Frontal Left Alpha Activity as an Indicator of Willingness to Interact with Virtual Agents: A pilot study.

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***Abstract*— Over the last decade, much effort has been made to develop virtual agents acting as assistants of elderly people in their daily activities. With the emergence of such technologies, several questionnaires have been developed to investigate the factors increasing user's acceptance of virtual agents. While questionnaires provide detailed information about user's preferences, they may not be sufficient for investigating user's internal affective states and impressions during the interaction with virtual agents. Therefore, improving assessment techniques for elders' acceptance of virtual agents is necessary for understanding the impressions they arouse and determining their design accordingly. This paper is a report of a pilot study that benefits from the predictive ability of left frontal alpha activity on positive affect and approach related motivation, and investigates the relationship between willingness to interaction of virtual agents and user's left frontal alpha activity to gain insight on user's affective and motivational states during the interaction with an agent.**

Keywords—frontal alpha asymmetry, assistive technologies, user acceptance, EEG, Affective-motivational states, left frontal activity.

I. Introduction

World Report on Ageing and Health by World Health Organisation (2015), highlighted the importance of maintaining independent living for older adults emphasized the need of action across multiple sectors to work on the goal of preventing care dependency of elderly as a part of Active Ageing: A policy framework released earlier in 2002 [1, 2].

The EMPATHIC (Empathic, Expressive, Advanced Virtual Coach to Improve Independent Healthy-Life-Years of the Elderly) project aims to contribute to technological progress by innovating, researching and validating new interaction paradigms for future generations personalized emotionally-expressive Virtual Coaches (VC) to promote independent living and active aging [3]. EMPATHIC-VC aims to engage senior users by providing enjoyable social interactions, introducing healthier lifestyle and physical activity to maintain pleasant autonomous life while minimizing the risk of potential chronic diseases and increasing emotional well-being [3].

For achieving this goal, understanding user's requirements and expectations from Virtual Coaches is crucial for assuring user acceptance for such technologies and increasing user-coach real-time interaction requires consideration of combination of modules, consequently, EMPATHIC project developed Virtual Agent Acceptance Questionnaire (VAAQ) accounting the factors that influence user acceptance [4] such as;

- Pragmatic Qualities: Usefulness, usability, and accomplishment of tasks by the proposed agent.
- Hedonic Qualities-Identity: Agent's Pleasantness
- Hedonic Qualities-Feeling: Positive and negative feelings aroused by the agent
- Attractiveness: How attractive and engaging the agent is,

In addition to these factors, questionnaire consisted assessing seniors' preferences regarding the social and physical appearance of the agent, including face, voice, age, gender, professions entrusted, and WoZ effects on agent's attractiveness [4].

Several findings of EMPATHIC project shed light on the factors influence senior's acceptance using VAAQ questionnaire and in general results showed that agent's gender, physical appearance, facial expressions, and voice play an important role in senior's acceptance [4-6].

While VAAQ found to be useful in investigating various factors on user acceptance to implement findings on improving Personalised Virtual Coaches, we were interested in the idea of additional and a real-time measurement on user's willingness of interaction with the Virtual Coaches.

To do so, we decided to set up a pilot study using electroencephalogram (EEG), a non-invasive method for recording electrophysiological activity on participants scalp during user and virtual coach interaction in order to get additional insight on user's willingness of interaction.

EEG distinguishes positive-negative affect and approach-avoidance motivation

Frontal alpha asymmetry (FAA) refers to the difference between right and the left alpha (frequency band of between 8-12Hz) activity over the frontal regions of the scalp [7]. Based on the inverse relationship between alpha power and cortical activity, smaller values indicate greater right hemispheric activity and larger values indicate greater activity in the left hemisphere [8].

FAA is considered as a marker of affective and motivational states as well as traits and common findings show that greater relative frontal activity reflects approach motivation whereas greater relative right frontal activity reflects negative affect and avoidance motivation (for review, see Reznik and Allen, 2018) [9]. For instance, Davidson and Fox examined frontal alpha activity of infants while they are watching sad or happy facial expressions and results showed that infants had greater left frontal activity during watching happy facial expressions than sad expressions [10]. Another study found that genuine smiles caused greater relative left frontal activity in comparison to non-genuine smiles [11]. Similarly, one study assessed differences in left and right frontal activity during the presentation of various dessert pictures and participants were asked level of liking the dessert as well as the time since they had eaten and results indicated that individuals with stronger tendencies of approaching the desserts (more liking of desserts, longer time since eaten) had greater left frontal activity to dessert stimuli than neutral stimuli [12]. Moreover, one experiment investigated differences in frontal activity of male participants towards erotic versus neutral pictures and results showed that erotic stimuli evoked greater frontal activation in all male participants [13].

Since considerable amount of research found that left frontal alpha activity is related to positive affect and approach motivation, right frontal alpha activity is linked to negative affect and withdrawal motivation, predictive power of alpha asymmetry has been favouring other areas of research such as consumer and neuromarketing. For example, Ravaja et al. [14] individual's approach motivation towards 14 different grocery products and found that higher perceived need for a product and higher perceived quality evoked greater left frontal activation. Also, some studies used classification method preference prediction by categorising EEG components related to approach motivation/ positive affect such as 'like' versus EEG components related to negative affect /avoidance motivation such as 'dislike' [15, 16, 17].

This pilot study explores the relationship between frontal left alpha activity and willingness of interaction with virtual agents.

To this aim an experiment has been conducted at the Psychology Department of University of Campania Luigi Vanvitelli.

METHOD

Participants:

Healthy, five right-handed participants ages between 20-45, who speaks Italian as native language and who have no sort of current psychiatric or neurological diagnosis.

Materials:

14-channel Emotiv Epoc+ EEG Brainwear device was used to measure electrophysiological activity of participants. Presentation of 9 virtual agents and willingness to interaction scale was designed by using E-prime software. HP Pavillion Laptop was used both for E-prime presentation and EEG recording which was done by EmotivPro software. Virtual Serial Ports has been used to connect E-prime and EmotivPro softwares.

Procedure:

As soon as participants arrive to the laboratory, they were given study description were given to the participant containing information about the phases of the experiment, inclusion criteria, the use of EEG. Their written consent was obtained to participate in the experiment.

During the experiment, 14-channel Emotiv Epoc+ device used to record brain activity over the scalp. Participants were attached saline-based electrodes on their scalp and for increasing the conduction between their scalp and electrodes, water-based liquid were used. An electroencephalogram (EEG) is a non-invasive method used to measure electrophysiological activity over the scalp and it is safe to use.

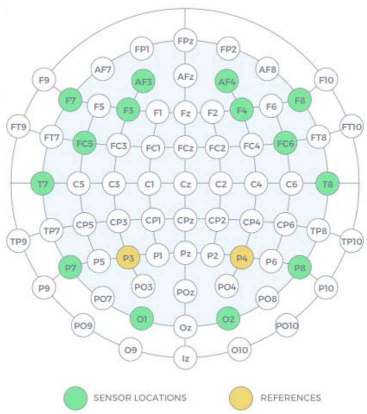

Fig 1: Channel locations of Emotiv Epoc+ 14 Channel Mobile Brainwear.

First, participants were seated in front of a computer screen, instructed to relax and their EEG activity were recorded 15 seconds eyes open and 15 seconds eyes closed for the baseline.

In the second phase of the experiment, while recording their EEG activity, participants were presented series of pictures of virtual agents/coaches. During the picture presentation, they were requested to evaluate their internal affective states towards them such as whether or not they like them and if they are willing to interact with them.

After each picture, they were asked to rate their willingness to interact with each agent on a 9-point scale. 1 was not willing to interact, 9 was very willing to interact.

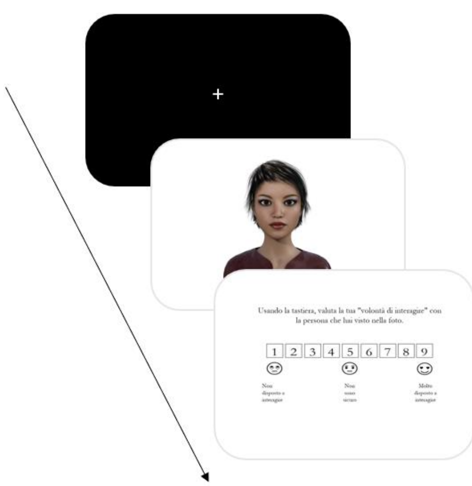

Figure 2: Order of E-Prime Presentation.

Participants were informed that they were free to withdraw at any point throughout the duration of the experiment without any penalty. Also, informed that all information they provided will remain confidential and will not be associated with their name.

Duration of the experiment was approximately 15 minutes. Debriefing were given to the participants after the experiment which included detailed information about the experiment with the contact information of the experimenters.

EEG Recording:

EEG signals were measured with the 14-channel saline-based EEG electrode system of Emotiv EPOC+ Brainwear. All EEG recording sites were carefully prepared by applying conductive water-based liquid. In the present study 14 saline soaked electrodes positioned according to the international 10/20 placement system [AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4] were fitted Emotiv EPOC+ headset with the additional two standard references at P3/P4; left/right mastoid. Emotiv EPOC+ headset was connected to the HP Pavillion laptop wirelessly via Bluetooth and signals sent to the EmotivPro software. In this study, the EEG signals were recorded from all 14 electrodes with the sampling rate of 128 Hz, with a digital notch filter at 50 Hz. The contact quality was checked through EmotivPro software.

Data processing:

The recorded EEG data was processed using the toolbox EEGLAB [18] in MATLAB R2020a. First, the data was split into two parts as a resting-state and state-dependent. In this experiment, only state-dependent data was analysed. Average of all scalp channels were computed, and data was re-referenced to Common Average Reference. Data was filtered from 0.5 Hz to 40 Hz. Bad channels and bad data segments were removed by visual inspection and Automatic Artifact Rejection was applied for cleaning the data exceeding -500 µV or +500µV. Subsequently, data was processed using ICA for correcting artifacts. Channels that were previously rejected were interpolated and the data was segmented into 9 epochs of -500 to 24.500 seconds, with 0ms marking the onset of the picture. Baseline correction was done for the pre-stimulus interval. Finally, data was split into two parts as 'Willing to Interact' and 'Not Willing to Interact' for each participant, based on their high and low ratings. Fast Fourier Transform was performed to obtain the alpha power over the frontal regions F3 and F4. Difference between alpha power over the F4 and F3 computed for obtaining frontal alpha asymmetry scores.

Analysis:

Alpha power over the frontal regions obtained from MATLAB has been analysed using SPSS for computing the results.

Hypothesis:

1. The mean value of frontal alpha asymmetry scores will differ between low and high rated agent groups. Significant difference in values is not expected but FAA scores will be higher among ‘willing to interact with the agent’ than ‘not willing to interact with the agent’ groups.

2. Left frontal activity scores will differ between ‘willing to interact’ and ‘not willing to interact’ conditions. Frontal alpha activity (F3) will be lower in high-rated agents.

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RESULTS

To test the hypothesis 1, difference of frontal asymmetry scores between high rated and low rated groups analysed using Wilcoxon Sign Ranked test because Shapiro-Wilk test revealed that data was not normally distributed (see table 1; $p<0.05$). Wilcoxon Sign Ranked test showed that there was no significant difference between the groups (see table 2; $p=0.686$).

Table 1: Shapiro-Wilk test of Normality.

	Shapiro-Wilk		
	Statistic	df	Sig.
FAA_LowRated	.949	5	.727
FAA_HighRated	.840	5	.165

Table 1 shows that data was not normally distributed ($P<0.05$).

Table 2: Wilcoxon Signed Rank Test Results

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between FAA_LowRated and FAA_HighRated equals 0.	Related-Samples Wilcoxon Signed Rank Test	.686	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 2 shows that there was no significant difference between ‘willing to interact’ and ‘not willing to interact’ conditions.

Table 3: Descriptive statistics report of frontal alpha asymmetry scores.

Report

	FAA_LowRated	FAA_HighRated
Mean	-1.121150	1.122436
N	5	5
Std. Deviation	11.2308963	8.9346231

Table 3 shows the mean values and standard deviations of frontal alpha asymmetry scores of both ‘willing to interact’ and ‘not willing to interact’ conditions.

Results showed that mean value of frontal asymmetry scores of ‘not willing to interact’ (M= -1.121, SD=11,23) is lower than ‘willing to interact’ condition. (M=1.122, SD=8.934) (see graph 1).

For testing the hypothesis 2, first Shapiro-Wilk test applied to check normality. Then difference in alpha scores between low-rated and high rated data groups were analysed by Wilcoxon Signed Rank Test because data was not normally distributed (see table 4; $p>0.05$). Wilcoxon signed rank test revealed that there was no significant difference between the groups (see table 5, $p=0.225$).

Table 4: Shapiro-Wilk test of Normality.

Tests of Normality

	Shapiro-Wilk	
	df	Sig.
LowRated_F3_Alpha	5	.045
HighRated_F3_Alpha	5	.190

Table 4 reveals that data was not normally distributed.

Table 5: Wilcoxon Signed Rank Test Results.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between LowRated_F3_Alpha and HighRated_F3_Alpha equals 0.	Related-Samples Wilcoxon Signed Rank Test	.225	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5 shows that there was no significant difference between the groups.

Results revealed that the mean of alpha values at F3 were higher in low-rated (M=4.404, SD=8.842) than high-rated (M=2.266, SD=5.960) willingness of interaction conditions.

Table 6: Descriptive statistics of alpha values at F3.

	LowRated_F3_Alpha	HighRated_F3_Alpha
Mean	4.403738	2.265744
N	5	5
Std. Deviation	8.8416586	5.9609143

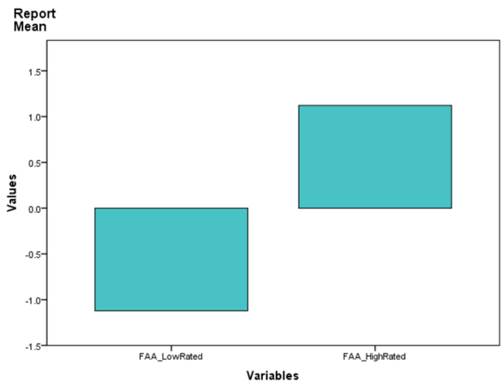
Report

Table 6 describes the mean values and standard deviations of alpha values at F3 for both low and high willingness to interaction conditions.

Discussion

This pilot study has been conducted to investigate if left frontal alpha activity indicate willingness of interaction with the agents. First, we examined the differences in frontal asymmetry scores of 'willing to interact' and 'not willing to interact' conditions and Wilcoxon signed ranked test showed no significant difference however, when we closely look at the mean FAA scores of conditions (see table 3 above), we see that mean score of 'not willing to interact' condition is lower compared to 'willing to interact' condition (see graph 1).

Graph 1: Bar graph of frontal asymmetry scores

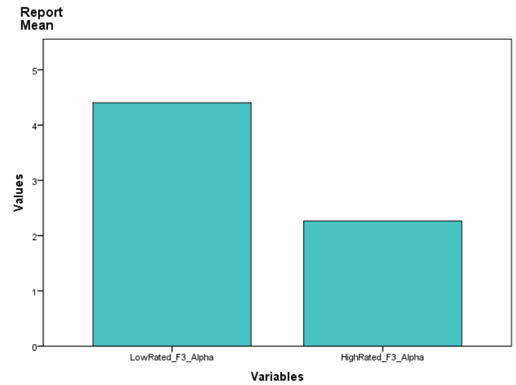


Graph 1 illustrates the frontal asymmetry values of 'willing to interact' and 'not willing to interact' conditions. Frontal alpha asymmetry is higher when participants are willing to interact with an agent.

Due to the inverse relationship between alpha power and cortical activity, low alpha asymmetry values indicate greater right cortical activity and larger values reflects greater left cortical activity [8]. Bar graph 1 illustrates that when participants interact with agents that they were willing to interact, there was increased left frontal activity and vice versa. This finding is in line with the previous findings that there is a relationship between approach motivation and asymmetrical alpha activity [7]. Results shows that our expectation of lower FAA in 'not willing to interact' condition and higher FAA in 'willing to interact' condition was fulfilled, and first hypothesis was supported.

Secondly, we wanted to pay closer attention to the left frontal alpha activity (F3) differences between two different conditions. Results showed no significant difference however, mean scores of alpha power were higher in low-rated (not willing to interact) condition than high-rated (willing to interact) conditions expected (see graph 2 below).

Graph 2: Bar graph of alpha power values over the F3.



Bar graph 2 reveals that alpha power values are higher when participants are willing to interact with an agent in comparison to low willingness of interaction condition.

This means that there was greater left cortical activation when participants were willing to interact with an agent compared to the agents that they were not willing to interact. This finding supports the previous findings that left frontal activity can reflect the level of our approach motivation as well as positive affect towards the stimuli [7, 10-14].

Our motivation for doing this pilot study derived from the need of exploring internal motivational and affective states of individuals during the interaction of our agents. We decided to benefit from previous frontal alpha asymmetry findings for improving user acceptance studies and provide additional measurement in assessing individual preferences. In our experiment we used 9 agents and investigated each participant's EEG activity towards each agent and grouped the conditions as low-willingness of interaction and high-willingness of interaction rather than grouping stimulus ourselves and presenting them as blocks in order to gain insight on individual preferences. Our sample size (both agent and participant size) were small for a pilot study but we got positive results in investigating frontal cortical activity towards desired and undesired agents. Future studies can use larger sample size as well as more virtual agents and it is also possible to group the agents by their characteristics to explore what factors influence approach related motivation. It is also possible to investigate individual preferences by looking at individual cortical left activity towards each agent and design personalised virtual coaches. This method can be used as a direct measurement of impressions towards various stimulus and it is less time and energy consuming compared to traditional methods such as presenting agents then asking participants to fill a questionnaire to evaluate each agents' characteristics after the presentation.

We also sorted our agents based on the mean scores of participant's ratings of willingness of interaction (see Figure 1 below)

Figure 1: Agents ranked (left to right) based on their ratings.

33 32 31 30 28 27 23 21 18

Figure 1 illustrates the agents used in the experiment ranked based on their mean ratings of willingness of interaction.

In our experiment, we only ranked the agents based on their ratings however it would be interesting to rank participants frontal cortical activity scores accordingly for agents to see how they are related.

By looking at the figure, we can say that agents with formal clothing were preferred over informal clothing and female agents were preferred over male agents as it was stated in EMPATHIC findings [3-6]. Therefore, it is worth to investigate further by combining their methods such as VAAQ questionnaire and looking at affective/motivational processes by using EEG as an additional measurement. For instance, in our experiment we only explored willingness of interaction and frontal cortical alpha activity and future studies can improve the methodology and assessment to explore various factors that influence user acceptance.

CONCLUSION

Since WHO highlighted the importance of maintaining independent living of older adults [1-2], lots of effort has been made to improve assistive technologies for elderly. For instance, EMPATHIC project [3-6] aims to innovate and validate new interaction paradigms such as personalized and emotionally expressive Virtual Coaches to provide active aging and independent living. For achieving this goal, improving user acceptance studies in this area to explore user-coach real time interaction is crucial. Previously, preliminary study [19] suggested the use of EEG as an additional measurement of user acceptance and in we conducted a pilot study to investigate the usage of EEG in underlying motivational processes. More specifically, we investigated the frontal cortical activity in relation to willingness of interaction with virtual agents. Our findings showed that it can be useful to track frontal cortical activity during the interaction with agents in user acceptance research and it is possible to gain further insight can be gain about user's motivational states towards agents.

By combining multiple methods, we hope to maximize the understanding of user-agent interaction and contribute to the progress of assistive technologies for maintaining pleasant autonomous life of older adults.

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