A Virtual Agent for enhancing performance and engagement of older people with dementia in Serious Games

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A Virtual Agent for enhancing performance and engagement of older people with dementia in Serious Games

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ABSTRACT

Older people with dementia have many difficulties while using Serious Game for their cognitive training. Besides of the lack of game culture and a limited acceptance toward new technology, memory and cognitive disorders influence negatively also on their performance. We propose a virtual agent that can enhance performance of player using engaging strategies. We assess the efficiency of the agent compared with a therapist through an experiment with 47 older adults distributed in two groups (Mild Cognitive Impairment and Alzheimer). The experimental results report that the agent can help participants producing similar performances (score, precision, learning effect) than in the case with therapist. Moreover, participants have appreciated the agent and desired to continue playing temporarily with the agent instead of the therapist.

Keywords
Virtual Agent; Serious Game; Older Adults; Performance.

1. INTRODUCTION

Alzheimer's disease (AD) declared as great national cause by the French Prime Minister in 2007 due to an important impact of this disease on the society. In France, 900,000 people have been affected by AD and 220.000 dementia cases are diagnosed annually [1]. The disease is classified the fourth cause of mortality [2] (after cancers or cardiovascular diseases) and the only of the 10 most important causes that cannot be neither prevented nor treated.

Unfortunately, there are no cures against this disease. Nowadays, study cases have focused on treatments allowing delaying process of the disease and reducing cognitive disorders. If drug treatments have meet side-effects and limits such as the case of acetyl-cholinesterase inhibitors [3], many non-drug treatments have been associated widely in the global treatments in order to bring additional benefits. The most used interventions by doctors are cognitive stimulation, orientation re-education and cognitive rehabilitation for maintaining and enhance eventually the impairments of different cognitive functionality. Other less used treatments (reminiscence and validation) take an interest for stimulating evocation of the past and recognizing AD people's emotion [5].

Since the last decade, Serious Game becomes progressively new training tendency for stimulating cognitively the patients with dementia. This media is appreciated widely thanks to some advantages compared with classical training approaches. Serious Game has an effective cost and an easy access for older users. In additional, this flexible solution can motivate their adherence by immersing the user in a playful environment and achieve positive effects on different cognitive functionalities.

However, older people meet some significant barriers for using regularly and efficiently this leisure activity in many contexts (living home or hospital). Most of them present a lack of game culture and get some negative look toward video game. In additional, they feel hesitate [4] to use new technology tools in daily activities because a lack of knowledge on technology evolution. Playing with new devices such as Kinect or Wii integrated in video game is not an easy task and can influence negatively on user performance. For example, Kinect camera requires good positions of user right in the range of camera. The control of device becomes harder when users set too close or too far from the device. Moreover, older people suffering from AD or other related pathologies have other boredoms for playing easily game. They can be distracted and make repetitive errors because of attention disorders. Memory disorders make rules and interaction mechanism of game becoming harder to recall.

Consequently, their game performance can be badly touched and their engagement can become quickly discouraged when facing to repeated problems and on help in time. More importantly, they can rapidly abandon the game after a short use. For avoiding these critical situations, we propose in this paper an engaging approach using a virtual agent able to enhance the performance of older player during their cognitive training with serious game by offering helps in the appropriate moments.

In section 2, many studies related with various virtual agents are described. We give the details of our engaging approach including proposed agent in section 3. We assess the efficacy of our agent by comparing with a person through an experiment in section 4. Conclusion and discussion are presented in last section.

2. RELATED WORK

For compensating the problems cited above, we take an interest of all of virtual like-human agents (e.g. relational agents or conversational agents) that can product various positive effects on users. Doris in his review [6] on the impact of animated interface agents (AIA) has reported that AIA can influence on the player's experiences and behaviours. In fact, users have perceived a virtual card matching game with an animated face as more entertaining and more engaging than one without face. In addition, people using a tutoring system incorporated these agents can get a better understanding of the issue in question then a system without agent. Despite these positive effects, we wonder if the same things might happen with older adults with dementia because all of subjects in experimental phases are active young people.

In the critical review of Campel [7] on the relational agents in different domains, an agent for health and behaviour change among older adults, named Laura, has kept our attention. The agent has designed to be an exercise advisor who can interact with users through a script dialog mode for encouraging user to make exercise and talk with empathy to user performance. Two groups of older adults have participated in the experiment of walking exercise at home [8] in which one group (called relational group) will interact with the agent and the other (called control group) will not. Each subject in both groups has been instructed to report their daily steps computed by a pedometer on a paper log sheet. Subjects in relational group has been asked to participate in a short interaction session after the walking steps report in which the agent will adapt the dialog content in terms of subject's performance in order to always maintain his engagement. After two months of experiment, most of subjects in relational group have desired to continue using the system with the agent and have performed more walking activity than subjects in control group. So far, the same agent has been used in two other studies [9] for measuring the effects of his behaviour variability and back stories on long-term engagement. When the agent has showed variably its behaviours, the subjects have tended to interact more with the agent and have reported high desire to continue interacting. Furthermore, when the agent has used first-person stories to talk with the subjects, they have reported greater enjoyment of the stories and were more likely to use the system. These studies have proved successfully that Louise agent can maintain user's long-term engagement by being more like-human thanks to behaviour variability and back stories. However, the target subjects have been still active and the tasks in these studies have been relatively simple. Further, the agent cannot handle critical situations in which subjects can forget completely to report the walking steps and participate to interaction sessions with the agent because of their memory disorders. Other similar work aim to render the agent more like-human by adapt dynamically emotions. Kasap and al. [10] have developed a memory-based emotion model for his agent, Eva. In short, in each session of interaction, the agent has assessed the overall relationship level by user emotional impulses in order to adapt her face emotional mood. The particularity of this model is that all past relationship levels have been stored and the current level are updated by the current emotional impulses of user and the past relationship levels.

We have found also the agents who have been tested with older adults with dementia. Ortiz and al. [12] have tested 15 older people distributed in three different groups (normal aging, mild cognitive impairment and Alzheimer) with three prompting interface: with a virtual agent, with text and voice and with only text. In each interface, subjects have performed two tasks: writing the answer to the question posed by the interface. The obtained results have showed that subjects have followed instructions better with the agent. (92% of subjects have performed correctly the tasks when asked by the agent against 66% performed correctly when asked by the text interface. Yasuda and al. [11] have presented an interesting result of his conversational agent efficiency compared with a human partner. 8 subjects (±78.5 year old, ±22.2 MMS score) have answered 15 reminiscent questions asked by the agent then by the human partner. The agent can automatically detect the end of speech sound of a subject's reply to a question and begin asking the next question. The result showed that the agent have succeed to elicit 74% utterances of subjects and can be an alternative tool of conversation when no human conversation partner exists.

We finish our research by the recent study on attention management of older people with dementia of Wargnier and al [13]. 8 subjects (2 normal states, 3 MCI and 3 Alzheimer) have been seated in front of the screen on which the conversational agent was displayed and were instructed to answer to questions posed by the agent. During current interactions, the agent has used an algorithm for assessing the attention level of the person by computing the angle between his shoulder line and the Kinect camera posted ahead of the screen. The level values have ranged from 0 to 10. The value is maximal when the user's body and face are directly oriented towards the sensor. A user has been considered "distracted" when the value has decreased below 6. At this moment, the agent automatically has stopped and prompted the subject to attract his or her attention. The results have reported accurate 80% of attention management method and the findings were independent of the user's cognitive status.

To summarizing, cited works confirm many positive effects of a virtual agent with user. Its presence influences favorably on user engagement with the system. Most of cited agents have been designed like-human through different methods (emotion, back stories or behavior variability) for gaining user's perception. Attention level algorithm of Wargnier can be useful in our Serious Game context because user's engagement might be stable as long as the user looks at the screen. However, among users with dementia, "forget of instructions", caused by memory disorders, can happen even if they are looking at screen. Then they can perform badly instructions. Further, no works have been made for comparing the efficiency of these agents with a human being because in some specific context (problem of lack of staff or a use of application in home) we need to know if these agents are enough efficient for replace temporarily human being.

3. DESCRIPTION OF ENGAGING APPROACH

We propose an approach for enhancing user's performance during his Serious Game activities. The main key of this approach is determining appropriate moments to interact with users based on predefined engaging strategies. Users with dementia might quit the game if they cannot solve problems and no helps are provided in time. Here, we have to provide dynamically helps when the moment happens. If possible, we should anticipate this moment before bad things can happen. For determining appropriate moments, we collect data from different sources using an interactive system. Once the moments are determined, we use an animated agent for provide helps to users.
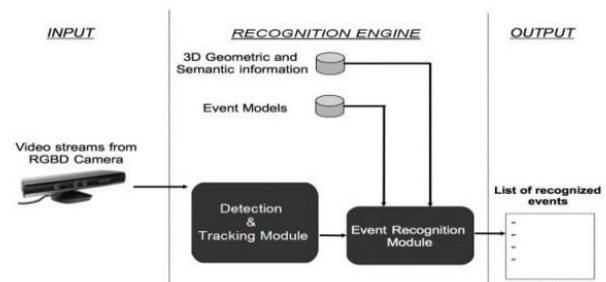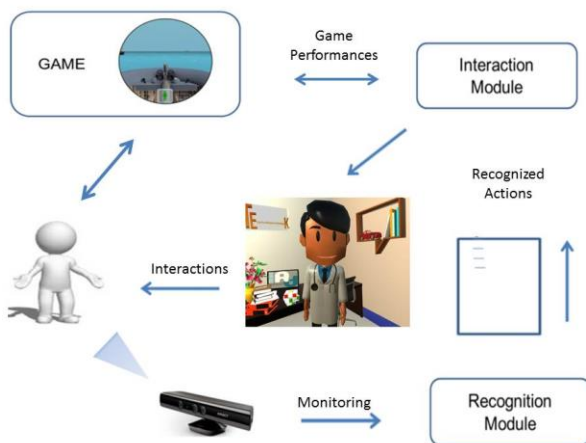
3.1 Interactive System

Figure 1- Structure of SUP framework

The system takes a role of decision maker in our approach. It determine moments of interaction based on environmental actions

and current game performance of users. For that, the system consists of two modules: *Recognition* and *Interaction.* The first module is designed as an eye of the system. It tracks and monitors all of user's actions achieved in the space around game devices that can help for enriching as much as possible engaging strategies. These actions are updated and transmitted regularly to the second module that gathers the last ones with current game states for determining the appropriate moment and then notifies the agent (see Figure 2). In our research context, we have implemented inside Recognition Module the SUP platform[1] which is an event recognition framework. From image streams captured by RGB-D camera, the framework detects and tracks different user's actions (position, move path, velocity or gestures and postures) in other to determine events thanks to a descriptive language able to define the spatial-temporal constraints between the actions and users' states (see Figure 1).

Figure 2 - Interaction cycle consists of the interactive system and the animated conversational agent

3.2 Engaging Strategy

Thanks to the SUP framework, the general system gets a global perception in the environment that allows establishing regular interactions with the person based on predefined scenarios. The main purpose of these interactions is the engagement of the person toward the video game. For example, the system recognizes that the person sit on the crouch in front of during his free time, it can be a great moment for interacting with the person. The interaction can be started by a little conservation about a familiar topic and then the system can suggest to the person playing a game session.

Once the person accepts to play game, it is important that he plays as long as possible. The more the person is kept active during the game and provided with advices and prompts as soon as possible, the more his engagement would be maintained. We realize that recognizing the person actions is not enough for covering all of possible critical situations that can happen because his game performance is related with his cognitive level. Here, we need also to perceive what he is going to do in the game, in other words we need to survey his game performance. Two values related with game performance can influence greatly on their performance: the accuracy of each answer and the reaction time for each interaction with the game. A great number of errors mean that participants might be distracted or forget the rules of game. When they take a

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[1] https://team.inria.fr/stars/software/sup/

long time for reacting to current interaction, it can be due to a misunderstanding of instructions or a distraction.

3.3 Virtual Agent

Once the appropriate moment is determined, the system has to interaction with the person by a friendly way. For that, we decide to use a virtual agent that is a virtual doctor-like male character (see Figure 3). It is rigged and animated by 3ds Max editor. In fact, the agent can walk, perform body part gestures, wink, smile and move lips for pretending "speaking" by chording lips forms with words in pre-recorded speeches. The agent's emotion and pre-recorded speeches are always positive in order to encourage users' sentiment even when they have achieved bad interactions. An interaction is selected by computing current game state with notifications sent by the interactive system.

Figure 3- The animated conversational agent

4. EXPERIMENT

The engaging approach has been experimented in our previous studies. In [13], we proved that our agent can initiate and encourage user to continue playing game based on his position thanks to the monitoring of SUP. In [14], we assessed the approach by implementing the interaction system and the agent into a concentration-based game with older participants distributed in three groups (mnesic plaint, mild cognitive impairment and Alzheimer). The results reported that, first, participants have always finished the game session when playing with the agent accompaniment whereas two participants in Alzheimer group have abandoned the game session when playing without the agent assistances. Also all participants in Alzheimer group performed significantly much better when playing with the agent. In short, playing with the agent is better than playing without helps.

In this paper, we are interested to assess the efficiency of our approach compared with a therapist. For that, we have chosen a real context where older adults come to health institution for achieving memory and cognition training with a therapist. They will play together with the therapist than play alone. The agent now has introduced instead of the training and we have compared people performance in both modalities: playing with therapist VS playing with agent. Through the experiment, we aim to confirm some hypotheses:

H1: Participants would perform much better with agent help than without any help and this performance would be similar than the one with therapist help.

H2: Participants would perform more accurately with agent help than without any help and this accuracy would be similar than the one with therapist help.

H3: After playing with agent help, participants would acquire similar learning effect than playing with therapist help.

4.1 Population Description

We have tested our engaging approach with 47 cognition-impaired older adults distributed in 2 groups (see Table 1). During their consultation in Memory Center[2], they were suggested randomly to perform a training of stimulation in the form of a video game. All of participants agree to sign an inform consent of images. The only inclusion criteria are their mini-mental state examination scores (MMSE). We have recruited in this experiment more Alzheimer participants than Mild Cognitive Impairment (MCI) participants because results of previous study have reported that normal people did not need the agent's help and the performance of MCI participant is not significantly better than playing with the agent. Only Alzheimer participants have a better performance thanks to the agent's helps.

Table 1 - Population Description

	Number	Average of age	Average of MMSE
MCI	17	76.5 ± 7.5	24 ± 1.7
Alzheimer	30	79.2 ± 8.5	17.7 ± 2

4.2 Experimental Protocol

Participants are conducted in a private room and placed in front of a touch-screen table installed the serious game. The therapist explains first to participants how to use interaction mode of the table. Next, he instructs the protocol. We underline that no participant has already experimented the game before.

The protocol consists of three modalities: "playing together with therapist", "playing together with conversational agent" and "playing alone without any help" (see Figure 4). Each participant has to achieve two passages in which the participant plays with one of the three modalities. Order of the passages is following: a randomization on the three modalities for the first passage and other randomization excluding the modality of previous passage for the second passage (see Figure 4).

Except "playing together with therapist" modality, participants play the game by staying alone in the room in order to avoid the distraction. In some special cases, when the participant does not want to be alone, the therapist rests but does not give any reaction with participant until he finished the passage. At the end of each passage, the results are stored for assessing cited hypotheses above. After two passages, participants are instructed to answer a questionnaire on their satisfaction on the game and the agent assistance.
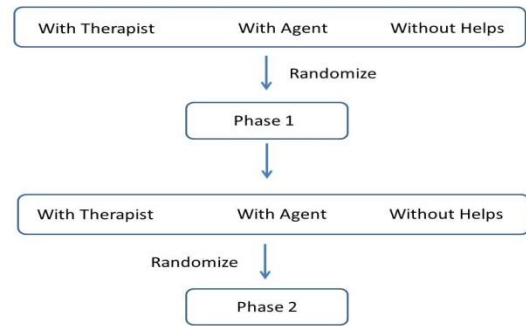
Figure 2 - Experiment Protocol

For the experiment, we have designed a mini game inspired by the digit-symbol substitution test[3] that is often used for assessing the memory. We were asked by the doctor to modify a little the design and the mechanic of the game in order to avoid the learning effect on the test. We have included a tutorial that was proposed to the participant at the beginning of game. In short, participants have nine images in the table at the bottom of the screen. When new image has appeared in the center of the screen, participants have to match the same image in the table and touch it for answering. New image only has appeared when participants have arrived to make a correct answer. In two minutes, they might to match as much as possible. The number of correct and wrong answers has been displayed at the end of passage.

Here is our strategy included with the agent:

- Participants have 15 seconds reacting to current interaction; otherwise the agent intervenes first for recalling his attention. In the second time, the agent supposes that participants can have other problems than distracted. He displays on the screen fourth cases ("I'm thinking", "I don't know what to do", "I want to resume the game" and "I want to quit the game") and participants touch on the cases they desire.
- Participants can make errors and the agent does not intervene for each error for avoiding the pressure on them. We have programmed the agent interventions only when participants make three consecutive errors. We pretend that one correct answer after two consecutive wrong answers can keep engagement level of participants.

Figure 4 - Three modalities (from left to right): playing together with the agent, playing together with therapist and playing alone without any helps

4.3 Results

For validating the hypothesis 1, we observed the scores (e.g. the number of matched images) of participants in the first passage (see Table 2). We estimated that first performance might up their real capacity of comprehension and adaptiveness towards the game. The results showed that, in the one hand, the helps of agent or therapist did not make great impact on the performance of participants in MCI group. In the other hand, participants in Alzheimer group can benefit totally the helps of agent and therapist. Moreover, participants playing with agent achieved only 4 matched images in two minutes, by means, less than participants playing with therapist.

Table 2 - Average score of MCI and Alzheimer group in three modalities

	Without helps	With agent	With therapist
MCI	66.83	67.83	68.60
Alzheimer	17.43	32.92	36.55

Table 3 - Average accuracy of MCI and Alzheimer group in three modalities

	Without helps	With agent	With therapist
MCI	86.92 %	86.75 %	87.75 %
Alzheimer	58.85 %	84.36 %	86.56 %

We assessed next the accuracy of participants for validating the hypothesis 2. The accuracy was computed as the ratio of correct answers and the number of answers in total included wrong answers. Again, we obtained the same results (see Table 3). Participants in MCI group made some errors during the passage 1 and they played with equivalent ratios of errors in three modalities. It can be explained by the tolerance of engaging strategy for errors. Agent and therapist did not intervene on each error and the participants continue making correct answers after few errors. Regarding participants in Alzheimer group, the different of accuracy between "playing without any help" with two others modalities were significant. In fact, adaptivity of Alzheimer participants with the game for the first time when playing without any help was not easily accomplished. Once again, the agent performs a similar efficiency compared with the results with therapist.

For validating the last hypothesis, we have assessed the performances in second passage of all participants who either play "with therapist" or play "with agent" in first passage. The results have been encouraged (see Table 4 and 5). Most of participants in "playing with agent" modality have acquired learning effects close enough that other participants in "playing with therapist" modality despite a slight difference in accuracy of Alzheimer group.

Table 4 - Average score of MCI and Alzheimer group in second passage with "Playing without any help" modality

	After playing with therapist	After playing with agent
MCI	65.40	64.67
Alzheimer	36.36	35.7

Table 5 - Average accuracy of MCI and Alzheimer group in second passage with "Playing without any help" modality

	After playing with therapist	After playing with agent
MCI	90.10 %	82.99%
Alzheimer	87.69 %	74.52 %

For acknowledging more information about user's perception, we have analyzed the questionnaires asked at the end of two passages. The content has been divided in two parts: about the game and about the agent. Here are the results extracted from the questionnaires:

- 92% participants have never played a video game before. Only 4 participants have already used Ipad touch-screen with their little children.
- 96% participants have enjoyed the game because of game mechanics and the easy-perceived game design and they have desired to replay the game in the next consultation with the doctor. 2 participants don't like to play game in their daily activities so they found the game "normal".
- Most of participants have assessed the agent "friendly" and have appreciated agent characteristics (voice, speech, animation and appearance)
- 96% of participants have thought that the agent can temporarily play with them instead of therapist.

5. CONCLUSION

An approach for enhancing user performance in Serious Game is proposed using a virtual agent included engaging strategies. We assess the efficiency of the agent compared with a therapist through an experiment with 47 older adults with distributed in two groups (MCI and Alzheimer). The results reported that participants can product similar performances (score, accuracy, learning effects) when playing with the agent than when playing with the therapist. Further, subjective results reported that agent characteristics were greatly appreciated and the agent can temporarily accompany participants instead of therapist in the game. A long-temps study of using the agent in other reel context (in living home) can be the next research object for exploring more strategies for enhancing user performance with Serious Game in long-term.

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