chosen taking into account that the image had to start with the same letter as the one used in the L paradigm. For example, the tree is "ARBRE" in French, starting with the letter "A". Boat is "BATEAU" in French, starting with the letter "B". Bell is "CLOCHE" in French, starting with the letter "C". For the FF paradigm, the chosen criterion was the same; the family name had to start with the same letter of the L paradigm: Woody Allen for letter "A", Beyoncé for letter "B", Hilary Clinton for letter "C", etc.

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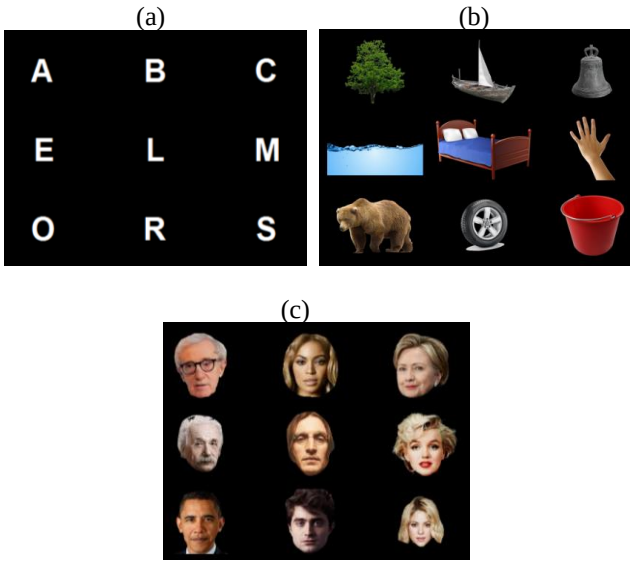

Figure 1. Spelling paradigms used in the experiment: a) Letters (L), b) Images (I) and c) Famous Faces (FF).

For all the RSVP paradigms, a Stimulus Onset Asynchrony (SOA) of 300 ms and an Inter-Stimulus Interval (ISI) of 100 ms were used, so each stimulus was presented for 200 ms. Each trial included 9 flashes, and the duration of a trial was 2.7 s (9 x 300ms). A 5s pause was established between each selection. The flashing stimuli were presented in the center of the screen. Although not all the stimuli in each paradigm had the same dimension (depending on the Letter, Images or Famous Faces), Letters had a size around 3 cm × 4 cm, Images around 12 cm × 8.5 cm and Famous Faces around 6 cm × 8.5 cm.

D. Procedure

Participants sat at a distance of, approximately, 60 cm from the screen. Each participant participated in one session to evaluate the three RSVP paradigms. The order of the paradigms was counterbalanced across participants. Each session consisted of a calibration phase and a copy-spelling phase.

We used two four letters words for calibration purpose, having a total of 8 characters per paradigm, with a short break between words (variable at the request of the user). During the calibration phase, there were 10 trials so, each symbol (i.e., letters, images or famous faces) flashed 10 times. The user was asked to mentally count the number of occurrences (10) of the target, always fixating the center of the screen. The writing time for each selection in this phase was 32s (2.7 s per trial X 10 trials + 5 s pause). The specific words were: "MARE" and "CLOS". If for the Letter paradigm, the target was easy to identify, for the Image and the Famous Face paradigms, each target was signaled before the beginning of the trial flashes. In this phase, there was no feedback, and the recorded EEG was used to train the classifier.

The copy-spelling phase started after the calibration and training of the classifier. In this phase, the number of trials used to select a target was dependent of the offline classification accuracies. The used criterion was that the number of trials should be two trials more than the minimum number of trials required to obtain 100% accuracy in the calibration phase. In the copy-spelling phase, participants had to spell three four letters French words: "MALE" (male), "ROSE" (rose) and "BOLS" (bowls). In case of incorrect selection, the participants were instructed not to correct and to continue with the next target. During this phase, the selected symbols was shown at the top of the screen.

E. Evaluation

Three parameters were used to evaluate the effect of the RSVP paradigm and stimulus type on the performance: i) the accuracy in the calibration phase, ii) the accuracy in the copy-spelling phase (i.e., the number of correct selections divided by the total number of characters, that is, 9) and iii) the information transfer rate (ITR, bits/min) based on the next formula [14].

$$ITR = \{\log_2 N + P \log_2 P + (1 - P) \log_2 [(1 - P)/(N - 1)]\}/T$$

where P denotes the classification accuracy, N denotes the number of target (N was 9 in this experiment) and T denotes the time interval per selection (that is, the number of sequences to select a symbol in the copy-spelling phase).

It should be advised that the pause between selections was not considered to calculate the ITR.

Due to the small sample size, non-parametric analyses were carried out. Due to the preliminary nature of the present study, no correction method was applied for multiple comparisons. Thus, the obtained conclusions should be considered carefully, being admitted that more tests will be necessary to carry out, increasing the number of participants and the number of characters in the copy-spelling phase.

III. RESULTS AND DISCUSSION

Figure 2 shows the mean classification accuracy achieved by users for each RSVP paradigm, as a function of the sequences (due to the small simple size, statistical significance is not considered), in the calibration phase.

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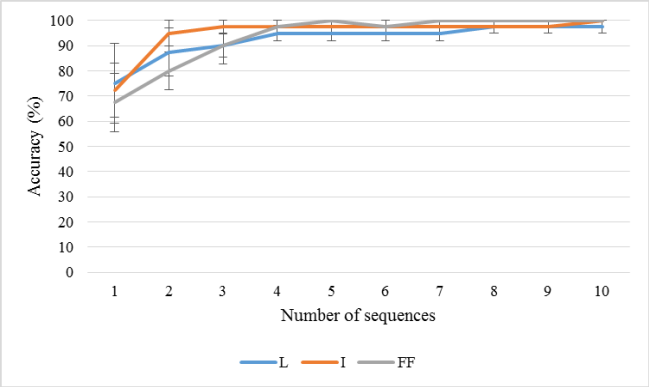

Figure 2. Classification accuracy (mean ± standard error) of the three RSVP paradigms as a function of the number of sequences during calibration (L: Letter RSVP paradigm; I: Image RSVP paradigm; FF Famous Faces RSVP paradigm).

Despite the low number of users, these preliminary results show some trends that are worth to be mentioned. The I (Image) paradigm seems to require a lower number of sequences to get high classification accuracy. This paradigm starts with 72.5%, and achieves 97.5% in only three sequences. However, the other two paradigms need a higher number of sequences to get similar accuracy. Specifically, the FF (Famous Face) paradigm starts with the lowest performance in the first sequence (67.5%), but it gradually improves until it achieves 97.5% in the fourth sequences. Regarding the conventional RSVP paradigm, that is, the L (letter) paradigm, it starts with 75%, but needed 8 sequences to get 97.5% of accuracy. In this sense, in spite of the number of subjects is rather small, it is important to notice a sign of superiority of the I and FF paradigms compare to the L paradigm, requiring a much lower number of sequences to achieve good performance during the calibration phase.

Figure 3 and Figure 4 show, respectively, the mean classification accuracy and the ITR achieved by users for each RSVP paradigm, in the copy-spelling phase.

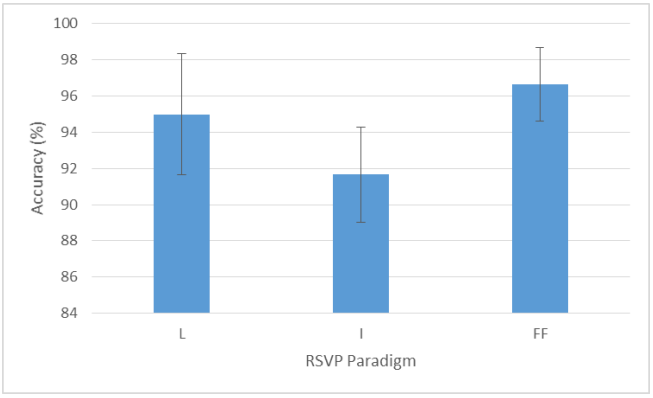

Figure 3. Classification accuracy (mean ± standard error) of the three RSVP paradigms during copy-spelling phase (L: Letter RSVP paradigm; I: Image RSVP paradigm; FF Famous Faces RSVP paradigm).

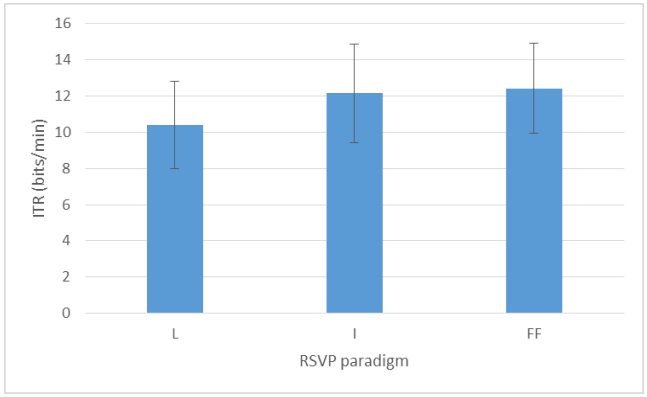

Figure 4. Information Transfer Rate (ITR; mean ± standard error) of the three RSVP paradigms (L: Letter RSVP paradigm; I: Image RSVP paradigm; FF Famous Faces RSVP paradigm).

Classification accuracy and ITR are two important parameters to measure the performance of a BCI system. Regarding the classification accuracy during the copy-spelling phase, even though the mean classification accuracies obtained in the three paradigms are high, we observe some differences. If the I paradigm was the best classified during the calibration phase, in the copy-spelling phase it has been the paradigm with the lowest classification accuracy, being the obtained values: 91.66%, 94.99% and 96.62% of the I, L and FF paradigms, respectively. These classification accuracies combined with the number of sequences required in the calibration phase to obtain good performance, allow to reach the ITR showed in Figure 4. The mean ITR of the FF paradigm (12.43 bits min^{-1}) was very similar to the ITR of the I paradigm (12.16 bits min^{-1}) and both higher than the L paradigm (10.39 bits min^{-1}), getting an improvement in the ITR of 2.04 bits min^{-1} and 1.77 bits min^{-1} for the FF and the I paradigms, respectively.

In the literature, there are some studies which try to improve the ITR of an RSVP speller system even achieving better results than those obtained in the present work. For example, in [14], the authors propose a P300 BCI speller based on the triple RSVP paradigm, stimulating characters every 250ms. This high frequency of stimulation (4 Hz) allows to obtain an ITR of 20.259 bits/min. In our study, each stimulus is presented each 300ms, decreasing the ITR. In this sense, it is important to mention that the main objective of our study was to compare three different paradigm presentations. The next step, could be to reduce the time presentation in order to increase the ITR.

IV. CONCLUSION AND FUTURE WORK

The present preliminary study about the effect of different sets of flashing stimuli using an RSVP speller has shown some trends that should be further explored in future proposals. The main finding is that the use of images and famous faces could improve the ITR compared to a classical RSVP paradigm based on letters. Moreover, it would be necessary to increase the number of symbols in the copy-spelling phase and to use a larger sample of participants in

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order to carry out statistical comparison and to obtain stronger results and conclusions.

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