



**HAL**  
open science

# Maintaining the engagement of older adults with dementia while interacting with serious game

Minh Khue Phan Tran

► **To cite this version:**

Minh Khue Phan Tran. Maintaining the engagement of older adults with dementia while interacting with serious game. Human health and pathology. COMUE Université Côte d'Azur (2015 - 2019), 2017. English. NNT: 2017AZUR4024 . tel-01578114

**HAL Id: tel-01578114**

**<https://theses.hal.science/tel-01578114v1>**

Submitted on 28 Aug 2017

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## **ECOLE DOCTORAL STIC**

SCIENCES ET TECHNOLOGIES DE L'INFORMATION ET DE LA COMMUNICATION

# **Thèse de doctorat**

en vue de l'obtention du  
grade de docteur en Informatique  
de l'Université COTE d'AZUR

par

Minh Khue PHAN TRAN

## **MAINTIEN DE L'ENGAGEMENT DANS LES JEUX SERIEUX DE PERSONNES AGEES SOUFFRANT DE DEMENCE**

Dirigée par François BREMOND

Soutenue le 20 Avril 2017

Devant le jury composé de :

Fabio SOLARI	Professeur adjoint, Université de Gênes	Examineur
François BREMOND	Directeur de recherche, Inria Sophia Antipolis	Directeur de thèse
Philippe ROBERT	Professeur, CoBTeK CMRR CHU Nice	Examineur
Mounir MOKHTARI	Professeur, LIRMM	Rapporteur
Xavier ROCA	Directeur de recherche, Universitat Autònoma de Barcelona	Rapporteur

---

# Acknowledgements

---

Foremost, I am deeply grateful to my supervisor, Research Director Francois BREMOND, for the continuous support of my Ph.D study and research, for his patience, source of inspiration, enthusiasm and research methodology. He always engages me in the new ideas, requires a high quality of works during three years of research and without him, this thesis would not have been finished and written.

Beside my supervisor, I would like to thank Prof. Philippe ROBERT who is my advisor for the experimentations of the thesis. He has provided me the best conditions to test my approach to the patients with dementia within his institution.

Additionally, I would like to thank my Jury members Professor Mounir MOKHTARI, Research Director Xavier ROCA, and Assistant Professor Fabio SOLARI for their interest in my work.

For financial support, I want to thank the Genius Interactive Montpellier company for their work environment. I acquired a lot of professional competences in Serious Game development.

The thesis was accomplished with the help and the support of the fellow lab-mates in Stars and CoBTek team. Their warm welcome since the first day and help rest always in my mind.

Finally, special thanks also to my parent, my uncle and my wife for always supporting me all the time. Despite the geographical distance, they have followed my activity research and engaged me in difficult moments. My sincere thanks also go to Vietnamese friends for their presence and their help during my stays in Nice and Inria Sophia Antipolis

---

# Résumé

---

Le nombre croissant de cas de démence chez les personnes âgées attire l'attention de nombreux chercheurs de différentes disciplines. Diverses solutions non médicamenteuses ont été proposées dans lesquelles la stimulation cognitive prend place parmi les choix possibles. D'ailleurs, les jeux vidéo ont été impliqués dans de nombreux projets de santé comme soutien privilégié pour étendre et résoudre les limites des traitements non médicamenteux. Cependant, l'utilisation du jeu vidéo pour les personnes âgées avec la démence pendant une longue période est considérée comme une activité difficile. Ils n'ont pas les mêmes expériences de jeu que la jeune génération et ne peuvent pas utiliser activement et indépendamment cet outil en raison des troubles cognitifs et de la mémoire causés par la maladie. Dans cette thèse, une approche est proposée avec le but de maintenir l'engagement des personnes âgées avec la démence en interagissant avec les jeux vidéo. Cette approche vise à fournir dynamiquement les interactions appropriées aux utilisateurs en fonction de la situation courante définie par leurs activités physiques et leurs activités de jeu. Un système de support est développé pour valider l'approche à travers 3 expériences réalisées avec des participants recrutés via le centre de mémoire. Les résultats montrent que: 1) les personnes âgées atteintes de démence peuvent interagir successivement avec le système proposé 2) leur performance du jeu est maintenue, 3) l'efficacité du système de support est similaire à celle d'un thérapeute. Les futurs travaux visent à tester le système de support à domicile pendant de longues périodes avec des personnes âgées avec démence.

---

# Abstract

---

Recently, the world witnesses an increasing number of the dementia cases in the older population, which causes an important impact in the society. This phenomenon attracts the attention of many researchers in multi-disciplines. Various socio-medical non-drug solutions have been proposed in which cognitive stimulation takes a place among the possible choices. In parallel, video games have been involved in many healthcare projects as privileged support for both extending and solving the limits of non-drug treatments. However, using video game for older adults with dementia in long period of time is considered as a difficult activity. They do not have the same gaming experiences as the young generation and cannot use actively and independently this tool because of memory and cognitive troubles caused by the disease. In this thesis, an approach with the purpose of maintaining the engagement of older adults with dementia while playing video game is proposed. This approach aims to provide dynamically the appropriate interactions to the users based on the current situation encompassing their physical activities and game activities. A support system is developed for validating the approach throughout 3 experiments with participants recruited from the memory center. The results show that : 1) older adults with dementia can interact successfully with the support system, 2) their game performance (playing time, accuracy rate, learning effect) is maintained, 3) the effectiveness of the support system is similar to the one of a therapist. Future work aims at testing the support system at home for long periods of time with older adults with dementia.

---

# Contents

---

<b>Acknowledgements</b>	<b>2</b>
<b>Résumé</b>	<b>3</b>
<b>Abstract</b>	<b>4</b>
<b>List of Figures</b>	<b>8</b>
<b>List of Tables</b>	<b>11</b>
<b>I How to maintain engagement of older adults with Serious Game ?</b>	<b>12</b>
<b>1 Introduction</b>	<b>13</b>
1.1 Context of Study . . . . .	13
1.1.1 Motivations . . . . .	13
1.1.2 Context of work . . . . .	16
1.2 Objectives . . . . .	17
1.3 Contributions . . . . .	18
1.4 Structure of the manuscrit . . . . .	19
<b>2 State Of the Art</b>	<b>20</b>
2.1 Age-Related Changes among older adults with dementia . . . . .	20
2.2 Concepts of engagement . . . . .	21
2.3 Interface Design for Older Adults . . . . .	26
2.4 Virtual Agents . . . . .	29
2.5 Game Design for Older Adults . . . . .	32
2.6 Conclusion . . . . .	36
<b>3 Approach: structure of a support system based on a making-decision mechanism</b>	<b>38</b>
3.1 Engaging Strategy and Support System . . . . .	38

3.2	Support Manager . . . . .	39
3.3	Recognition and Interaction Component . . . . .	45
3.3.1	Recognition . . . . .	45
3.3.2	Interaction . . . . .	50
<b>II Experiments</b>		<b>52</b>
<b>4</b>	<b>Experiment 1: Can the older adults interact successfully with the support system ?</b>	<b>53</b>
4.1	Pre-studies . . . . .	53
4.1.1	Pre-study 1 . . . . .	54
4.1.2	Pre-study 2 . . . . .	62
4.2	Experiment 1 . . . . .	66
4.2.1	Context and Objective . . . . .	66
4.2.2	Target Population . . . . .	66
4.2.3	Games used with the support system . . . . .	67
4.2.4	Implementation of the support system . . . . .	69
4.2.5	Protocol and Interaction Scenarios . . . . .	72
4.2.6	Collection of data . . . . .	74
4.2.7	Results . . . . .	74
4.2.8	Discussion . . . . .	75
<b>5</b>	<b>Experiment 2: Can the support system improve the game performance of the older adults in Serious Game ?</b>	<b>77</b>
5.1	Context and Objective . . . . .	77
5.2	Target Population . . . . .	78
5.3	Game used with the support system . . . . .	79
5.4	Implementation of the support system . . . . .	81
5.5	Protocol and Interaction Scenarios . . . . .	82
5.6	Collection of data . . . . .	83
5.7	Results . . . . .	84
5.8	Discussion . . . . .	87
<b>6</b>	<b>Experiment 3: Assessing the efficiency of the support system compared to the therapist</b>	<b>94</b>
6.1	Context and Objective . . . . .	94
6.2	Target Population . . . . .	95
6.3	Game used with the support system . . . . .	95
6.4	Implementation of the support system . . . . .	100
6.5	Protocol and Interaction Scenarios . . . . .	103

6.6	Collection of data . . . . .	105
6.7	Results . . . . .	106
6.8	Conclusion and Discussion . . . . .	107
<b>7</b>	<b>Conclusion and Discussion</b>	<b>108</b>
7.1	Contributions and Limits . . . . .	108
7.1.1	Approach . . . . .	108
7.1.2	Experiments . . . . .	111
7.1.3	Conclusion . . . . .	113
7.2	Perspective . . . . .	113
<b>A</b>	<b>Annexes : Az@Game Partners</b>	<b>116</b>
	<b>Bibliography</b>	<b>119</b>



---

# List of Figures

---

1.1	Infographic of World Alzheimer Report 2015 [1]	14
1.2	Schematic comparison between a healthy brain and an affected brain	15
2.1	The Acceptance of technology Model 2	22
2.2	Overview of Engagement Modes-Model	23
2.3	Model of engagement and its attributes [2]	24
2.4	Touch interface based on NFC technology	27
2.5	On the left, a touch interface for calls. On the right, a touch interface for TV remote control.	28
2.6	On the left, SharePic application. On the right, SharePic in a tabletop.	28
2.7	the SWEET-HOME system diagram	30
2.8	First animated agent[3]	31
2.9	agent Eva with Emotion Editor [4]	32
2.10	The guessing-base card game using a tabletop augmented reality platform.	33
2.11	On the left, the interface of table tennis game playing with depth sensor. On the right, the interface of table tennis game playing with mouse.	35
2.12	The interface of SilverBalance game using the Nintendo Wii Balance Board	35
2.13	Overview of Cupcake Heaven - a wheelchair-based game using the Kinect <sup>Wheels</sup>	36
3.1	Composition of Support System	40
3.2	Structure of the Support Manager	41
3.3	Composition of Recognition Module	45
3.4	Detecting people in different scene of background subtraction algorithm	46
3.5	Tracking people in different scene of multi-features tracking algorithm.	47
3.6	An example of PrimiviteState model	48
3.7	An example of CompositeState model	48
3.8	An example of PrimitiveEvent model	49
3.9	An example of CompositeEvent model	49

3.10	Overall composition of the Interaction component which consists of an animation Controller, a sound Controller and an animated agent. . . . .	50
3.11	The virtual agent is modeled and rendered by the Unity3D editor. . . . .	51
4.1	First pre-study in coffee space at Inria local . . . . .	55
4.2	Shape Game - a game on Kinect sensor with voice command and motion control . . . . .	55
4.3	The young girl agent is immersed in a virtual living room by the Unity3D editor . . . . .	57
4.4	Animation scenarios of the young girl agent are organized with the game engine Unity3D. Here are the animations "reminding the rules of game" (top) and "congratulating" (bottom). . . . .	57
4.5	A desktop (running in Windows OS) and Kinect sensor (Figure top) is used to implement the support manager, the game controller and the interaction component. Other kit(desktop running in Linux Fedora 14) (Figure below) is used to implement the recognition component. . . . .	59
4.4	Set of events to recognize in the first pre-study, in which three main events allow to determine the moment to interact with people . . . . .	60
4.6	Structure of the socket server/client to compute data between the support manager and the recognition component . . . . .	61
4.7	Screenshot from the interface of the Recognition component in the second pre-study led in waiting room at Claude Pompidou Institute . . . . .	62
4.8	New set of events of the second pre-study for recognizing user's positions and movements relative to the screen. . . . .	64
4.9	Good View Hunting: a training game on upper limb with Kinect sensor. The user controls tools for cleaning dirty marks by wiping with his/her arms. The game is also available in multi-player mode that allows family members to play together. . . . .	67
4.10	a) Menu containing 6 scenes (3 contexts in 2 modes). b) The player cleans bird dirt in a Star Ferry context in mode Night. c) Cleaning tools: each tool is used to clean a specific dirty mark. . . . .	68
4.11	a) Evaluation report on the success rate and the average response time of wiping actions. b) Final score . . . . .	69
4.12	Extraction of tutoring videos: a) Shape Game tutorial b) Good View Hunting tutorial. . . . .	69
4.13	The space to play is divided into two virtual zones. . . . .	71
4.13	Set of events to recognize of experiment 1 to track the user positions and movements relative to the screen. . . . .	72
4.14	The private room of experiment is equipped with a screen, the support system, the game and a playing space. . . . .	73
5.1	a) Two versions of the game are used in the experiment 2. At left, the game is built with assistance of the support system. At right, the game is devoid of the support system. b) Notice page presenting the rules and the advices before playing. . . . .	79

5.2	Examples of the choice of answer: a) a correct answer with a red arrow b) a correct answer for a blue arrow c) symbol for a wrong answer. . . . .	80
5.3	The results are presented at the end of the session including the number of the correct answers, the wrong answers and the success rate. . . . .	81
5.4	The agent intervenes to recall the user attention . . . . .	81
5.10	Results of precision rate of 3 groups in two modes (with agent and without agent). . . . .	86
5.5	Extraction of tutoring video: a) checking the user position facing to the sensor b) learning the rules and instructions of the current difficulty level c) practicing the rules . . . . .	89
5.6	The agent is improved with new cloths style and animations. . . . .	90
5.7	Protocol of the experiment 2 . . . . .	90
5.8	a) The user interacts with the agent b) The user plays game . . . . .	91
5.9	Results of playtime of 3 groups in phase 2 and 3 (playing with agent and without agent). . . . .	92
5.11	Results of subjective evaluation of the player on the agent's properties. . . . .	93
6.1	The user plays the digit symbol substitution game on the touch table. . . . .	96
6.2	The game is build in two mode: mode with the support system and mode without the support system. . . . .	97
6.3	Before playing, the user is asked if he / she plays already the game. If not, a tutorial is launched to help the user to learn the rules of the game. . . . .	97
6.4	Extract of the tutorial. . . . .	98
6.5	a) Right matching b) Wrong matching . . . . .	98
6.6	At the end of the tutorial, the user has possibility of either retrying the tutorial or passing to the game. . . . .	99
6.7	The main game interface with a countdown timer. . . . .	99
6.8	At the end of the game, the number of the matched symbols and of the errors are displayed. The user has possibility of retrying the game or getting away. . . . .	100
6.9	New virtual agent with an appearance of doctor is placed in a doctor office. . . . .	101
6.10	The agent guides the user for the tutorial: a) the agent asks if the user plays already the game b) the agent explains the rules and helps the user to match the symbols c) the agent asks if the user want to retry the tutorial of to pass to the game. . . . .	102
6.11	The agent asks to the user more information when the inactivity is recognized more than 2 times. . . . .	103
6.12	The agent explains to the user the mean of the displayed results. . . . .	103
6.13	Protocol of the experiment 3 . . . . .	104
6.14	The therapist uses the game mode without the support system for playing with the user. . . . .	105
A.1	Partners of Az@Game project . . . . .	116
A.2	CoBTek team's research activity . . . . .	118

---

# List of Tables

---

2.1	Overview of wheelchair-based and body-based input supported by Kinect <sup>Wheels</sup> . . .	36
3.1	Interaction Strategies . . . . .	44
4.1	Speech vocabulary of Shape Game’s voice commands . . . . .	56
4.2	Description of the target population in the experiment 1 . . . . .	67
4.3	Results of interaction . . . . .	74
4.4	Results of subjective evaluation about the agent properties. . . . .	74
5.1	Description of the target population in the experiment 2 . . . . .	78
5.2	Evaluation form about the agent’s properties in the experiment 2. . . . .	83
5.3	Difference in percentage of playing time between the phase 2 and the phase 3 . . .	85
5.4	Difference in percentage of accuracy rate between the phase 2 and the phase 3 . . .	87
6.1	Description of the target population in the experiment 3 . . . . .	95
6.2	Evaluation form about the agent properties in the experiment 3. . . . .	105
6.3	Average score of MCI and Alzheimer group in three phases . . . . .	106
6.4	Average accuracy of MCI and Alzheimer group in three phases . . . . .	106
6.5	Average score of MCI and Alzheimer group in second phase with “Without help” .	106
6.6	Average accuracy of MCI and Alzheimer group in second passage with “Without help”	107

## **Part I**

# **How to maintain engagement of older adults with Serious Game ?**

## Chapter 1

---

# Introduction

---

## 1.1 Context of Study

### 1.1.1 Motivations

In 2015, the world population aged 60 or older counts more than 900 million people, equivalent to 12 percent of the total population. This part progressed gradually from 9 percent in 1994 to 12 per cent in 2014 [5]. In French, this population occupies 27,7 percent of the total population in 1<sup>st</sup> January 2015 and is expected to reach 31,9 percent in 2050. Especially among the people aged 75 or older, they could expand from 9,3 percent in 2015 to 16 percent in 2050 [6].

This emerging increase can be explained by two main reasons. On the one hand, it's linked with the arrival of these ages of many generations following the baby-boom<sup>1</sup>, meaning born between in 1945 and in 1975. On the other hand, it is simply because the global life expectancy continues to improve better. According to INSEE [7], the life expectancy of man in French raises to 5.6 years and the one of woman raises to 3.6 years in 20 years. Among the people aged 60, the life expectancy of man gains 1.7 years and that one of woman is 1.2 years in the last decade. If the first reason is a consequence of an event in human history (war is over, dead rate decreased and birth rate increased), the second reason is due to a great evolution in term of medicine and technology science.

People are now living longer, but these years gained thanks to the medical and scientific progresses only make senses if they could take place in the best conditions, that means people in old age need to remain their active life as long as possible until when they become dependant. Many studies in Social-Gerontology have given different definitions [8, 9] for this purpose and most of them have been inspired by the classical definition of Rowe and Kahn [10]: "*We define successful ageing as including three main components: low probability of disease and disease-related disability, high cognitive and physical functional capacity, and*

---

<sup>1</sup>*baby-boom*: a significant increase of the birth rate just after the end of the second world war

*active engagement with life*". The last component means that older adults have, not only, maintain usual activities but also discover new areas by experimenting new activities.

The more the number of older adults and their expectancy are increasing, the more new diseases related to their age are diagnosed progressively, especially the ones in dementia that can affect directly on their functional and cognitive abilities. According to World Alzheimer Report in 2015 [1], " 46.8 million people worldwide are living with dementia in 2015. This number will almost double every 20 years, reaching 74.7 million in 2030 and 131.5 million in 2050". " Over 9.9 million new cases of dementia each year worldwide, implying one new case every 3.2 seconds". Unlike 2010, Europe with 2.5 million of new dementia cases has been surpassed by Asia with 4.9 million, followed by the Americas with 1.7 million and Africa with 0.8 million. In France, 900.000 people are affected by AD. 220.000 dementia cases are diagnosed annually. In 2020, 1.275.000 people should be affected (i.e. a French out of 4 older than 65) and 2.150.000 in 2040.

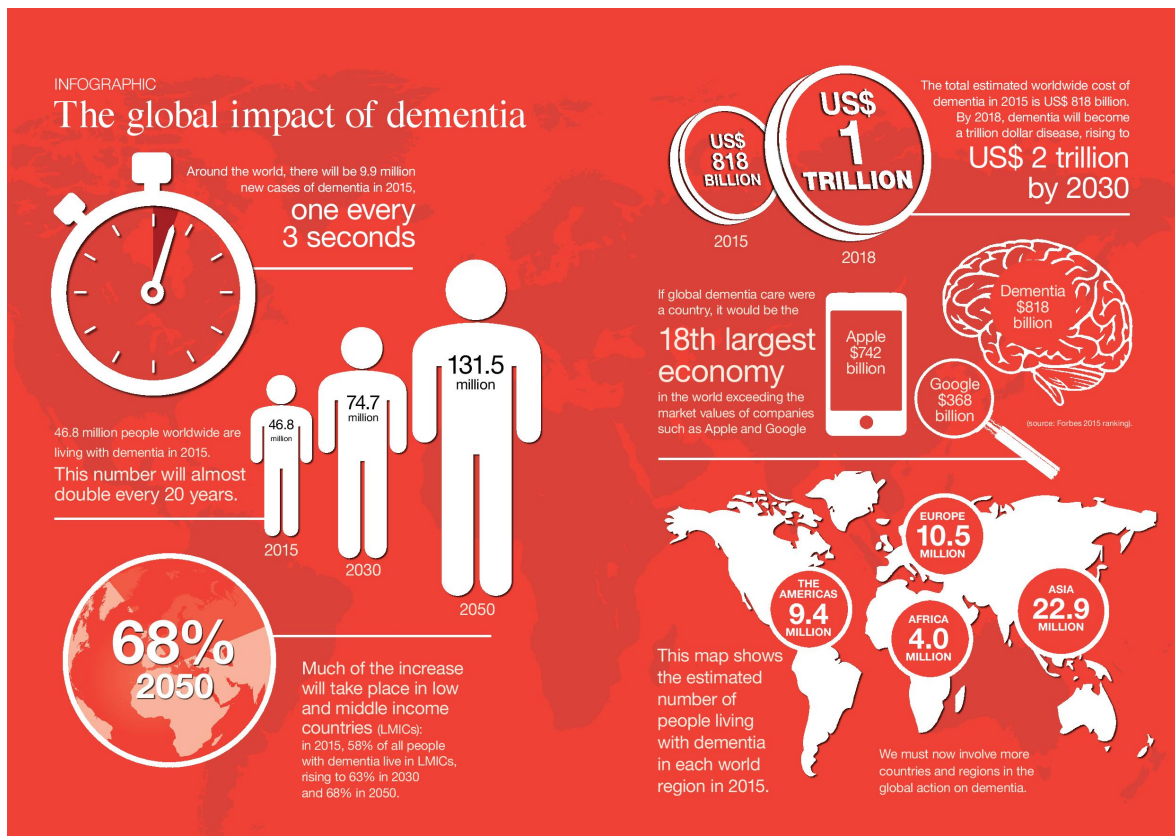


Figure 1.1 – Infographic of World Alzheimer Report 2015 [1]

Most of dementia cases are related to AD, which is characterized by a progressive and irreversible impairment of neurons in the cerebral cortex (Fig. 1.2). People who are affected by the disease manifest progressively itself deterioration of cognitive abilities (memory, language, attention, thinking and learning capacity) and behavioural symptoms (restlessness, aggressiveness, apathy, depression). These troubles embarrass greatly in their daily activities as well as their interaction with society they live. Older adults become day after day less active and finally dependant. Unfortunately, there are no cure against this disease. Nowadays,

study cases have focused on treatments (non-drug and drug) allowing the delaying process of the disease and reducing cognitive disorders. If drug treatments have meet side-effects and limits such as the case of acetylcholinesterase inhibitors [11, 12] in the one hand, non-drug treatments have been proposed more and more in order to bring additional benefits in the other hand. Some typical examples can be mentioned like psycho-cognitive stimulation (cognitive training, reality orientation therapy, validation therapy or reminiscence therapy) and behavioural stimulation (social activities) or sensory stimulation (musical therapy) [13]. A wide study [14] on almost 3000 elderly in 10 years has been achieved to determine the effects of cognitive trainings on their cognition and daily functioning. The results reported less difficulty with instrumental activities of daily living and most of the trainings (reasoning, speed-of-processing and booster) have maintained the effects on related performances for older adults.

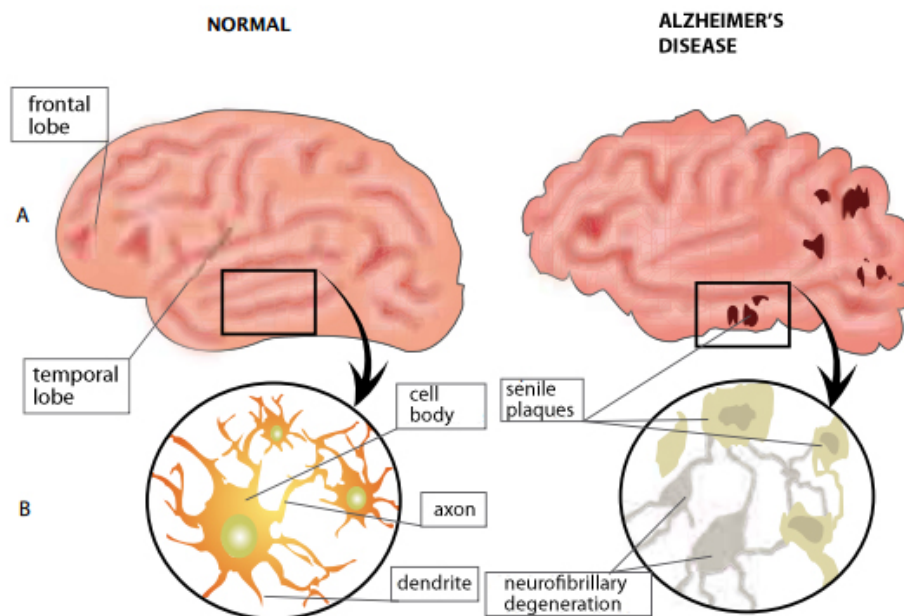


Figure 1.2 – Schematic comparison between a healthy brain and an affected brain

In parallel, Serious Game takes part of new technologies for elderly health care. Olufuwa [15] have categorized the use of Serious Games in 4 themes: improvement of patient autonomy, enhancement of health care delivery, enhancement of elderly patient safety (improvement of balance and mobility, fall detection and risk reduction) and enhancement of holistic care which improvement of cognitive ability takes part of sub-categories. This media offers more advantages compared to classical training approaches. On the one hand, the video game has a reasonable cost and an easy access for older users. In additional, the target user can be immersed in a playful and personalized environment which can boost their engagement to adhere in the long-term with the cognitive training programs. On the other hand, the classical trainings (e.g. physical exercises in the hospital) claim a large expense (staff, equipment and material costs) and cause some barriers (transportation, monotone activities) to older adults to struggle against the disease.



## 1.1.2 Context of work

This thesis is carried out within the framework of the Az@game project<sup>2</sup> with CIFRE fellowship<sup>3</sup> financed by the Ministry of Advanced Education and Research. The project manifests itself in the context that the increasing number of French people suffering from AD makes a great impact on society and the disease have been declared Great National Cause in 2007 by the Prime Minister. The project fixed two main purposes :

- Setting in place a playful environment, e.g. a Serious Game, to support a older adult affected by Alzheimer's disease (or a related disease) within a hospitalization and/or home care.
- Giving to professional and family helpers the tools to support the patient within every stage of the disease.

Otherwise, the older adult accomplishes cognitive, functional and physical trainings integrated in Serious Game in order to maintain maximum autonomy. During these trainings, some feedback is established allowing to trace his health state evolution. In parallel, caregivers adapt a tailored training program, according to the results of his training and his knowledge stands at present. In addition, the medical team can follow-up the disease course of their patients thanks to Az@Game project.

The project aims to help people with AD maintain their health state and their autonomy as long as possible through a series of cognitive, functional and physical exercises in the proposed Serious Game. These objectives require continual interactions between the game and the users because they only can benefit advantages from the game while practising it regularly. That raises some related questions:

- Most of target patients in the project are still independent and living in their own home. Many of them desire to play games at home because they have several difficulties to get to health institution. Here comes the problem. Since its appearance in public, video game gets often a negative look from the older adults. They consider it as an activity reserved for young people. According to a new study<sup>4</sup> in 2014 on the consumption of French video games achieved by Nation Center of Cinema (CNC), 33.9 million french people play video game, of which 60.1 percent of players are between 15 and 49 years old. Only 16.7 percent of players are older 50 years old. It can be explained by many reasons. Most of baby-boom's generations do not follow and upgrade with video game evolution. When they were young, they did not have easy access to computer and arcade game machine because its prize was very expensive and its distribution was limited. In a few decades after, these generations have become adults and parents. They consider that playing game is not a serious activity compared with their age. In addition, this particular type of user always feels hesitate [16] to use new technology tools in daily activities because a lack of knowledge on technology evolution. Therefore, video games

---

<sup>2</sup><http://www.azagame.fr>

<sup>3</sup><http://www.anrt.asso.fr/>

<sup>4</sup><http://www.cnc.fr/web/fr/ressources/-/ressources/5985145>

with new devices such as Kinect camera or Wii Remote cause serious problem with the adaptation of this leisure activity in daily life. These barriers cause the significant negative effects on their engagement to participate voluntarily in the game. So the question is "*how can stimulate them to play the proposed Serious Game ?*".

- Besides the difficulties due to physical and mental decreases related to the natural process of ageing, the older adults suffering from the Alzheimer's Disease or other related pathologies have an other boredom of playing easily game. They can be distracted and make errors because of attention disorders. Memory disorders make rules and interaction mechanism of the game becoming harder to recall. Consequently, they become discouraged quickly while facing repeated problems and feeling lost in a game session. So this is important to handle this undesirable situation and maintain their engagement during the game activities.

## 1.2 Objectives

Taking into account cited questions, the main objective of this thesis is to propose an approach to help people with dementia playing regularly games and enhancing their game performance. This approach has to focus on the essential point: the regular interactivity between the game and the patients. The main challenge of interactivity is how to stimulate patients to take part in the game and maintain their engagement during the game activities. The approach needs a decision-making mechanism which can ensure interaction during game activities. These decisions can be made based on the selected strategies to make the use of the game more easy and attractive. In order to learn how these strategies can optimize the interactions between the users and the game, various characteristics of the approach need to be studied:

- *Comprehension of user behaviours*: the interaction only makes sense if it takes a place at a right time with an efficiency. To achieve this purpose, the approach has to be able to know what people are doing both in the environment around and inside the game. The system can be equipped with the movement sensors that can recognize physical activities of people. For example, by following the movements of the people in the living room, when they sit on the couch for a long time, the system can suggest them to play the game.
- *Attractiveness*: it is really important that people have always felt pleasant and attracted during interactions. The interface is the first and probably one of the most important factors affecting directly to their aesthetic sense which could influence on the success of the interactions. Then the approach must contain a varied and realistic interface linked to the center of interest of the patient.
- *Ease of interaction*: most of the target patients are older and have difficulties in adapting to new technologies. Moreover, one of the ultimate goals of the project is to make people disregard all system presences in their daily life. They can feel embarrassed and discouraged if interaction mechanism is too complicated in comparison with their

knowledge. With these constraints, the approach have to propose a simple and intuitive mode of interaction to people.

### 1.3 Contributions

The thesis takes an interest on the game usability of the older adults with dementia in Serious Game. These specific users cannot use regularly and efficiently the games because of their lack of game knowledge and their memory and cognitive disorders. Most of the solutions from the literature works focus on the game design for the older adults (e.g. suitable interface or simple game scenarios), which can compensate the lack of game knowledge, but do not take into account the critical situations related to their memory and cognitive impairments (e.g. handling of the game, distraction or forget of the rules of game). To take into account these, an approach is proposed, which aims to realize the dynamic and intelligent interactions with the older users using decision-making mechanism based on people actions outside and/or inside Serious Game in order to stimulate and maintain their engagement with the game. A support system is designed to validate the proposed approach. The support system consists of 4 components: Activity Recognition, Game Controller, Interaction and Support Manager.

The Activity Recognition (AR) uses an activity recognition framework which can detect, track and recognize many activities performed by the person on the scene based on different people properties (i.e. positions, postures or trajectory of move). These data is useful to define the interaction strategies with the users outside of the games. For example, the system can start a conversation with the users and invite them to play a game session while the AR recognizes their presence in front of the screen related to the game since a long time. The support system can also guide the users to place themselves in the best positions to play the games thanks to the data provided by the AR component. In parallel, the Game Controller (GC) is used to connect to the games and collect game data and game performance of the users. The component can also change the game behaviours to adapt with the specific situations related to memory and cognitive problems of the users. Thanks to this functionality, the support system has an additional data source to enrich more the interaction strategies.

The Support Manager (SM) is the main brain of the support system. First, the component computes the current situation thanks to data sources provides by the AR and the GC components. Second, the SM selects an interaction strategy to determine the expected interactions to act with the users. Third, these determined interactions are sent to the AR, the GC and the Interaction components. The last one is used to act with the users by controlling an 3D animated-agent emerged in an 3D environment.

3 experiments have been realized with the older participants to validate the functionality of the support system. The participants are recruited and categorized in terms of their cognitive states. The first experiment report that most of the participants can interact successfully with the support system to initiate to the game. They accept to play a second game after finish the first one and appreciate positively the agent's appearance. The second experiment

confirms the usefulness of the support system on the game usability of the participants. They finish the game session faster and perform a better score while playing with the helps of the support system than while playing without any help. The third experiment enhances the results of the previous experiment by comparing the support system with a therapist. The results reported that the participants realize the similar performance while playing with the helps of the support system than while playing with the therapist.

## 1.4 Structure of the manuscript

**Chapter 2** presents the literature works on the engagement of the older adults towards new technology. Some notions of engagement concepts are underlined firstly and many solutions in maintaining of older adults engagement in different research fields (e.g. User Interface and Human Machine Interaction) are cited secondly. **Chapter 3** describes the structure of the proposed approach and the support system. Three following sections evaluate the usefulness of the support system across three experiments. The first experiment (**chapter 4**) proved that the support system can stimulate the participants taking part in the game based on their movement and their position on the environment around. When they get close to the screen, the agent appears and invites them to play the game. If the participants accept, the agent guides them in a good position and starts the game. 19 older participants accept to test the system. Only 3 participants with reduced mobility and important memory disorder fail to interact with the system. The second experiment (**chapter 5**) reported that the support system can maintain the game performance of the participants. This time, the agent communicates with the participants by speech and animations to instruct the rules of game and recall their attention. The participants answer at their turn by achieving only two gestures "*raising left hand*" and "*raising right hand*". 30 older participants with different cognitive impairments (Mnesic Complaint, Mild Cognitive Impairments and Alzheimer's disease) are tested with the support system in a concentration-based game. As the experimental results, the participants playing the game with the assistance of the support system finish the game faster and make less the errors than the participants playing the game alone. Moreover, 2 participants playing the game alone abandon the game after making many errors. The last experiment (**chapter 6**) evaluates the efficiency of the support system in maintaining the game performance of the participants in comparison with a therapist. 47 older adults with dementia categorized in two groups (Mild Cognitive Impairment and Alzheimer) participate in a session of cognitive training using a concentration-based game on a tactile device. The experimental results reported that the support system can help the participants producing the similar performances (score, precision, learning effect) than the case with the therapist. Moreover, the participants appreciate positively the agent and desire to continue playing temporarily with the agent instead of the therapist. **Chapter 7** concludes the contribution of the thesis and proposes the future improvements for the support system in order to treat other situations more complicated.

## *Chapter 2*

---

# **State Of the Art**

---

This chapter provides an overview on various works related with the engagement of older adults. Many contributions in different domains which can be useful to the objective of the thesis are extracted. The chapter starts firstly by listing the age-related changes of older adults, that can cause divers problems to them while interacting the video game. Next, some concepts of engagement in the literature are cited in order to. In the following sections, the works in Interface Design, Virtual Agent and Game Design for older adults are highlighted.

## **2.1 Age-Related Changes among older adults with dementia**

The ageing provoke a lot of diverse changes among older adults. Many changes impose negative impacts on the use of new technology. This section provides a collection of main age-related changes which can disturb the interactions between older adults with dementia and video games.

Fisk et al.[17] have underlined many changes in physic and cognition. Older adults suffer from a reduction of visual acuity and sensitivity to glare, breadth of field and speed of processing. They have also a deterioration of hearing ability, which does not support the sounds above 4000 vibrations per second. These impairments of vision and audition make more difficult the tasks of perception of small or dynamic targets or synthetic speech in video games. Motor impairments cause to older adults a movement control more slowly and less precision than younger adults. The authors have also focused on the impairments of many cognitive functions such as memory, attention. The loss of four memory functions (working, semantic, prospective and procedural memory) has been cited, which can be important obstacles to older adults in interacting with video game. Indeed, this loss can make them be difficult to learn the rules of game (semantic memory), forget the control mechanism (working memory), forget the tasks to do (prospective memory) and forget how to realize the current task (procedural memory). In parallel, the reduction of attention process (selective and

dynamic attention) has also mentioned. Older adults have a lot of difficulties in processing information in complex tasks.

Besides the physical and cognitive changes mentioned below, the ageing has imposed also negative impacts on the experiences towards new computer technology, including video game, among older adults. Indeed, most of them did not have access to the technology and not need it during their working lives. Consequently, they present a significant fear to learn the conceptual model and to adapt the video game in their daily activities. Older adults suffer also the chronicle diseases such as diabetes or hypertension [18], which can impose many negative impact on their physical ability and prevent them to play the specific video games (i.e. exergames). Furthermore, older adults with dementia suffer more impairments. Besides the changes in physic and cognition (which are significantly impaired rather than the normal older adults), they present also behavioural and psychological changes such as loss of social skills, inappropriate responses or behaviours, frustration and anger with self and others, anxiety or depression.

## 2.2 Concepts of engagement

"Engagement" is a term used by the sociologists in analyses of both individual and organizational behaviour. Becker has expanded the notion of engagement [19] by determining the major elements of engagement: the situation where the decision of an individual on some particular actions has consequences for other interests, his own prior actions in this situation and his conscience of consequence beyond it. The author has arrived also to distinguish different origins of engagement. If some engagements are made by conscious decision, others developed progressively by itself. *"The person becomes aware that he is engaged only at some point of change and seems to have made engagement without realizing it"*.

In some specific contexts, many studies have detailed more precisely the notion of engagement. Physical body characteristics have been intuitively analyzed such as head and eyes movement related naturally to engagement in human-human interaction. Function of gaze has been remarked by Argyle and Cook [20] as a social signal to express personal attitudes and the lack of direct gaze during interaction is evidence of the less engagement. McClave has offered many observations [21] on head movements (shakes, sweeps, change of head position and head nods) which can highlight the engagement level of an individual during conversation.

In parallel, a lot of studies have focused on human perception and behavior in human-machine interaction. A person is engaged in using a technology while he/she, firstly, accepts in voluntary the technology for a regular use. David [22] has proposed a model to analyze this acceptance. The model (Fig. 2.1) has been based on two theoretical constructs: perceived usefulness and perceive ease of use. People intend to use an application if they perceive that the system characteristics could be useful for their work. The model covers also the other possible situations. People will accept to use the technology if they believe they can easily

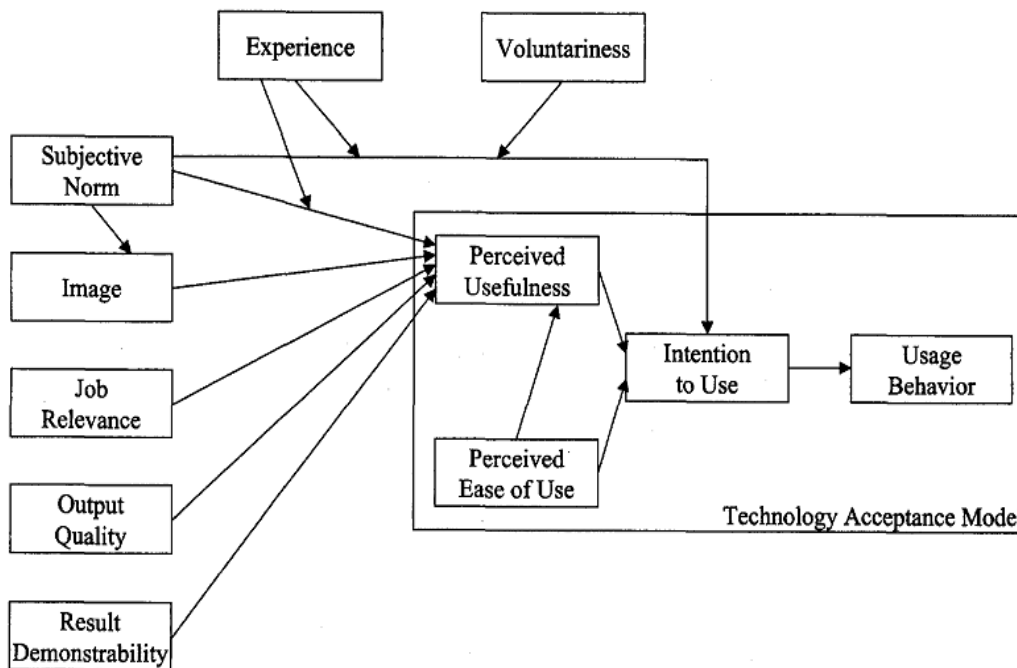


Figure 2.1 – The Acceptance of technology Model 2

control this one. It is also possible that even when people perceive the usefulness of the application, they can eject the application when they believe that the application is too hard to control and that the benefit of use are outweighed by the effort of using the application. David and Venkatesh [23] have extended the model by interpreting external variables in terms of cognitive instrumental processes (job relevance, output quality and result demonstrability) and by incorporating new additional construct which was social influence processes (subjective norm, voluntariness and image). The extension has been developed around the new construct "subjective norm" that was not directly related to the application. The extension has theorized that people have intended rapidly to use application when they have been suggested by most people who were important to them. The positive effect of subjective norm has taken place when application use was mandatory (not voluntariness). At other times, subjective norm could also make people perceiving the usefulness of the application before intending to use. In parallel, the image of a person in a social group at work could be influenced by subjective norm if the important members have believed that using the application could perform his or her work and the person has followed advise to maintain and enhance his or her standing inside of the group.

Kearsley and Shneiderman [24] have proposed an engagement theory which is a model of learning and teaching in group activities for students. In principle, engaged learning means that student activities involve in cognitive processes such as "creating, problem-solving, reasoning, decision-making and evaluation". The authors have defined three components "Relate-Create-Donate" of the model to accomplish engagement. The *Relate* component indicates team effects which can help students improving their "communication, planning, management and social skills". In collaborative work, their motivation can be increased

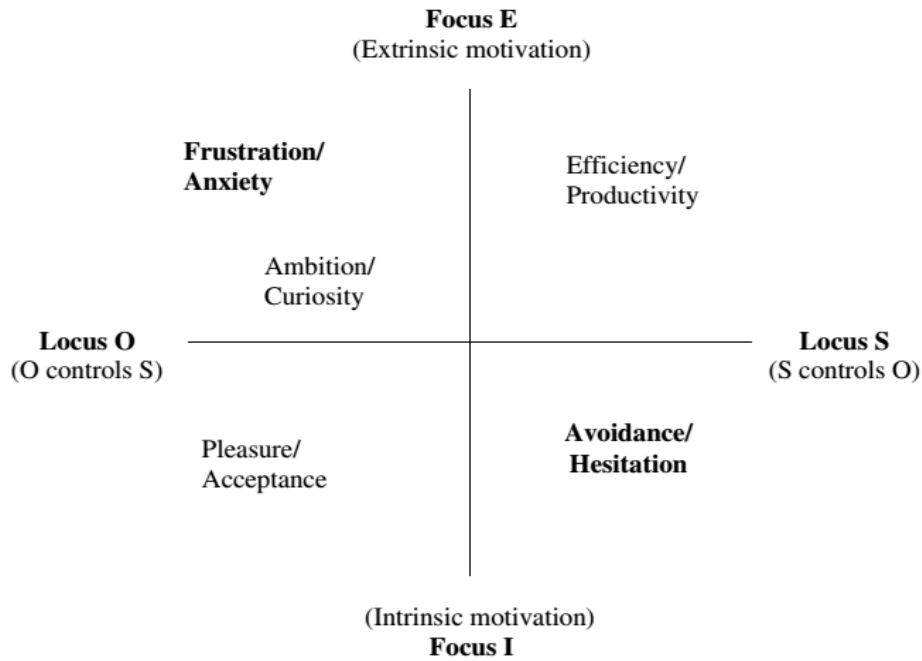


Figure 2.2 – Overview of Engagement Modes-Model

and each one of them can learn and enrich their "understanding of diversity and multiple perspectives" from others. The *Create* component makes working their creative skill. Learning activities can transform in a project of specific context. By developing their own project, students can be attracted and occur a sense of control over their learning. The last component of engagement makes value the useful outcome of the project (i.e. the "target costumer" of the project). Doing the project for realistic "costumer" increases also student motivation and satisfaction.

Shafari et al.[25] have designed an engagement modes model to describe how information technology (IT) user engages in an activity with an IT object (applications). The model is based on the user's perception of current activity on three dimensions: evaluation dimension (user evaluates the object negative or positive), locus of control dimension (i.e. user controls object (Locus S) or object controls user (Locus O)) and focus of motivation dimension (the activity is focused on goals inherent in the activity itself (Focus I) or on external goals (Focus E)). Five engagement modes have been defined through different combinations of Locus and Focus dimensions (Figure 2.2). There are two cases in which user can evaluate negatively the object (i.e. the locus of control is incongruous with the focus of motivation). First, when users want to attain an external goal and they do not have the right skills, the engagement will be in mode of *Frustration/Anxiety*. Second, when the users' motivation is focused now on the activity itself in different ways, the use of object that they control hardly are less attracted and the engagement mode becomes *Avoidance/Hesitation*. On the contrary, engagement is positive when Locus and Focus are matched together. The users will perceive the efficiency of the object if they control it to acquire an external reward. In this case, the engagement mode transforms into *Efficiency/Productivity* mode. The users are also engaged to use the object,



even when they do not have sufficiently specific skills, but they have pleasure in learning skills to gain advantages afforded by the activity (e.g. user do not know playing piano but have pleasure in learning to play classical music they enjoy). The engagement mode becomes now *Pleasure/Acceptance* mode. There is still a special case where engagement is positive. Users could be frustrated if they do not have the skills to attain an external goal, but they could be ambitious to learn the skills if they think they can master the object (e.g. pianist learns playing guitar for the next album).

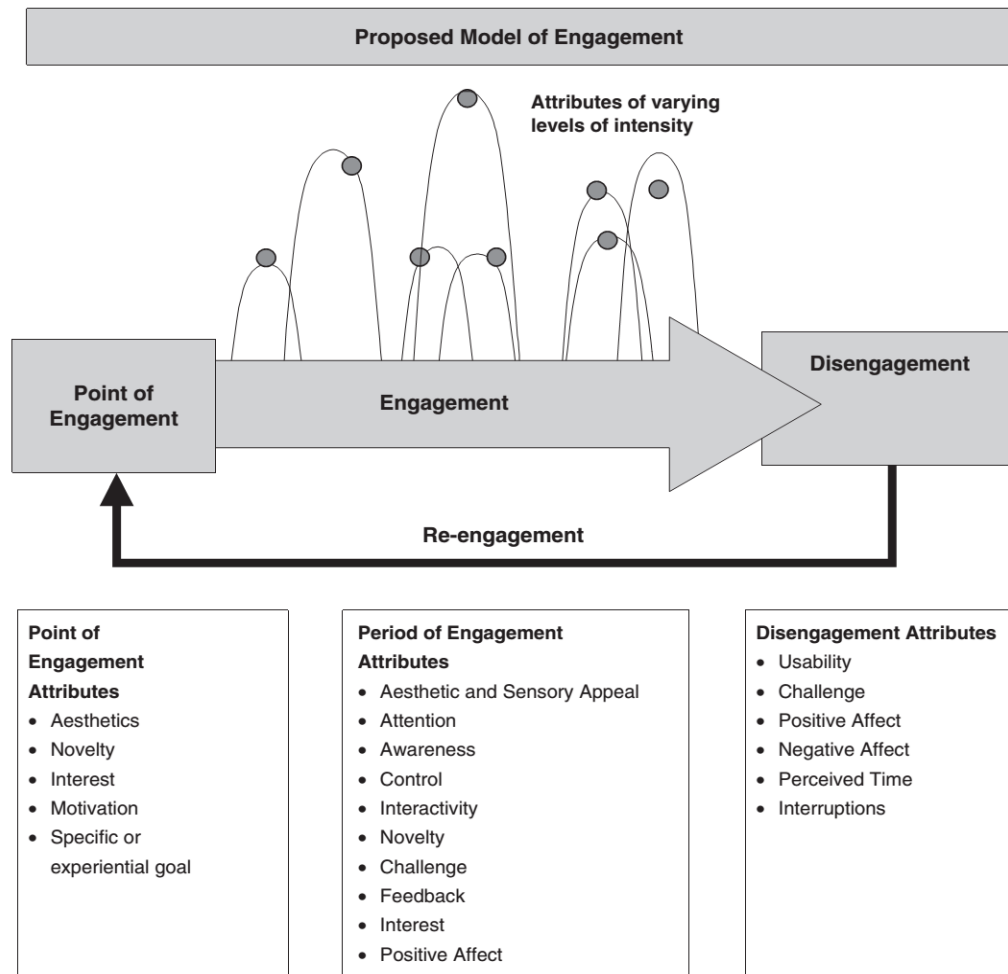


Figure 2.3 – Model of engagement and its attributes [2]

O'Brien and Toms [2] have defined the notion and proposed a model of engagement (Fig. 2.3) with technology by inspiring from multidisciplinary review and their study of users of Web searching, on-line shopping, Webcasting and gaming applications. First, they have examined on flow, aesthetic and play theories and information interaction in order to extract attributes which could be related to engagement and allow to understand user experiences. They have suggested some attributes of flow theory such as focused attention, feedback, control, interaction and intrinsic motivation [26] which could be shared with engagement. Attention, curiosity and interest [27] of aesthetic experiences have been also associated with engagement. In addition of these examinations, motivation, challenge and affect of play theory [28] and affective appeal, interactivity, feedback and perceived control of information

interaction have been added also in the set of attributes which can categorize the definition of engagement. Second, the authors have intended to confirm the past findings and research eventually more attributes in 4 applications areas: Web searching, on-line Shopping, Web-casting and Gaming applications. The results have emphasized new arrivals of durability, sensory appeal and variety in the above set of attributes.

Based on these findings, the authors have proposed a definition of engagement which was "a category of user experience characterized by the attributes of challenge, positive affect, durability, aesthetic and sensory appeal, attention, feedback, variety, inter activity, and perceived control". To explore more user engagement with technology, they have conducted a semistructured interviews with 17 participants of these four applications. All were educated and most of them were at the level of master program. All used e-mail on a daily basis and searched the Web daily. O'Brien and Toms have developed the interview questions based on "thread" of the experiences of McCarthy and Wright [29] which have consisted of 4 threads of experience: (a) emotional (i.e. positive, negative or neutral affect), (b) sensual (i.e. qualities of used systems), (c) spatiotemporal (i.e. interaction tasks of the participants and their perception of their physical environment) and (d) compositional (i.e. the beginning, middle and end of these other threads). The results data have been analyzed and interpreted in terms of these 4 threads of experience which have allowed designing a model of engagement based on user experiences (Fig. 2.3).

The *compositional thread* has described engagement as a process composed by 4 states (*Point of engagement, Engagement, Disengagement* and *Reengagement*) in which have find attributes of these other threads. In short, the user engagement with applications has initiated when their attention and interest have been kept by the aesthetic or information composition of the system interface. In some cases, the initiation could take place because of social reasons, satisfaction of a specific goal or simply performing of experience. Once the user engagement has been built, their attention and interests must be maintained permanently. This was achieved by feedback and novelty of information on the system interface. The state could also be extended when users have been stimulated by the challenge and they have felt control totally the system. According to the results, some internal and external factors have caused them to cease being engaged. Disengagement has been provoked when users have decided consciously to stop the application because of the influence of others or a physical tiredness after a long period of interaction with applications. The engagement has been stopped also by the interruption of other activities in current time, the lack of novelty of the system interface or usability issues with technology. The results have underlined a interesting remark on user disengagement which was "not necessarily the end of their engagement". In some cases, the decision was temporary, for example shopping and video games. Users have not maintained their engagement on one website but explored others to compare the prices and the models. Video game players have just made a quick break for drinking, eating or simply relax and have resumed the game later. User engagement with an application has restored in other times thanks to positive experiences in the past (fun, reward or discovery). The results have

particularly exposed the evidence of the factors that have contributed to noneengagement. This has included lack of time, feeling less pleasure of online experiences compared to real life experience, technology issues, being required to multitask or manage interruptions.

## 2.3 Interface Design for Older Adults

The user interface of a system is the component that the users perceive firstly. This important component is the main bridge which transmits the interactions between the users and the system. It's also the component which often causes the problems to the older adults. Consequently, various contributions of providing for older adults more accessibility to the interface in different context.

Morris [30] has suggested many adaptations to compensate their impairments of visual, auditory, physical and memory functions. Some points which could be shared with the context of video game for older players are cited below.

### Recommendations

- *The interface resolution must be maximized with multiple font sizes allowing to the user to select the best size for the current task. Using effective color combinations avoids bothering user perception (e.g. white text on blue background) and providing multiple visual dimensions (e.g. shape) enriches information encoding.*
- *The environment around the user must be freed from unnecessary noise. Significant sound tones must be kept in range of 800-1000 Hz and speech speed should be moderated.*
- *The interface has to provide a interaction mode that do not require a series of precise movements and that is adapted with physically impaired users.*
- *Interaction tasks must be simple and sequential and all of objects must be visualized.*

In the context of Web design for older adults, Kurniawan et al. [31] have established a set of guidelines developed through an extensive review of the HCI and ageing literature. Some guidelines which could be useful also in the context of the thesis are cited.

### Recommendations

- *"Icons should be simple and meaningful"*
- *Provide only one open window (e.g. pop-up) and animated advertisements or multiple overlapping windows should be avoided*
- *Avoid irrelevant information on the screen*
- *Important information should be highlighted*
- *Reduce the demand on working memory by supporting recognition rather than recall and provide fewer choices to the user*
- *Avoid moving text*
- *Text should have clear large headings*
- *An online help tutorial should be provided*
- *Support user control and freedom"*

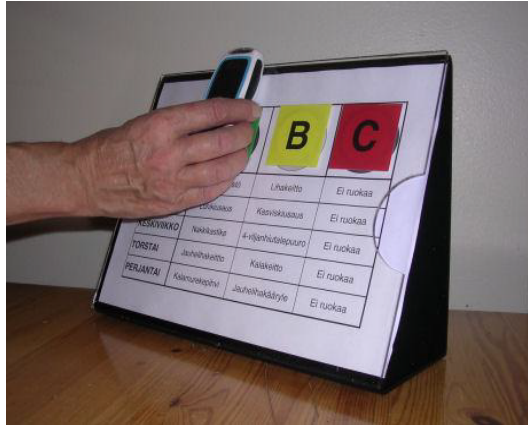


Figure 2.4 – Touch interface based on NFC technology

In the same context, Zajicek [32] has proposed a Web interface design for older adults. The author has remarked that their visual and memory impairments, including their perception not really positive toward the Internet, are significant barriers for an efficient use. To accommodate these disadvantages, Zajicek has integrated a speaking interlocutor into a web browser to "talk" with the users. For each possible state, the interlocutor provides a spoken output, which informs to the users the name of the state and the related actions that the users can choose. The users are informed also the set of keys of keyboard corresponding to the cited actions. Then, the users press the key they want and receive the new spoken output for the new state.

If these contributions cited above aim to adjust the interface elements in order to offer a perception and an understanding easier for older adults, other works introduce a new interaction mode to simplify the usability of the interface. That is the case of touch interfaces which are often considered as intuitive, natural and easy to use. For example, Haikido et al[33] have built a touch interface based on the Near Field Communication technology (Fig. 2.4) allowing to older adults to order their daily meals. The interface consisted of an NFC-enabled mobile phone and NFC-enhanced meal menu displayed in a plastic stand. The menu offers 3 options presented by the tag symbols (A, B and C). The users order meal by touching the tag symbol with a mobile phone implemented a tag reader. Culen and Bratteteig [34] have been interested to touch-based interactions with older adults in smart phones and tablets or touch-screens embedded in the home environment. They have designed two touch interfaces for a video conferencing and a TV remote control on Ipad (Fig. 2.5). They have conducted firstly a study to understand the useful use of these tools by older adults. They have found that among the proposed channels, only 4 channels or less were regularly watched as well as the "on/off" button was regularly used and the "volume" button was occasionally used. Regarding the classical video conferencing interface, a heat map has shown that older adults touch everywhere, even the empty space while trying to reach the call button. So, Culen and Bratteteig have proposed an TV remote control interface which displays only a few of touches corresponding to the channels that the older adults watch in most of time and a 'volume



Figure 2.5 – On the left, a touch interface for calls. On the right, a touch interface for TV remote control.

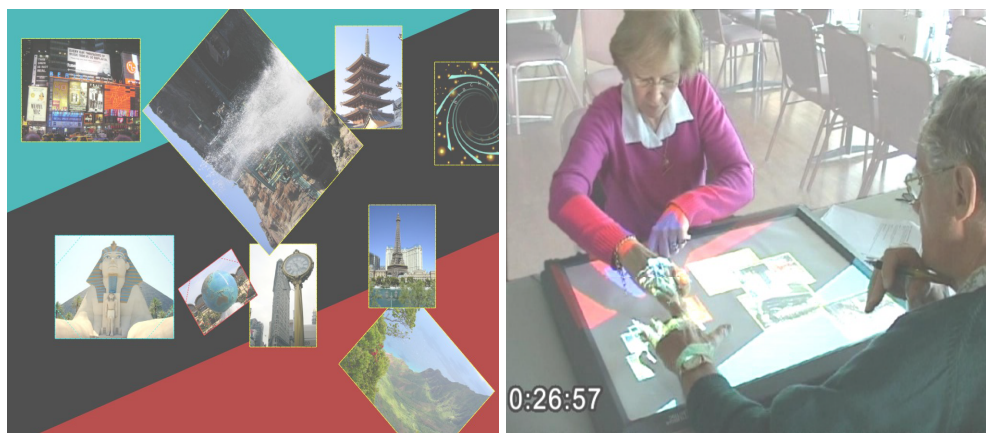


Figure 2.6 – On the left, SharePic application. On the right, SharePic in a tabletop.

touche'. The new interface also displays a special touch to enable the possibility to select more channels if needed. Regarding the video conferencing interface, they have provided a large area where the touch may be applied, combining this with large icons similar to those of phone for that older adults can find quickly the button and reach easily the touch.

Apted et al. [35] have designed a multi-user, multi-touch, gestural collaborative digital photograph sharing application for older adults, named SharePic (Fig. 2.6). The users can interact simultaneously together to perform actions with the pictures. All actions for the interaction have been created in one touch (select, move), two touches (resize / rotate) or finger-gesture (copy). For the delete action, they have proposed "Black Hole", which is a semi-translucent image always shown in front of other pictures. The users need simply to move the picture they want to delete within the "Black Hole".

So far, Bruno and Rui [36] have presented a set of 113 design guidelines of multi-touch interface for older adults. This set of the guidelines has been selected by a methodology from the 14 works in literature. First, an initial set which collects all of guidelines from the literature. Next, a filter is applied to merge the identical guidelines, rewrite the indistinct guidelines and categorize these guidelines in 10 groups (Target Design, Use of Graphics, Navigation and Errors, Content Layout Design, User Cognitive Design, Audio, Text Design,

User Feedback and Support, Multi-touch Interaction, Interface testing). Some guidelines which could be useful also in the context of the thesis are cited below.

### **Recommendations**

- *Error messages should be simple and easy to follow.*
- *Design error messages that make it clear that the user is not the cause of the error.*
- *Avoid forcing users to read at very close distances.*
- *Give them time to read. Older adults usually read more slowly (than younger adults).*
- *Give them time to learn.*
- *Use only one type of input device.*
- *Avoid some complex gestures in the multi-touch interaction.*
- *Gestures in use are increasingly becoming inconsistent across different manufacturers, it is necessary to define a standard gestures.*
- *Tapping on the background outside of an object should be avoided.*
- *Do not use elder's speak.*
- *Adjust your volume appropriately and repeat and paraphrase if necessary.*
- *Use simple language.*
- *Do not standardize your approach to the elders.*

The full set of guidelines can be founded online<sup>1</sup>. In parallel, some works have recently studied the vocal interaction in the interface for older adults. The interest of this interaction mode that the users do not need to perform any physical contact with the interface. Francois et al.[37] have implemented an assistance system with voice and tactile commands in the SWEET-HOME<sup>2</sup> project. The system operation is described in the Figure 2.7. The system takes as input the sound from the microphones transmitted through radio frequency channel. The input is processed by a real time multi-threaded audio processing system to extract the sound and speech information which are analyzed after. At the output, either the system executes the vocal order given by the users (e.g. "close the door", "turn off the light") or provided speaking interaction with the user in the case of misunderstanding the vocal order or alert message (e.g. "turn off the gas", "remind the person an appointment").

## **2.4 Virtual Agents**

This section takes an interest of the works in Artificial Companions community. Many contributions have proved that virtual like-human agents (e.g. relational agents or conversational agents) can product various positive effects on user perception and behavior in the use of new technology. Doris in his review [38] 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 the game without the face. In addition, people using a tutoring system

---

<sup>1</sup><https://eldermultitouchguidelines.wordpress.com/>

<sup>2</sup><http://sweet-home.imag.fr/>

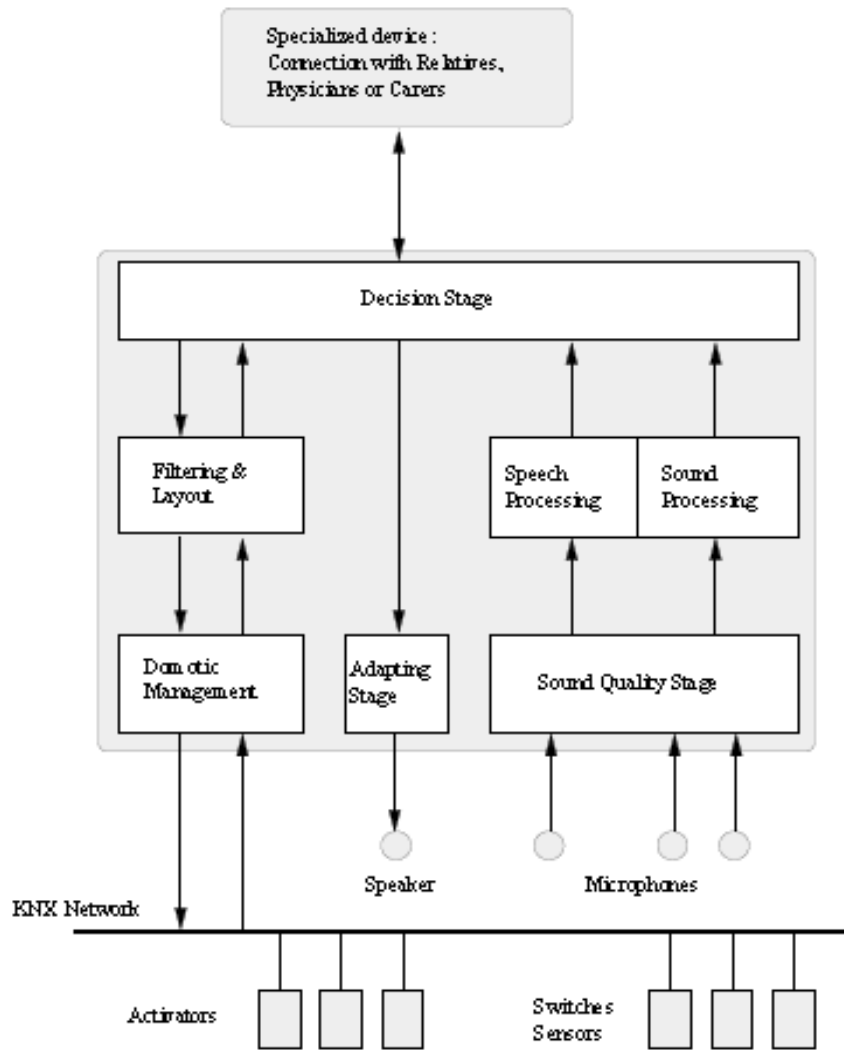


Figure 2.7 – the SWEET-HOME system diagram

incorporated these agents can get a better understanding of the issue in question than a system without an agent. However, the production of these positive effects which may happen among older adults with dementia remains an issue because all subjects in experimental phases are active young people.

Campbell et al. [39] have presented an agent for health and behaviour change among older adults, named Laura, in their critical review on the relational agents in different domains. The agent has designed to be an exercise advisor who can interact with users through a script dialog mode to encourage 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 [3] 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. The subjects in the relational group have 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 the subject's performance in order to always maintain their engagement. After two months of experiment, most of the subjects in



Figure 2.8 – First animated agent[3]

relational group have desired to continue using the system with the agent and have performed more walking activity than the subjects in control group. So far, the same agent has been used in two other studies [40] to measure the effects of his behaviour variability and back stories on long-term engagement. When the agent has shown variably its behaviours, the subjects have tended to interact more with the agent and have reported a 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 agent Louise can maintain user's long-term engagement by be more like-human thanks to behaviour variability and back stories. Other similar work aim to render the agent more like-human by adapting dynamically the agent emotions. Kasap et al [4] 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 is updated in terms of the current emotional impulses of user and the past relationship levels.

There are also some agents who have been tested with older adults with dementia. Ortiz et al. [41] have tested 15 older adults categorized in three different groups (normal aging, mild cognitive impairment and Alzheimer) with three prompting interface: with an agent, with text and voice and with only text. In each interface, the subjects have performed a specific task: writing the answer to the question posed by the interface. The obtained results have shown that the 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 et al [42] 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



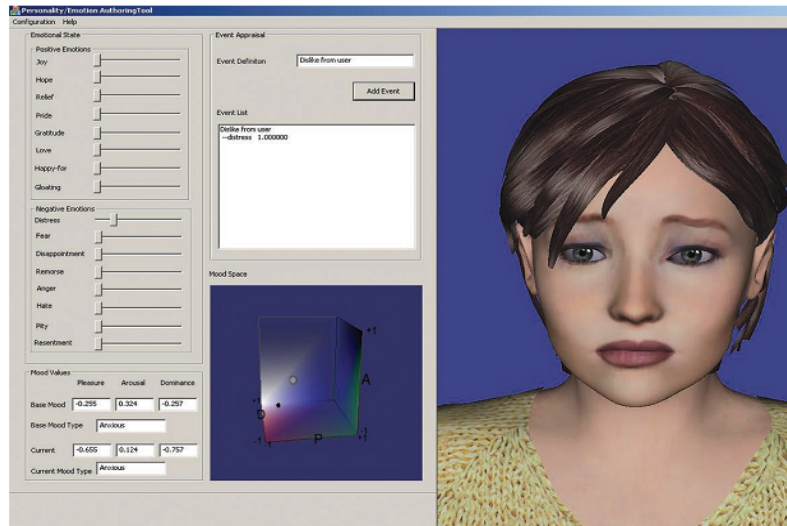


Figure 2.9 – agent Eva with Emotion Editor [4]

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.

The last agent cited in this section is the one of Wargnier et al. [43]. The particularity of this agent is the capacity of managing the attention of the older adults. 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 the current interactions, the agent has used an algorithm to assess 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.

## 2.5 Game Design for Older Adults

The last literature related to the engagement of older adults while interacting with video game is referenced from the Game Design field. Taking account of the increasing aged population, there are more and more digital applications, including video game, either newly developed or adapted for elderly users. The interface design community has proposed many contributions to make that interactive, attractive and usable for these new specific users. Two types of contribution are selected in this section: 1) the guidelines focusing on the general game design for older adults; 2) the specific techniques to make the game more usable and more attractive to play.



Figure 2.10 – The guessing-base card game using a tabletop augmented reality platform.

IJsselsteijn et al. [44] have presented a review and discussion about digital game design for elderly users. First, the authors have remark some opportunities to apply the specific design in creating digital games to relax and entertaining, socialize between older adults, stimulate memory and attentional abilities and experiment new ways of interacting with new digital devices. Next, they have proposed some adaptations to carry out of the age-related changes of older adults. The game has to able the user to adjust easily font, color and contrast setting, windows size and scroll rate as well as using lower frequency tones for sound (in the 500-1000 Hz range) to deal with the reduction of many visual and auditory functions. Because of the motor impairments, the game should not propose to elderly users small targets or moving interface elements during the game activity. Moreover, with age-related changes in cognition, the tasks in the game should be simple and intuitive, that consumes only a minimum of the load on memory and cognitive processing.

Lee et al.[45] have taken an interest of graphic interface configuration of video game for older adults. The results of their experiment, involving 100 older adults in playing 25 types of video game with a lot of dynamic interfaces, have focused on the screen layout importance suitable and the size of a text and an object in the interface. The authors have split the interface into 9 zones ((left, center, right) mixed with (top, middle, bottom)). The finding of analyzing of the information appeared in these zones has shown that, except the middle center zone, the left and bottom zones had a high concentration of the users. Moreover, the upper right zone has been suitable to express the text. Regarding the size of a text and an object, the authors have suggested the font size more than 35 pt for the characters of the text and the size of the object near 20% of the total space containing the object.

Mamuh et al.[46] have designed a guessing-based card game to stimulate the social interaction among older adults. Two versions of thh game have been built: a paper-based version and a digital version using a tabletop augmented reality platform. This is a four-person game in which each player starts at a corner of the board that is projected a city map with

a rectangular grid. The users sitting in the opposite corner are part of a team. The main objective of the game is to move the individual checkers around on the game board. The advance steps correspond to the numeric value on the current drawn card. The players are instructed to cross three famous monuments in a specific order. The team for which both players reach the final monument first wins the game session. The game has been tested with 8 older adults forming 4 teams. Each team pair has played 2 game session: one session with the paper-based version and one session with the tabletop version. The players have answered the questionnaires at the end of the test about their game experience. The evaluation results have reported that the tabletop version of the game has been assessed being more immersive than the paper version. The same results in terms of the flow have been found in the tabletop version. The players have been excited by the color light, the music and the animations of the tabletop version. They have been also stimulated completely the social interactions, as they have interacted not only with their team member but also with their opponent team. 4 elements have provided the success of the game: 1) the choice of card which is a popular type of game; 2) the choice of guessing as the game play; 3) the choice of playing game in collaboration; 4) the choice of device (tabletop augmented reality platform).

Pan et al.[47] have proposed a familiarity design framework on the adoption of wellness games of the elderly. The framework contains 3 dimensions of familiarity design elements: *symbolic, cultural and actionable* familiarity. Precisely, the idea of the familiarity design is to involve object, activities or processing occurring in the target users' daily life in the game. In parallel, the concept of the game has to be common in comparing with the target users' culture and the interactions with the symbolic familiarity elements and the cultural familiarity in the game must be similar to the interactions with these elements in the real life. The proposed framework has been tested in an experiment in which older adults have to play two table tennis games (Fig. 2.11). Both games contain symbolic familiarity because playing table tennis is activity familiarity of Singaporean participants. However, the interface of the first game is decorated culturally with some familiar objects in the background and the users use body gestures similar to play table tennis to control the virtual paddle thanks to the depth sensor, whereas the interface of the second game is decorated only with some simple elements and the users use mouse to control the virtual paddle. Each participant has to play both games uninterrupted for about 2 minutes each and are interviewed at the end of each session. The results shown that the participants prefer the first game rather than the second one. It can be explained by the decoration elements in the first game interface are related with the Singaporean culture and controlling the virtual paddle with the body gesture is quietly similar than the same actions in the real life.

Gerling et al.[48] have studied the game design of older adults regarding the safe and usable exertion games. They have conducted the case study on their game, named SilverBalance, using the Nintendo Wii Balance Board to encourage the older users to actively engage in game play. The authors have underlined some important guidelines on the simplicity and the diversity of interaction mechanism of the game, the safety of movements and the personal



Figure 2.11 – On the left, the interface of table tennis game playing with depth sensor. On the right, the interface of table tennis game playing with mouse.

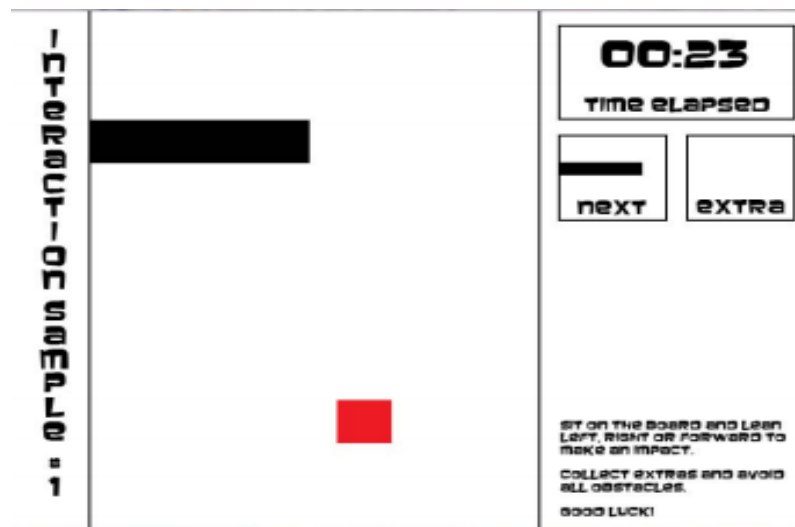


Figure 2.12 – The interface of SilverBalance game using the Nintendo Wii Balance Board

adjustment of the difficulty level, the game speed and the sensitive of the input device. In the SilverBalance game, the older users have to control an object and avoid the obstacles on the way as long as possible while their speed is increased after each turn by shifting weight to the left or right side of the Balance Board (Fig. 2.12). The users can play the game in two positions: sitting in an upright position with the feet placed on the board and standing on the board. 9 older adults have been asked to play the SilverBalance game and all of them have engaged to play the game and have successfully interacted with the balance tasks. The key of the success is that the users can play the game while being sitting. They did not feel confident enough to remain standing for a longer period of time. So, playing in sitting is quietly advantageous to their physical ability.

Gerling et al.[49] have followed the positive results and have designed a wheelchair-based game using a software library developed from the Microsoft Kinect SDK to encourage older adults to develop a positive relationship with their wheelchair. The library uses the Kinect sensor to capture the wheelchair movements as input to define the gestures (Tab. 2.1). The

Table 2.1 – Overview of wheelchair-based and body-based input supported by Kinect<sup>Wheels</sup>

	<b>Wheelchair Input</b>	<b>Body Input</b>
<i>Gesture 1</i>	Move forward	Clap hands
<i>Gesture 2</i>	Move backward	Raise left arm
<i>Gesture 3</i>	Turn left	Raise right arm
<i>Gesture 4</i>	Turn right	Lift legs



Figure 2.13 – Overview of Cupcake Heaven - a wheelchair-based game using the Kinect<sup>Wheels</sup>

authors have integrated into a 2D game (Fig. 2.13) to allow the older adults to realize the wheelchair movements for playing. 10 older adults using manual wheelchair have played the propose game for about 10 minutes and have fulfilled a questionnaire after. The results have provided some interesting remarks. All participants have been able to interact with the game. Most of them have found the game fun and have appreciated the idea to *"use the wheelchair for something other than sitting it"*. However, some participants had many difficulties to remember the rules of game and one participant did not find the game stimulating enough to play in the long term.

## 2.6 Conclusion

These cited works in the domains of Interface Design, Virtual Agent and Game Design for older adults have presented divers contributions to engage the older user in interacting with the interface of an application or a system, including the video game. Indeed, the guidelines could make the interface easy to perceive and the game more usable, which promotes the successful interactions between the users and the game. Moreover, the presence of the virtual agents has provided many positive effects of an agent toward older users in the use of new technology. Most of cited agents have been designed like-human through different methods (emotion, back stories or behavior variability) to attract more the user's perception and concentration. In parallel, the introduction of new interaction devices has offered to the users more possibility to

interact intuitively with the games. Thus, the specific techniques of game design can engage the older users in various types of game. All of these contributions could be applied to design the interface of the proposed system and the games used in this thesis.

However, these contributions did not focus on the problems caused by the memory and cognitive disorders. Not solutions to define the situations in which lack of memory or cognitive troubles can disturb the use of game have been defined as well as the techniques to recognize these situations. For example, the older adults are distracted while interacting with the user interface and occur many wrong actions. How these contributions can correctly determine the cause of the errors? Moreover, because of the memory lack, older adults can miss the daily training session. In a real situation, older adults could not always be available to react to messages sent from the agenda. They could be on other activities and can forget the message once finished these ones. Furthermore, they cannot even remember the sense of the signal of the agenda. Thus, older adults face also to problems during interactions with video game. "Forgetting instantly the rules of game" can place them in a critical situation. They can not remember next task-to-do and hesitate to perform an action. They will either abandon the game session if the situation is still blocking or perform a random action and make errors. With the games integrated new devices such as Kinect camera or Wii remote which allow players interacting with the games by postures, gestures or moves, the older players have to learn, adapt and memorize these new mechanics of control of game elements. Here, different types of problem can occur. They can forget the mechanic of control or realize wrong mechanic then make the repeated errors. In these cases, the interactions between older adults and the game become disturbed and if no helps are provided at time, they can abandon the session. They can also be distracted by external events such as rain, phone ringing or visitors. The attention level algorithm of Wagnier et al. [43] can be useful in the Serious Game context because the user's engagement might be stable as long as the user looks at the screen. However, among the older adults with dementia, "looking at screen" does not always mean that everything is fine. Therefore, they will achieve bad game performance and their engagement will decline quickly after being engaged. Here these disturbing situations must be detected, even anticipated, and handled before the older adults can play continuously and achieve good performance.

## *Chapter 3*

---

# **Approach: structure of a support system based on a making-decision mechanism**

---

Literature reviews showed that an understanding by itself (e.g., usefulness, aesthetic aspects, easy to use, fun) or by recommendations of others (e.g. subjective norm) influences positively on user engagement towards computer-based applications. In the most already developed serious games for older adults, these findings can help game designer to treat many problems related to lack of game culture, acceptance of technology or physical impairments. However, many situations caused by memory disorders and cognitive impairments haven't been covered yet. This chapter presents an engaging approach, allowing maintaining older adults' engagement, enhancing their game performance and keeping a regular and effective use of video game for them. To achieve these objectives, the approach models "the appropriate moments" in which older adults may encounter problems and proposes suitable types of interaction for helping them using a support system. The proposed approach and the system are described in the first section. The two next sections present the structure and the components of the system. The first one describes a support manager which applies the proposed approach to model various situations and suitable interactions. The second one details two other components, recognition and interaction modules, which are used to collect data for the modeling of the support manager and realize suitable interactions with older adults.

### **3.1 Engaging Strategy and Support System**

According to The Acceptance of technology Model [22] and the Engagement-Mode Model [25], an individual accepts/engages to use Serious Game when he/she perceives the usefulness of this media tool (by himself/herself or by suggestion of his/ her relatives) or the ease of use. Furthermore, some elements of game such as fun, learning or rewards can motivate the individual to continue playing game. In the context of the thesis, the main challenge is to

enable for older adults benefit fully positive effects offered by Serious Games. In other words, older adults can regularly play games and achieve good performance. Therefore, they should be placed in the comfortable conditions in which they can easily interact with the game and play without interruption. Older adults can be convinced to perform trainings in the games even when they are not attracted by different game elements.

An approach is proposed to establish these conditions. The approach uses an engaging strategy which aims to provide helps to users at appropriate moments. In the most cases, the reduction of user engagement is caused by a large number of problems that the users face during game activities. The more they have problems, the greater they qualify games "harder" and are discouraged to continue playing games. Thus, all possible problems must be covered in order to maintain user engagement. Moreover, these problems should be anticipated before causing negative effects. Taking into account the ideas, the engaging strategy is designed as follows:

- modeling all of possible situations in which the users can face up to the problems during game activities and the appropriate solutions to help the users.
- tracking user attributes (positions, postures, gestures, movements ...), including game states, to determine modeled situations.
- choosing suitable types of interaction with the users to suggest solutions to unblock situations.

The approach applies the strategy using a support system (Fig. 3.1) which consists of 4 components: a Support Manager, a Recognition component, an Interaction component and a Game Controller. The Support Manager takes a major role within the system. This component allows the system to understand what is happening, by estimating the current situations based on user attributes (tracked by the Recognition) and game data and game performance of the user (provided by an Game Controller). Once the current situation is understood, the Support Manager sends the various commands indicating the situation and the appropriate interactions to the Game Controller and the Interaction. The Game Controller, in its turn, makes new changes in the game. Regarding the Interaction, this component uses an virtual animated agent to interact with the user. The type of interaction (voice or prompt) and relevant agent's properties (animations states or emotions) are chosen in terms of the current situation.

## **3.2 Support Manager**

The fact that older adults with dementia can regularly and efficiently play video games means that the interactions between older cognitive impaired users and video games are permanently maintained. The Support Manager (Fig. 3.2) gives to the support system a capacity of taking care on all of problems that can prevent these interactions. More precisely, the Support Manager supervises what problems are possibly happening and determines a relevant behaviour of the system to cover the current situation. To achieve this objective, three tasks are implemented to the Support Manager:



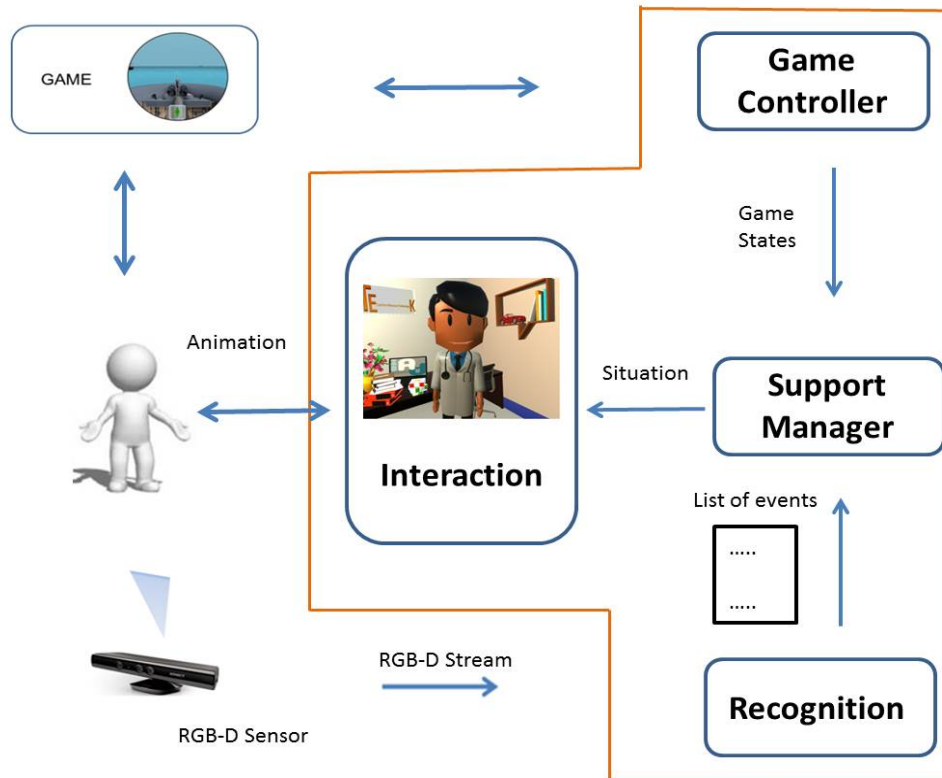


Figure 3.1 – Composition of Support System

- **Current Situation Estimation:** the first task is to recognize the current situation. A situation can be defined by a combination of the user performance in the game, his characteristics outside the game and the games states. These elements are provided by the Recognition component and the Game Controller. For example: the situation "repeated wrong answer" can be defined by "the user faces the screen", "distance between the user and the device are too large" and "wrong answer".
- **Interaction Strategy Selection:** Once the current situation is recognized, the Support Manager selects a set of possible interactions relevant to the current situation and an interaction strategy in Table 3.1 to maintain the user performance in the game.
- **Interaction Commands:** the selected strategy provides different is computed thanks to the selection in the previous task. The Support Manager, in the same time, transfers the interaction commands to the Game Controller and the Interaction component so that the last ones change their behaviour on the game and the agent. For example, when the expected situation "repeated wrong answers" is recognized by "the user faces screen", "distance between the user and the device are so long" and "wrong answer", the Game Controller pauses the game and the Interaction activates the animations "Recalling attention" and "Reminding rules of game" of the agent.

To cover the problems as much as possible, 4 types of situations are defined:

#### 1. Situations related to game states

- a) *Before starting the game:* the game in mode stand-by and waiting a interaction with the user for starting.

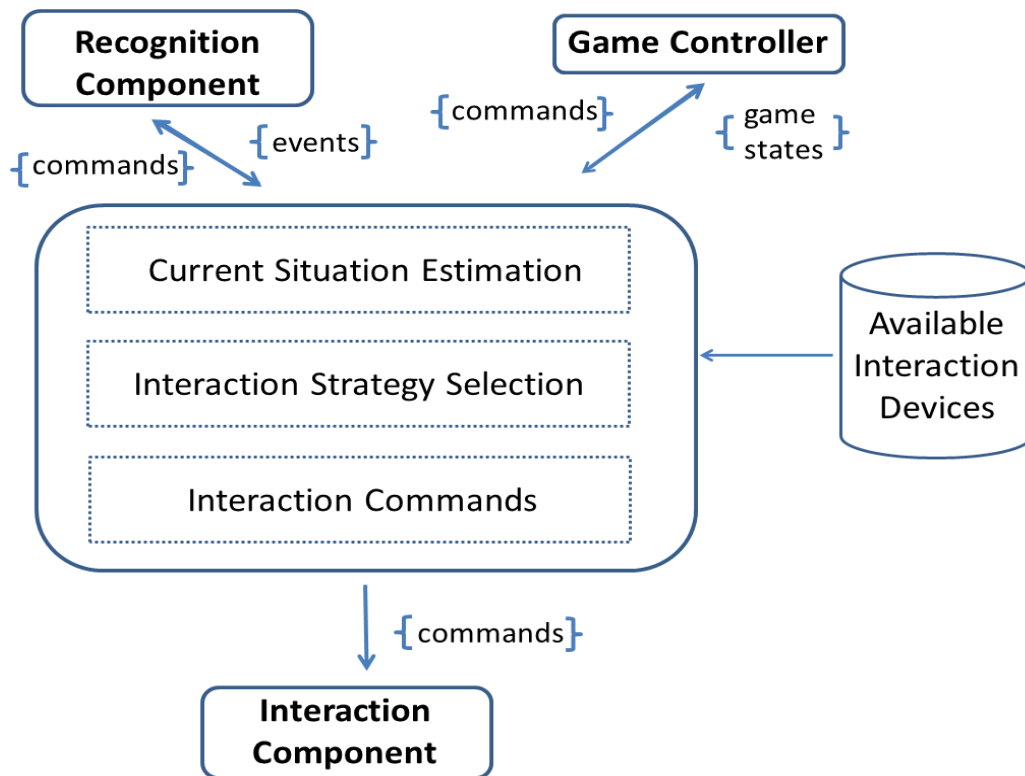


Figure 3.2 – Structure of the Support Manager

- b) *While starting the game*: the game starts and displays the first gameplays.
- c) *While playing the game*: the user have already started the game session.
- d) *While ending the game*: the user have finished the game session.
- e) *After ending the game*: the user quit of game. The game sets up in mode stand-by for next session.
- f) *While the game is suspended*: a problem takes place and the game is suspended.
- g) *Resuming the game*: the problem is treated and the game continues.
- h) *Starting new game*: the user has finish the session and desires to enchain another one.

## 2. Situations related to user performance in the game

- a) *Too fast*: the user has a fast reaction with the current task of gameplay.
- b) *Too slow*: the user takes a lot of times to interact with the current task of gameplay.
- c) *Well performance*: the user has a good understanding of rules and game mechanism and realizes good final result/score.
- d) *Poor performance*: the user has difficulties to play and realizes bad final results/score.
- e) *Distracted*: the user is distracted by external events.
- f) *Active*: the user plays game without interruption.

## 3. Situation related to user position wrt game devices

- a) *Correct*: the user puts himself in good position required by the game.
- b) *On the sides, Too close, Too far*: these situations happened in most time when the user plays the game that requires his position to interact activities in game.
- c) *Facing*: the user faces the screen.
- d) *Turned*: the user does not face the screen. In some cases, this situation could be related to the situation "distracted".
- e) *Standing or sitting*: posture of the user at the screen.

#### 4. **Situation related to game modes**

- a) *Single player*: user plays game alone in the environment.
- b) *Multi-players*: user plays game with other older adults around or on network.

As mentioned, each one of these situations happens either with user or with the game. Some are unfavourable for a continuous interaction (e.g. On the sides, Too close, Too far), for game performance (e.g. Slow, Distracted) and for user engagement (e.g. Suspended, Poor performance). Others provide an opportunity to stimulate (e.g. Before) or enhance (e.g. Fast, Active, Well and High performance) user engagement. When the user finds himself in an unfavourable situation and any helps are provided at time, their engagement declines quickly. It is necessary that an action must take place immediately to lead user in better situation. This means user engagement can be maintained. Therefore, a set of interactions is defined as follow:

1. **Welcoming** : the interaction is called when the game is starting. At this moment, the user is informed the name and the objective of the game. This is an important beginning task to create first positive appreciations of the user toward the game. The interaction is also necessary in the case that the user forgets completely all about the game.
2. **Casual Chatting** : the interaction is called not in the unfavourable situations, but to create, maintain and nourish a regular relationship between the user and the game. At some moments, the system establishes, through the appearance of the agent, an exchange of conversation with the user. The contents can be about different familiar topics such as the weather, the main news in the preferred paper or the health of the user. The interaction can be also used to recall the daily training that the user does not perform yet.
3. **Inviting to play** : Older adults suffering the Alzheimer's disease can forget permanently the daily training advised by the doctor or not be aware to decide a right time to play during the day. Therefore, they miss out on the benefits of the training. The interaction is applied to help them avoid this embarrassing situation. Different moments can be tried to invite the user to play the game. It could be "after the siesta" or "during the resting time in the lounge".
4. **Presenting rules of game**: When the game is started, the user needs to be informed how to play the game. The agent summarizes the objectives and the rules of the game.
5. **Tutoring**: The interaction guides the user step-by-step to learn how to play the game. If most healthy older adults find the tutorial only necessary in the first time to play, the

last one is always indispensable for older adults with dementia, which helps them to re-learn playing the game.

6. **Checking user position:** In some games integrated mobile sensor or motion camera sensor for the control, when a problem occurs, the user position (distance between the user and the sensor or the screen, angle) is firstly checked. Sometimes, it is just because the user does not respect the required position for the sensors.
7. **Checking user performance inside the game:** As the user position, the user performance in the game can be a significant element revealing the type of the current problem (e.g. repeated wrong answers, inactivity, low performance).
8. **Attracting the user attention:** The interaction is particularly launched in two situations: the "*distracted*" situation and the "*before starting the game*" situation. On the one hand, the user attention is attracted if the user does not concentrate to the game, on the other hand, the user attention can be caught by the agent to start a new conversation.
9. **Reminding rules of game:** The interaction is launched frequently when the "*poor performance*" situation is recognized and the "*checking user performance inside the game*" interaction launching get bad result. The agent reminds the rules of game.
10. **Guiding :** The interaction is particularly reserved for the situations related to the user surrounding. The agent guides the user step-by-step to reposition correctly.
11. **Congratulating:** When the user successes to unblock a problem or perform a good result, the agent congratulates him/her.
12. **Encouraging:** the interaction is launched when the user achieves a poor performance.
13. **Storing user performance:** After the training, the user performance is stored. In the next training, the agent behaviour and the difficulty level of the game are modified and adjusted in term of last user performance.

From the defined set of situations and interactions, the Support Manager can apply various strategies to determine the solutions treating the current problems. A strategy is a rule which defines a set of interactions, allowing to transfer from a situation to another one. Tables 3.1 summarizes all actions of the strategy:

1. While the game remains in standby mode (Before) and the user gets close to the screen, the system should establish a communication with the user (Welcoming, Inviting to play). The "Welcoming" could be personalized in terms of user properties (sex, clothes, etc.) and the communication contents can use daily topics to introduce the communication by which user can be interested and occurs friendly perception. The communication in this situation can be used to invite user playing a game session. Thus, this can also be used to maintain a good relationship with user or remind the user to respect the schedule of game sessions suggested by doctor in the case that the user has forgotten the session.
2. Once the user accepts to play and the game started, the agent makes a brief introduction detailing the objectives and the rules of the game. The agent proposes also a tutorial and launched this one if the user desires. Before starting the training, the stored results

Table 3.1 – Interaction Strategies

<b>Id</b>	<b>Current situation</b>	<b>Expected situation</b>	<b>Suitable Interactions</b>
1	Before starting the game Facing	While the game is starting	Recalling attention Casual chatting Inviting to play
2	While the game is starting	While the game is playing	Welcoming Presenting the rules of game Tutoring
3	While the game is playing	While the game is ending	Congratulation
4	While the game is ending	After Ending the game	Storing user performance
5	Ending the game	Restarting the game	Congratulating / Encouraging
6	While Suspended	Resuming	Checking position Checking user performance Treating problems
7	Poor performance	Well performance	Recalling attention Reminding rules of game Encouraging
8	Well performance	High performance	Encouraging
9	Distracted	Active	Checking user position Checking user performance Attracting attention
10	On the sides, Too close, Too far	Correct Guiding	Checking user position
11	Turned	Facing	Checking user position Checking user performance Guiding

of the last session are recovered in order to modify and adjust new difficulty level of the training.

3. At the end of a game session, the agent congratulates the performed results. The contents of speech must be always positive in all cases. For example, if the user realizes a poor performance, the contents should alleviate the user frustration and encourage the user to try another training.
4. Before closing the game, the current results of training are stored for the next session.
5. At the end of a training session, the agent invites the user to perform another one.
6. When a problem occurs, the game is suspended. The system has to check if this problem is caused by user position or game performance of user or both of them. Once the cause is found and treated, the game is resumed. This strategy is quite generic. Knowing that between these final situations, there are other in-between situation. The following strategies provide more details.
7. The training is suspended because the user makes a lot of errors. The system checks user performance inside the game to find the cause of errors. If the cause is confirmed, the agent reminds the rules of game and encourages the user to continue playing. Theses interactions can help the user understand the errors and remain motivated to continue

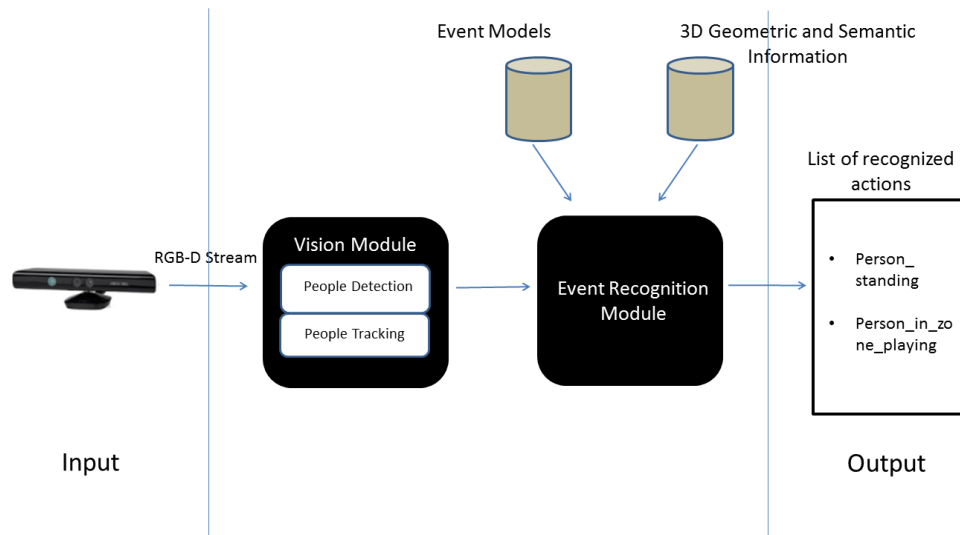


Figure 3.3 – Composition of Recognition Module

playing.

8. When the user performance is improved and becomes better, the agent can still encourage more in order that the user tries to boost his/her capacity.
9. When the user is distracted, the system has to bring back him/her to the game. The notion of "distracted" is quite difficult to be precisely described. In this thesis, two types of distraction are chosen. The user is considered "distracted" when his face does not focus on the interface of the game in a long time or his inactivity in the current task of game take so long. So in this situation, the agent checks both his position and his game performance to confirm the type of distraction. Then the agent attracts his attention and calls him back to the game.
10. While the user is not in a good position (distance and emplacement relative to the sensors) for playing, the agent guides the user coming back to good position.
11. Idem for this strategy. The system checks the user position and guides in good position so that the face is facing the sensors.

## 3.3 Recognition and Interaction Component

### 3.3.1 Recognition

The Recognition component is responsible to collect input data to the Support Manager. The component allows the Support Manager to perceive what the user is doing in the scene. There are many types of data which can be extracted from the user. In this thesis, an event recognition framework, developed by STAR team (A), is used. The overall structure of the framework consists of two main modules: the vision and the event recognition modules. The vision module uses different algorithms, locally developed, to detect and track people in the scene. Then, these results are served as input for the event recognition module which uses a

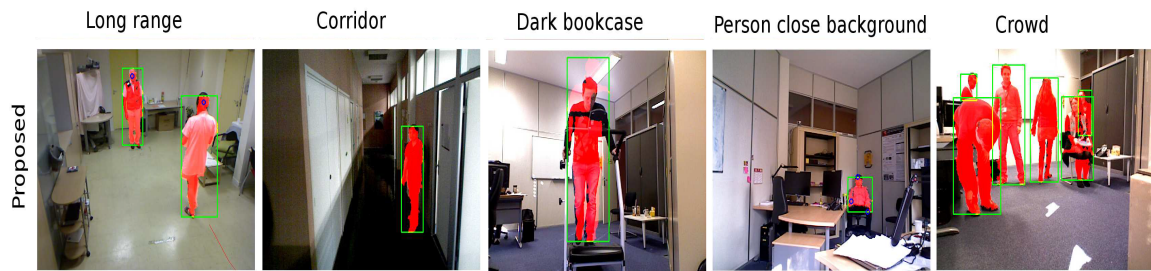


Figure 3.4 – Detecting people in different scene of background subtraction algorithm

constraint-based event ontology to model events, and the reasoning algorithm. Figures 3.3 describes the basic architecture of the event recognition framework.

## Vision Module

The vision module is a generic platform to implement and test different algorithms, developed locally, of image processing in computer vision chain. In this thesis, the module uses the background-subtraction algorithm of [50] for detecting and another of [51] for tracking people in the scene. Unlike other pixel-based background subtraction algorithms, the used algorithm gathers information about noises at pixel level. There are two types of noise regions: foreground regions containing only noise pixels (pure noise) and foreground regions containing both noise pixels and real people (mixed noise). A pure noise of a specific type is removed from the related regions if these regions are not classified as a noise regions of this type in many consecutive image frames. Future foreground linked to these regions will also be considered as not noise regions of this type. Regarding mixed noise, this type of noise can be detected based on the difference between the size of the foreground region and the normal size of the user. It simply now removes foreground pixels with label noise in this region difference.

Figure 3.5 describes the results of the algorithm in different contexts. The set of people detected by the algorithm is used as the input data for the multi-features tracking algorithm using the following features: 2D size, 3D displacement, color histogram, and dominant color. The tracking algorithm takes a set of detected objects in a temporal window as input. The tracking process is composed of three stages. First, the link similarity between any two detected objects is computed to establish possible links. Then the trajectories including a set of consecutive links previously computed are computed to get the highest possible total of global similarities. Finally, a filter is applied to remove noisy trajectories.

## Event Recognition Module

The module is responsible to recognize events related to the user on the screen and used that as input to the Support Manager. Based on work of [52], that module uses a constraint-based event ontology language to model event, thanks to a priory knowledge of the experimental scene and attributes of dynamic objects (e.g. a person or physical objects) detected and



Figure 3.5 – Tracking people in different scene of multi-features tracking algorithm.

tracked by the vision module. A priori knowledge is a set of 3D projection of the scene in a set of spatial zones having related information with events (e.g. kitchen zone, lounge space, TV zone, the main door zone ... ). The events are defined by a satisfaction of constraints on a combination of dynamic objects attributes and the priori knowledge.

An event model is composed of six components:

1. **Physical Objects** refers to real objects involved in the recognition of the event modeled. Three types of that component are defined: Person, Contextual Zones and Contextual Objects. The Person model contains information of mobile objects (e.g., 3D position, width, height) also attributes like body posture, appearance, etc. Contextual Zone and Object classes refer to static objects a priori defined in which the Person interaction with is of particular interest for an event modeling.
2. **Components** refers to sub-events that the model is composed of.
3. **Forbidden Components** refers to events that should not occur in case that the event model is recognized.
4. **Constraints** are the conditions that the physical objects and/or the components should hold. These constraints could be logical, spatial and temporal. Temporal constraints are expressed using Allen's interval algebra (e.g. BEFORE, MEET, and AND)
5. **Alert** describes the importance of a detection of the scenario model for a given specific treatment.
6. **Action** in association with the Alert type describes a specific action which would be performed when an event of the described model is detected.

Four models of events are hierarchically defined in terms of ascending complexity as follow:

- **Primitive State:** refers an instantaneous value of a property of a physical object. Figure 3.6 shows an example of the event model that refers to the value of a Person position. The event takes as input a Person and a Zone. The event is recognized when the sub-constraints are satisfied: the Person position must be in size a Zone which has a name as "ZoneKitchen".



```

PrimitiveState( Person_Inside_Zone_Kitchen,
                PhysicalObjects((p1 : Person)(z1 : Zone))
                Constraint((p1->Position in z1->Vertice)
                           (z1->Name = ZoneKitchen)
                           )
                Alarm((Leve : NOTURGENT))
                )

```

Figure 3.6 – An example of PrimiviteState model

- **Composite State:** refers to a composition of two or more primitive states. Figure 3.7 shows an example of the event model that refers to a set of value of the Person (e.g. posture and position). The event takes as input a Person, a Zone and two sub-events. The event is recognized when two sub-events are recognized instantly and together.

```

CompositeState(Person_Falling_Inside
               _Zone_Kitchen,
               PhysicalObjects((p1 : Person) , (z1 : Zone))
               Components((c1 : PrimitiveState
                           Person_Falling(p1), (c2 : PrimitiveSate
                           Person_Inside_Zone_Kitchen(p1,z1))
                           Constraints( c1 and c2 )
                           Alarm ((Level : URGENT))
               )

```

Figure 3.7 – An example of CompositeState model

- **Primitive Event:** models a change in a value of physical object property. Figure 3.8 shows an example of the event model that refers to a change of value of the Person posture. The event takes as input a Person, a Zone and two sub-events related to posture of the same Person. The event is recognized when the first sub-event is already recognized in more 0.5 seconds and the second sub-event is recognized at the time when the first sub-event is finished and it just needs less 3 seconds since the start of the second sub-event to validate the current event.

```

PrimitiveEvent(change_posture_stand_to_sit,
  PhysicalObjects((p1 : Person), (z1: Zone))
  Components((c1 : PrimitiveState
              Person_standing(p1))
             (c2 : PrimitiveState
              Person_sitting(p1, z1)))
  Constraints( (c1 meet c2)
              (duration(c1) > 0.5)
              (duration(c2) < 3))
  Alarm ((Level : URGENT))
)

```

Figure 3.8 – An example of PrimitiveEvent model

- **Composite Event:** refers to the composition of two previous event models which should hold a temporal relationship. Figure 3.9 shows an example of the event model that is defined by two sub-events with temporal constraint. The first constrain checks if the first sub-event is already recognized en the scene at least 1 second and the second constraint ensures that both sub-events must be recognized in the same time.

```

CompositeEvent(Person_making_Coffee,
  PhysicalObjects((p1 : Person), (z1 : Zone))
  Components((c1: PrimitiveState
              Person_Inside_Zone_MakingCoffe(p1,
z1))
             (c2:PrimitiveState
              Person_Standing_Long(p1)))
  Constraints((duration(c1) >= 1)
              (c1 and c2))
  Alarm ((Level : URGENT))
)

```

Figure 3.9 – An example of CompositeEvent model

### 3.3.2 Interaction

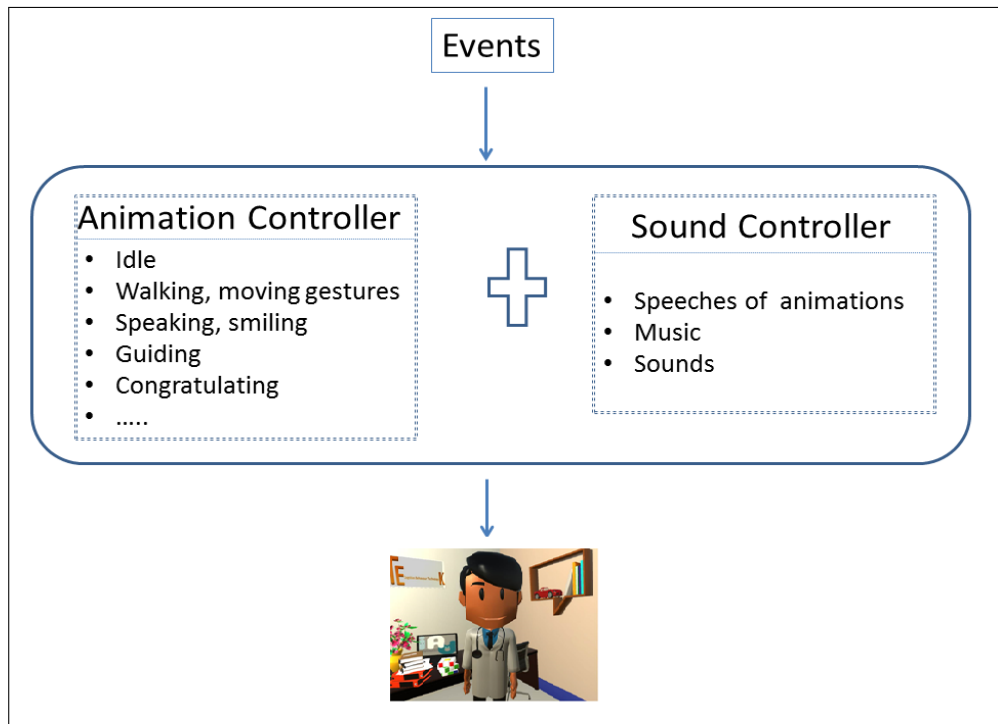


Figure 3.10 – Overall composition of the Interaction component which consists of an animation Controller, a sound Controller and an animated agent.

If the Recognition component are used as input to provide useful information of the user and the game to the Support Manager, the Interaction component is responsible of establishing direct contacts with the user, as an output of the Support system. To achieve this task, the component receives the current situation from the Support Manager and performs appropriate interactions with the user through an 3D-animated agent. The interest of using an agent has been proven in the literature. Indeed, it could bring to the user a feeling of company [53], increases attention and sympathy [54] and more importantly, improves the interactions with machines [55]. Figure 4.14 presents the overall composition of the component that contains an animation controller, a sound controller and a agent. Two controllers choose an useful combination of animation and sound, in terms of the current situation, to control the agent and create the relevant interaction with the user.

The agent is placed in an interface which is designed by Unity3d game engine. This engine is chosen because of its intuitive editor of integrating of objects and scripts (Fig. 3.11). Unity3d engine can import many popular 3D formats (Maya, FBX, etc.) and various types of resource (audio, video). This multi-functionality simplifies development and enables very fast an initialization in game design. Another advantage of this game engine are that it can connect with new devices like the Kinect camera Microsoft, which allows for mono or bidirectional interactions (voice or motions).

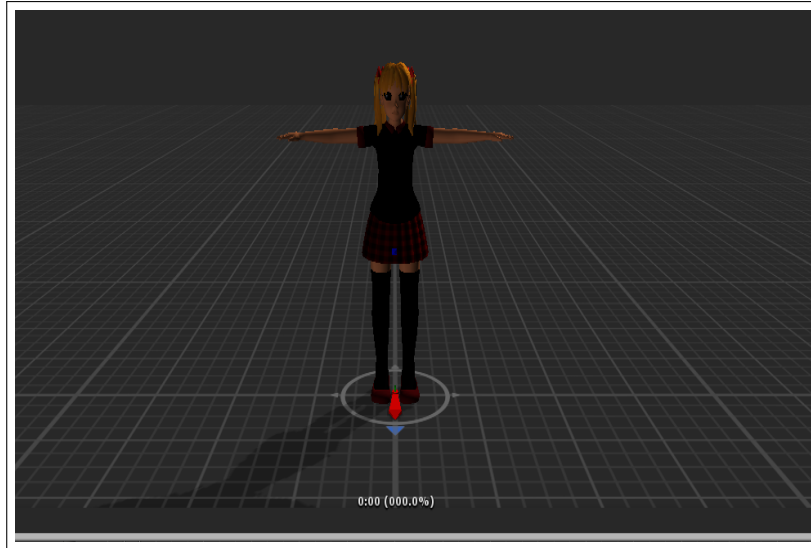


Figure 3.11 – The virtual agent is modeled and rendered by the Unity3D editor.

The agent is collected from a open source project and already rigged. The agent animations are created either by the game engine Unity3D<sup>1</sup> or 3ds Max <sup>2</sup> (a software of modeling, animating and rendering in 3D). Most animations are created in corresponding with the set of interaction defined for the Support Manager. Other animations are related to the agent emotions. The speech and sound are also prepared in corresponding with the animations. In this thesis, the speeches either are recorded directly with human voice in other to accentuate more emotional tone or generalized by a speech synthesizer. The speeches contents are analysed by a psychologist doctor to ensure that the communicative exchanges are always positive and encouraging.

---

<sup>1</sup><http://unity3d.com>

<sup>2</sup><http://www.autodesk.fr/products/3ds-max/overview>

# **Part II**

## **Experiments**

# Experiment 1: Can the older adults interact successfully with the support system ?

---

The main objective of this experiment is to validate the interactivity of the support system to the users. As a reminder, the proposed engaging approach and support system are for the purpose of providing users the best conditions to play Serious Games regularly and effectively. The system must be able to determine the problems and help the users to treat the problems throughout a set of dynamic interactions. To achieve this objective, the experiment must answer the following questions related to these interactions:

- Are the connections between the support manager and other components established?
- Can the support manager determine correctly the current problem?
- Do the users agree to interact with the system?
- Do the users succeed in interacting with the system?
- Are the interactions useful for the users?
- How do the users assess the system?

### 4.1 Pre-studies

Before realizing the experiment, two pre-studies are carried out in order to find and analyze the difficulties which can cause many obstacles against the support system functioning and make the interactions between the users and the support system fail. In parallel, the results of these pre-studies allow to build a prototype of the support system and to improve it progressively. An unwinding process is defined and applied to the whole experiment:

1. Defining the context and the objective.
2. Defining and recruiting the target population.
3. Selecting a game.

#### 4. Implementing the support system:

- Defining events to recognize for the Recognition Component..
- Designing the virtual agent appearance and selecting the interaction mode according to the interaction devices and the target population's abilities.
- Installing physical devices storing the support system and the game.
- Linking the support manager to the interaction and the recognition components.

5. Defining a protocol and interaction scenarios.

6. Computing and storing data requested by the protocol.

7. Assessing the data to conclude the experiment.

### 4.1.1 Pre-study 1

#### Context and Objective

The main objective of this pre-study is to build a first operational version of the support system. That means:

- The recognition component can recognize correctly the expected events related to the user.
- The connections between the support manager and the three other components are established permanently.
- The support manager can determine the problems thanks to data provided by the recognition component and the game controller, then compute a solution by applying the interaction strategies.
- The game controller and the interaction component (throughout the agent) react correctly on time once having received interaction commands from the support manager.
- The user can understand the interaction mode and interact successfully with the agent.

In parallel, collecting the user evaluation of the system elements and the troubles taking place during the experiment is also important. The subjective evaluation allows to understand if the users appreciate positively or not the agent appearance and the interaction mode is feasible for the user. Moreover, the troubles can help the support system improve its effectiveness.

The first version of the support system is tested in coffee space at Inria local (Figure. 4.1). In this context, the system must stimulate people to play a mini game when they stay for a long time in coffee space either to make a coffee or taking a break.

#### Selected game

A sample game using the Kinect sensor of Microsoft, named Shape Game <sup>1</sup> (Figure. 4.2), is chosen in this pre-study. The gameplay is pretty simple and easy to play. The user can control a tracked skeleton (moving arms, legs and head) to bump or even explode the shapes (circles, triangles, stars) falling from above. The user's score corresponds to the number of

---

<sup>1</sup><https://msdn.microsoft.com/en-us/library/hh855385.aspx>



Figure 4.1 – First pre-study in coffee space at Inria local

exploded shapes. Once the game is started, the user can say commands to change shape size, shape velocity, shape color or game states based on a speech vocabulary (Tab 4.1).

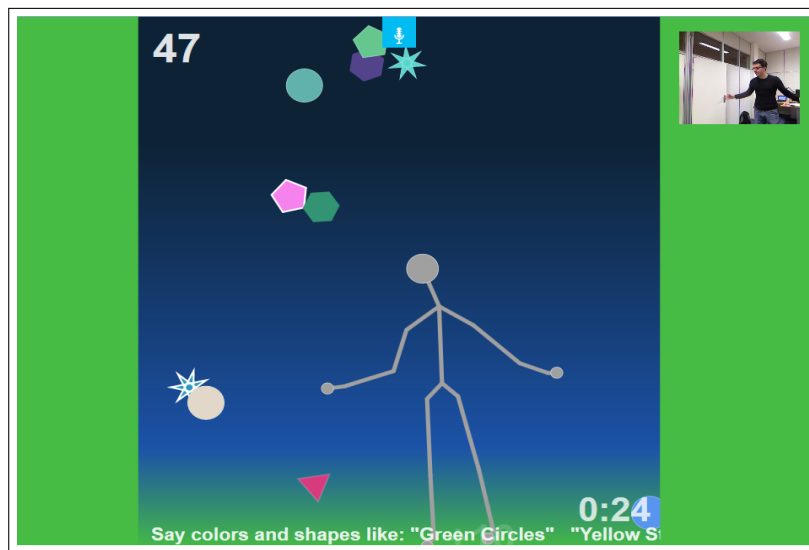


Figure 4.2 – Shape Game - a game on Kinect sensor with voice command and motion control

### Protocol and Interaction Scenarios

The public is free to interact naturally with the agent. On the contrary, the participants are asked to follow the interaction scenarios. According to the decision of the person, different scenarios are proposed:

1. **Scenario 1:** the person crosses the scene and does not stay for a long time. The system does not react.



Table 4.1 – Speech vocabulary of Shape Game’s voice commands

Command Sentence	Actions
"speed up", "faster" "slow down", "slower"	Changing shape falling speed
"larger", "bigger", "bigger shapes" "huge", "giant", "super big", "biggest" "smallest", "tiny", "super small"	Changing all shape size
"red", "orange", "yellow", "green" "blue", "purple", "violet", "pink" "brown", "gray", "black", "white" "bright", "dark", "every color" "all colors", "random colors"	Changing shape color
"triangles", "squares", "stars", "pentagons" "hexagons", "circles", "seven-pointed stars" "all shapes", "everything", "bubbles"	Changing shapes
"reset", "clear" "stop", "freeze", "pause game" "go", "unfreeze", "resume", "continue", "play"	Changing game states

2. **Scenario 2:** the person enters the scene but out of the two zones reserved for "making a coffee" (zone z1) and "taking a break" (zone z2) and stays for a long time (Definition of the event in Figure. 4.4). The system does not react.
3. **Scenario 3:** the person enters in one of the reserved zones or sits on the chair and stays for more than 30 seconds. The young girl agent appears, introduces herself and invites the person to play a game session.
  - *Scenario 3.1:* the person says "No" to refuse to play a game session or the person does not respond to the young girl agent. The agent thanks and says "goodbye" to the person and disappears.
  - *Scenario 3.2:* the person says "Yes" to agree to play a session. The agent starts the game.

After the game session, the person is invited to fill an evaluation form on the interaction with the agent, her appearance and the attractiveness of the game. The evaluation forms are also put next to the screen for the public. During the experiment, no personal information (image, name, ...) is stored.

### **Implementation of the support system**

To communicate with people, the support system uses an virtual agent with a young girl appearance. The agent is modeled, animated and rendered with 3ds Max software. In order to draw more attention of people, the agent is placed in a virtual living room and multiple interaction scenarios are implemented with the Unity3D editor (Figures. 4.3, 4.4).



Figure 4.3 – The young girl agent is immersed in a virtual living room by the Unity3D editor

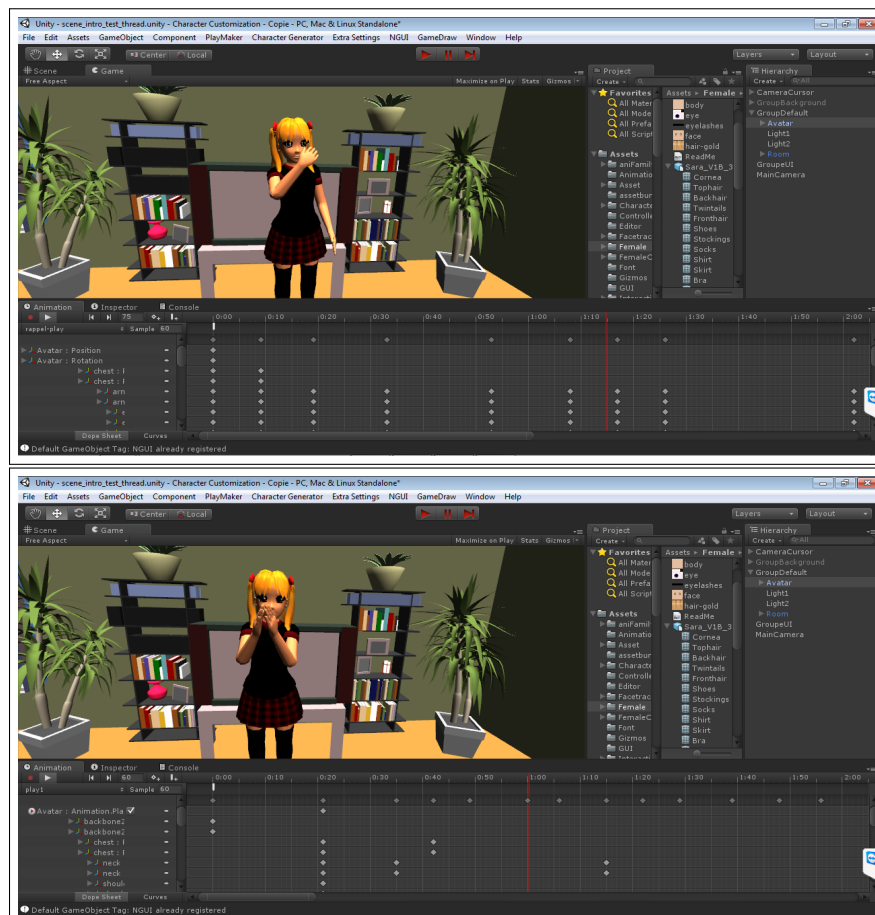


Figure 4.4 – Animation scenarios of the young girl agent are organized with the game engine Unity3D. Here are the animations "reminding the rules of game" (top) and "congratulating" (bottom).

The agent's speech is synthesized by a free online service <sup>2</sup>. This choice is to check if synthesized vocal can give the same effects as recorded vocal. The speech language used in

<sup>2</sup><http://www.acapela-group.fr/?lang=en>

*Hello. It's Sophie. Do you have a little bit of time for me?*

*I want to test an experiment of the Team Stars.*

*I will show you an application with Kinect sensor.*

*Please, say out loud "Yes" for agreement or "No" for disagreement.*

---

*You made a good choice, believe me.*

*Move your arms to play.*

*You can also command by saying the words below.*

*You can close the game with the command "Out".*

#### InfoBox 4.1 – Speech content of the agent in first pre-study

this pre-study is English because most people working around this space are fluent in English. Since the target population mostly comprises active people (computer engineers) and the selected game requires the Kinect sensor with speech recognition, the support system makes use of this functionality to create the interaction mode "voice-voice". The young girl agent speaks and is animated to attract attention, invite to play and present the gameplay to the user. The user answers "yes/no" to the agent if he/she accepts to play the game.

As mentioned in the objectives, the support system aims to interact with people in the coffee space to invite them to play game. Therefore, the system must recognize their presence and decide a right moment to interact with them. In most cases, they spend their time in the coffee space either to make a coffee or to take a break. The space is virtually divided in two zones: z1 and z2 (Figure. 4.1).

The zone z1 is used to recognize people who are staying a long time (more than 30 seconds) in the place. It is also a required zone to play game. The zone z2 is used to recognize people who are making a coffee. Therefore, a set of events (Figure. 4.4) is defined in which three important "CompositeEvent" allow the system to decide the moment to interact with people. Two events "Person\_Standing\_Long\_Inside\_Zone1" and "Person\_Standing\_Long\_Inside\_Zone2" are validated when the person is in the zone z1 and z2 more than 30 seconds. The event "Person\_sitting\_long" is validated when the person sits down more than 30 seconds.

```

PrimitiveState ( Person_Inside_Zone1,
    PhysicalObjects((p1: Person)(z1: Zone))
    Constraint((p1->Position in z1->Vertice)
    (z1->Name = z1))
    Alarm((Level: NOTURGENT))
)

PrimitiveState ( Person_Inside_Zone2,
    PhysicalObjects((p1: Person)(z1: Zone))
    Constraint((p1->Position in z1->Vertice)
    (z1->Name = z2))
    Alarm((Level: NOTURGENT))
)

CompositeState (Person_Not_In_Required_Zones,
    PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
    Constraint((p1->Position not in z1->Vertice)
    (p1->Position not in z2->Vertice) )
    Alarm((Level: NOTURGENT))
)

PrimitiveState (Person_Sitting,
    PhysicalObjects((p1: Person))
    Constraint((p1->Posture = sitting))
    Alarm((Level: NOTURGENT))
)

CompositeEvent (Person_Inside_Zone1_Long,
    PhysicalObjects((p1: Person) (z1: Zone))
    Component((c1:PrimitiveState Person_Inside_Zone1(p1,z1)))
    Constraint((duration (c1) > 30))
    Alarm((Level: URGENT))
)

```



Figure 4.5 – A desktop (running in Windows OS) and Kinect sensor (Figure top) is used to implement the support manager, the game controller and the interaction component. Other kit(desktop running in Linux Fedora 14) (Figure below) is used to implement the recognition component.

```

CompositeEvent (Person_Inside_Zone2_Long,
    PhysicalObjects((p1: Person) (z2: Zone))
    Component((c1:PrimitiveState Person_Inside_Zone1(p1,z2)))
    Constraint((duration (c1) > 30))
    Alarm((Level: URGENT))
)
CompositeEvent (Person_Sitting_Long,
    PhysicalObjects((p1: Person))
    Component((c1:PrimitiveState Person_Sitting(p1)))
    Constraint((duration (c1) > 30))
    Alarm((Level: URGENT))
)

```

Figure 4.4 – Set of events to recognize in the first pre-study, in which three main events allow to determine the moment to interact with people

Two kits of a desktop and an RGB-D sensor (Figure. 4.5) are used to implement and run the support system. The first kit hosts the support manager, the interaction component, the game controller and also the Shape game. That implements also Kinect SDK to run the Kinect sensor. The second kit is used only to host the Recognition component with a RGB-D sensor. The reason that all components of the support system are not implemented on the same computer is that the framework of event recognition runs on Linux Fedora OS and the game also runs on Windows OS the support manager, game controller and the Interaction component are integrated in Unity3D which also runs on Windows OS.

A socket server/client in .Net framework is used to communicate the data via TCP/IP protocol between the Recognition component and the support manager (Figure. 4.6). The server is implemented on the side of the support manager. It listens in a specific port and waits to accept a connection from the client. Once the connection is accepted, the server reads messages containing recognized events in order that the support manager uses them to compute new expected situation. After all this, the server sends interaction commands to the client socket. The client socket is implemented on the side of the recognition component. The client connects to the specific port and waits for the acceptance of the server. Once accepted, the client sends recognized events to the server and reads interaction commands sent from the latter in a continuous loop.

#### **Data collection**

For each user with a demanded scenario, many constraints must be checked:

- Does the recognition component recognize the main events related to the scenarios?
- Does the support manager correctly compute the expected situation thanks to the recognized events and the current game state provide by the recognition component and the game controller?
- Do both components (Interaction and Game Controller) correctly react once having received interaction commands from the support manager, according to the current

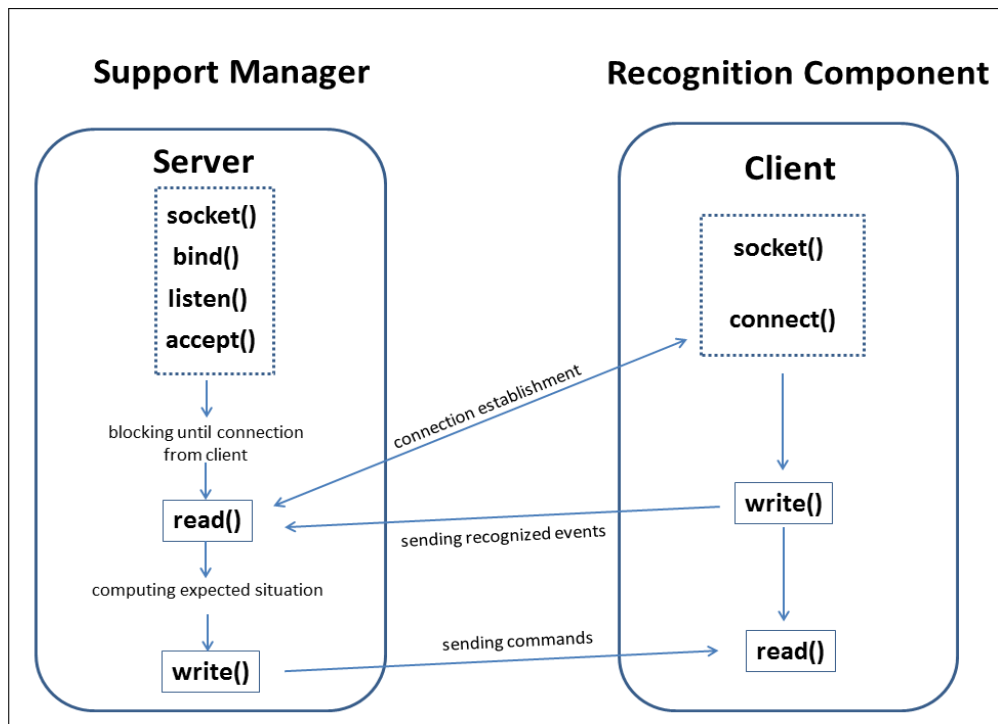


Figure 4.6 – Structure of the socket server/client to compute data between the support manager and the recognition component

scenario?

- Are there some problems not predicted during the experiment? What are the causes?
- How do the users assess the attractiveness of the support system throughout the young girl agent's properties (appearance, voice), the interface and the game?

## Results

10 persons have been invited to test the system and 6 persons in public have left their evaluation. Among invited participants, 3 persons made the coffee, 3 persons took a break, 2 others sat on the chair and accepted to play a game session (scenario 3.2). 2 persons refused to play, the first said "No" and the second said nothing.

All of the 3 main events were correctly recognized in the related interaction scenario, and the system exactly performed the actions mentioned in the Protocol. All of the subjective remarks throughout the evaluation forms give almost the same assessment. The users think that the young girl agent's voice is clear and sharp, her appearance is "nice" and "cute" and they can understand her speech content. However, they remark that her voice tone and her movements are still like a "robot", not really human-like yet. They also confirm that the virtual living room does not influence on their remarks. Regarding the game, they think playing with body motion and voice control is funny, but the gameplay is very simple and short so that they play only one game session. There are also some troubles. When the users answer to the agent if they want to play or not, they have to speak loudly because of the noise of the coffee machine. Once the support system recognize the coffee machine noise as the word "No". The system also faces problems when a crowd stays in the reserved zones. The support system

does not prepared to determine with which person the agent must interact.

### Discussion

Despite these troubles, the support system has succeeded in interacting with the users. On the one hand, the support system can determine the appropriate moments, based on their position and their posture, to invite them playing the game. On the other hand, the users can reply by speaking naturally. The use of a virtual agent in the communication, who can speak and move by itself, is well appreciated . Moreover, using a female agent seems a good choice. The success of the support system can be explained, firstly, by the simplicity of the interaction scenarios. The users do not need to perform complex interactions. Secondly, the target population are active and work, most of them, in computing science field. They can realize easily and adapt quickly with the situation. Playing the game with their body motion and voice control do not cause big problems to them. They can even auto-reposition when they get out of the range of the Kinect sensor. Therefore it is necessary to research if the same success can be achieved with the older population, knowing that this population do not have the same vision, experience and abilities with new technology and gaming as the young people. A second pre-study, using the support system with some improvements, is realized in the subsection below to confirm the issues.

### 4.1.2 Pre-study 2



Figure 4.7 – Screenshot from the interface of the Recognition component in the second pre-study led in waiting room at Claude Pompidou Institute

### Context and Objective

The previous pre-study showed that the first version of the support system can interact well with the computer scientists. All components of the system fulfill their role quite well. The support manager is capable of determining a new behavior adapted from the expected events recognized in the given interaction scenario. The scenarios and the interaction mode

do not cause difficulties to the target population. Therefore, the next challenge is to verify if the support system is also applicable to the older population.

In this pre-study, the objective is to prove that older people can also interact successfully with the support system and the system continues to run correctly without troubles. To achieve these purposes, the system is applied in a new context. The target population is recruited from the waiting room of the Claude Pompidou Institute. In this context, the system aims to stimulate people to play a game session while they are near the screen for a long time. The Shape game is re-used in this pre-study.

### **Protocol and Interaction Scenarios**

Both the public and the invited users are free to interact naturally on scene with the agent without knowing any information about the system and the game beforehand. For the invited users, they are asked to approach near the screen and read the information slide. According to the starting position of the user, different scenarios are proposed:

1. **Scenario 1:** the person enters in the *zone\_play*, stays there and reads the information slide. The agent appears, introduces herself and invites the user to play a game session. To accept to play the game, the user raises the right hand. Otherwise, the user does nothing.
  - *Scenario 1.1:* the user does not raise the right hand. The agent thanks and says "goodbye" to the person and disappears. The information slide re-appears.
  - *Scenario 1.2:* the user raises the right hand. The agent explains quickly how to play the game with body motion and voice control and starts the game.
  
2. **Scenario 2:** the user enters in the *zone\_stimulant*, stays there and reads the information slide. The agent appears, introduces herself and invites the user to play a game session. To accept to play game, the user raises the right hand. Otherwise, the user does nothing.
  - *Scenario 2.1:* the user does not raise the right hand. The agent thanks and says "goodbye" to the person and disappears. The information slide re-appears.
  - *Scenario 2.2:* the user raises the right hand. The agent asks the user to move forward, explains quickly how to play game with body motion and voice control and starts the game.

During the game session, if the user moves out of the *zone\_play*, the agent pauses the game and guides the user come back inside the zone. Once having played the game, the person is invited to fill an evaluation form on the interaction with the agent, her appearance and the attractiveness of the game. The evaluation forms are also put next to the screen for the public.

### **Implementation of the support system**

Basically, the implementation of the support system is the same as that the one developed in the previous pre-study. Taking the subjective evaluations and the troubles into account, many improvements of the components are realized in order to maximize the chance of



interacting successfully with the new target population. Two kits of a desktop and an RGB-d sensor are used to contain and run the support system and the game. The same young girl agent is reused, but now she "speaks" French and speech contents are also changed because most older people frequent this space are French and new interaction strategy is added (strategy number 10 in Table. 3.1). The young girl agent intervenes and guides the users to good playing position when while they are too close to or too far from the Kinect sensor.

A little trick is used to attract people's attention and to have them approach close to the screen. An information slide about the research team's activities is scrolled repeatedly. At the end of the slide, a message suggests that the viewers approach close to the screen to test.

```

CompositeEvent (Person_Inside_Zone_Play_Long,
    PhysicalObjects((p1: Person) (z1: Zone))
    Component((c1:PrimitiveState Person_Inside_Zone_Play(p1,z1)))
    Constraint((duration (c1) > 30))
    Alarm((Level: URGENT))
)
CompositeEvent (Person_Inside_Zone_Stimulant_Long,
    PhysicalObjects((p1: Person) (z1: Zone))
    Component((c1:PrimitiveState Person_Inside_Zone_Stimulant(p1,z1)))
    Constraint((duration (c1) > 30))
    Alarm((Level: URGENT))
)
CompositeState (Person_Change_From_Zone_Stimulant_To_Zone_Play,
    PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
    Component((c1:PrimitiveState Person_Inside_Zone_Stimulant(p1,z1))
        (c2:PrimitiveState Person_Inside_Zone_Play(p1,z2)))
    Constraint((c1 meet c2)
        (duration(c1) >0.5)
        (duration(c2) <3))
    Alarm((Level:URGENT))
)
CompositeState (Person_Change_From_Zone_Play_To_Zone_Stimulant,
    PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
    Component((c1:PrimitiveState Person_Inside_Zone_Play(p1,z1))
        (c2:PrimitiveState Person_Inside_Zone_Stimulant(p1,z2)))
    Constraint((c1 meet c2)
        (duration(c1) >0.5)
        (duration(c2) <3))
    Alarm((Level:URGENT))
)

```

Figure 4.8 – New set of events of the second pre-study for recognizing user's positions and movements relative to the screen.

Two zones are also drawn virtually on the scene (Figure. 4.7). The first zone, named "zone\_play", is located inside the field of view of the Kinect sensor. That is the best space

to play the game. The second one, named "*zone\_stimulant*", is reserved to recognize people who are near the screen and to invite to play game. A new set of events to recognize is defined to take into account new added interaction strategy (Figure. 4.8). Two events "*Person\_Inside\_Zone\_Play\_Long*" and "*Person\_Inside\_Zone\_Stimulant\_Long*" allow the support system to establish a communication exchange and to invite the users to play the game. They allow too to know if the users are in the good position to play. The system can also follow the users' movement and guide them to good positions to play thanks to two events "*Person\_Change\_From\_Zone\_Stimulant\_To\_Zone\_Play*" and "*Person\_Change\_From\_Zone\_Play\_To\_Zone\_Stimulant*".

### **Results**

10 older persons have been invited to interact with the system while waiting for their medical consultation. 4 persons in the public have tested and left their evaluation forms. Among the invited people, only one person has refused to play the game. The person said that interacting with a sensor was really difficult for him and did not want to try. Concerning the other 9 accepted users, 3 users have entered directly in the *zone\_stimulant* and 6 users have entered directly in the *zone\_play*. These users did not have difficulty to understand and follow the agent instructions. Furthermore, once the game is started, all of 9 users have took a long time to look at the forms falling from the sky and did not know what to do to play. Among them, 3 users could not manage the situation well and needed an external help, while 6 users finally realize that the skeleton on the screen moves in a harmonized way with their body moves. Then they start to discover the game. Nobody wanted to play a second session after having finished the first one. Regarding the evaluation forms, the results show some similarities with the previous pre-study. The agent's voice is still assessed as clear and sharp, her appearance is "nice" and "cute" and they can understand her speech content. They still think the agent remains robot-like. However, they are pleasantly surprised when playing the game with body motion control.

### **Discussion**

Basically, this pre-study is a success. With the new interaction mode, the "communication exchange" between the users and the system occurs correctly. The users answer to the support system by their position and their movement. Communicating with a virtual agent and playing with body motion control bring some nice surprises to the users. However, some remarks should be taken into account. First, the control mode makes the user employ a lot of muscles. They quickly become fatigue, stop playing and do not want to try another session. Second, a quick oral summary of "how to play" was not enough for 3 users to fully understand that they have to use their arms, their head and their feet to bump and explode the forms falling from the sky. Once again, the gameplay is so simple that it can not attract the users to play another session. Finally, the 9 users who accept playing have underlined that, without the invitation to test the system, they could refuse to play game if they were suggested by the agent. They think the waiting room is not an appropriate place to play. They prefer not to play game in public space, in front of everybody. This is also the reason which reduces their motivation in

trying another game session even that they find the game to be quietly funny.

## **4.2 Experiment 1**

### **4.2.1 Context and Objective**

The second pre-study showed that the support system is capable of interacting successfully with the older users in the given interaction scenario. The pre-study also pointed out two interesting remarks. First, the users need more guides or information in order to better understand the gameplay and play the game successfully. Second, the game scenario is too simple to attract the users taking more time to playing. These two points can cause more concerns to older population with dementia. With the comprehension capacity and the memory which are impaired by the diseases, the older people with dementia could have more difficulties to understand and remind the guide of gameplay. Moreover, a simple game scenario cannot sufficiently attract to compensate to this disadvantage. Thus, the main objective of this experiment is to validate the interactivity of the support system with older people with dementia. To fulfill this purpose, the support system must be firstly improved by taking into account the remarks above. On the one hand, the system structure continues to run correctly. On the other hand, the users can interact successfully with the support system. A successful interaction is defined by an sequence of actions, without interrupting from the users from the moment they begin to follow the instructions of the agent to initiate the game until they decide to stop playing. Secondly, a second game, which has a more complex gameplay and scenario, is added.

### **4.2.2 Target Population**

The older participants in the experiment are recruited in Claude Pompidou Institute during their medical consultation. Inclusion criteria are their age and their score at the Mini-Mental State Exam (MMSE)[56]. The participants who have motor disabilities or a MMSE score under 16 are excluded. 19 participants, including 11 men and 8 women, have accepted to test the support system. They are categorized into three groups (Table. 5.4): Mnesic Complaints, MCI and Alzheimer. The Mnesic Complaints group includes participants complaining about few symptoms, but their MMSE is higher than 26. The MCI group contains the participants diagnosed "Mild Cognitive Impairment" with the MMSE around of 24. The last group contains the participants who are diagnosed "Alzheimer" with the MMSE around of 18. Most of the participants have not experience with game video. Only 3 participants had played a few times with their grandchildren on touch pads and no one had tested the Kinect sensor before.

Table 4.2 – Description of the target population in the experiment 1

Group	Average Age	Average MMS Score	Men	Women
Mnesic Complaints	76.2 ±0.5	27.8 ±0.6	5	3
Mild Cognitive Impairment (MCI)	74 ±1.3	24.3 ±0.5	3	3
Alzheimer	74.3 ±1.4	17.8 ±3.3	3	2

### 4.2.3 Games used with the support system



Figure 4.9 – Good View Hunting: a training game on upper limb with Kinect sensor. The user controls tools for cleaning dirty marks by wiping with his/her arms. The game is also available in multi-player mode that allows family members to play together.

The Shape Game (page 55) is still used in this experiment because of its simple and easy gameplay for learning how to play with the Kinect sensor. The previous experiences show that this game is unfortunately not enough to keep the users playing more than one game session. That is not interesting in comparison to the objective of the Az@Game project A in which the thesis is included. Indeed, the more the user plays the game, the more he / she can benefit positive effects on their health. To improve this situation, a second game with a funnier gameplay is added, hoping that this one can keep the user playing the game longer.

The Good View Hunting game <sup>3</sup>, developed by KineLabs, provides training on the player's upper limbs and supports training of one and both hands (Figure. 4.9). In this game, the player can stand (or sit) in front of the Kinect sensor, and wipe the arms to clean up different types of dirt on the window. The game supports multiple players; this offers a chance for family members or friends, through the game, to interact together with the patient, in order to encourage him/her to participate further in this game-based training.

<sup>3</sup><https://www.polyu.edu.hk/bme/kinelabs/>

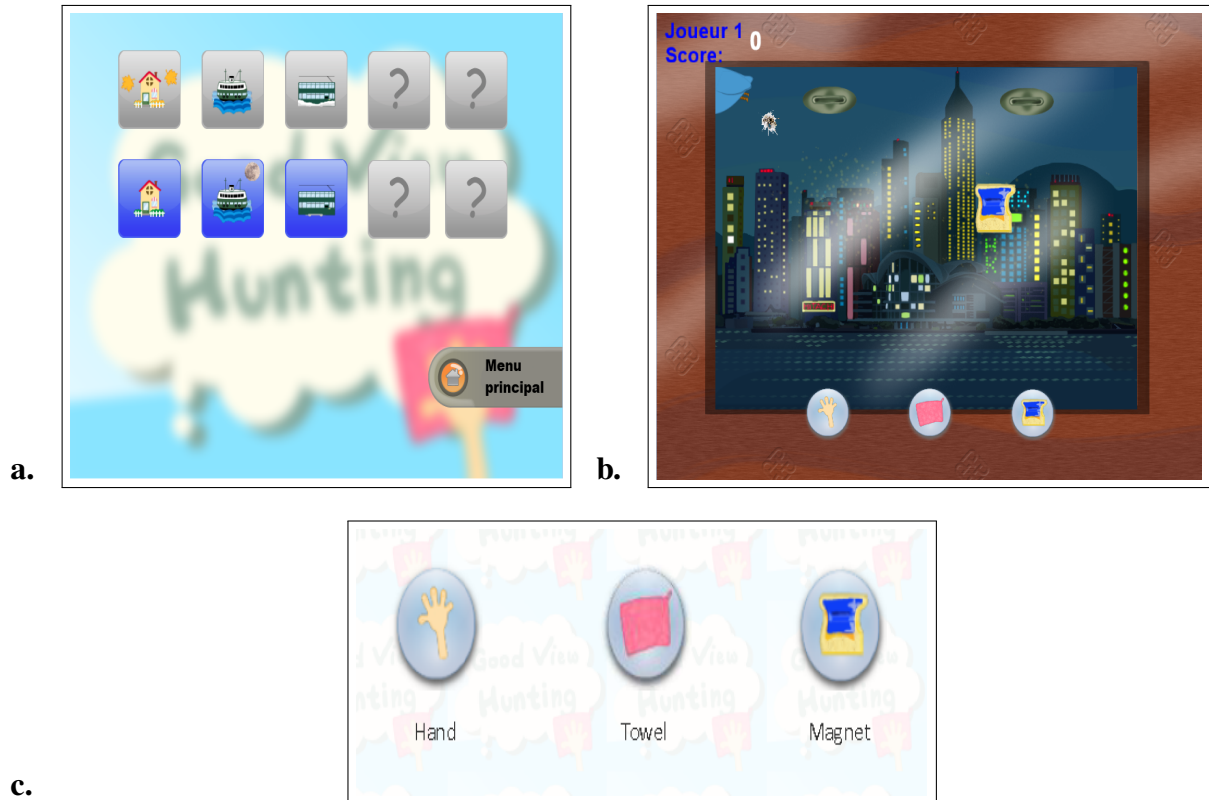


Figure 4.10 – a) Menu containing 6 scenes (3 contexts in 2 modes). b) The player cleans bird dirt in a Star Ferry context in mode Night. c) Cleaning tools: each tool is used to clean a specific dirty mark.

The game proposes 3 contexts including Home, Star Ferry and Tram (two transport modes very popular in Hong Kong) (Figure. 4.10a). Each context has two modes (Day and Night). The player has 3 cleaning tools (Hand, Towel and Magnet) (Figure. 4.10c) to clean different types of dirty marks. Each dirty type has a specific constraints to be cleaned. There are 3 types of dirt used in this experiment: bird dirt, water stains and kid drawing. To clean the bird dirt, the player has to use the magnet by wiping 3 times (Figure. 4.10b). With the water stains, the player can use the towel or the magnet to clean by wiping 3 times. As for kid drawing, the player has to wipe 4 times to clean, using the towel or the magnet.

For each selected scene, the player has to clean 3 dirty spots within their own time limit. The dirty spot must be cleaned up before the end of its time limit, otherwise it disappears. The player earns a score once having successfully cleaned up a dirty spot. The less time the player spends on cleaning the spot, the higher the score that the player can receive. When the player finishes a game, an evaluation report is displayed (Figure. 4.11), summarizing the success rate for each wiping action, the percentage of using the left and right hands and also the average response time. After the evaluation report, the final score is also displayed including the earned trophy.

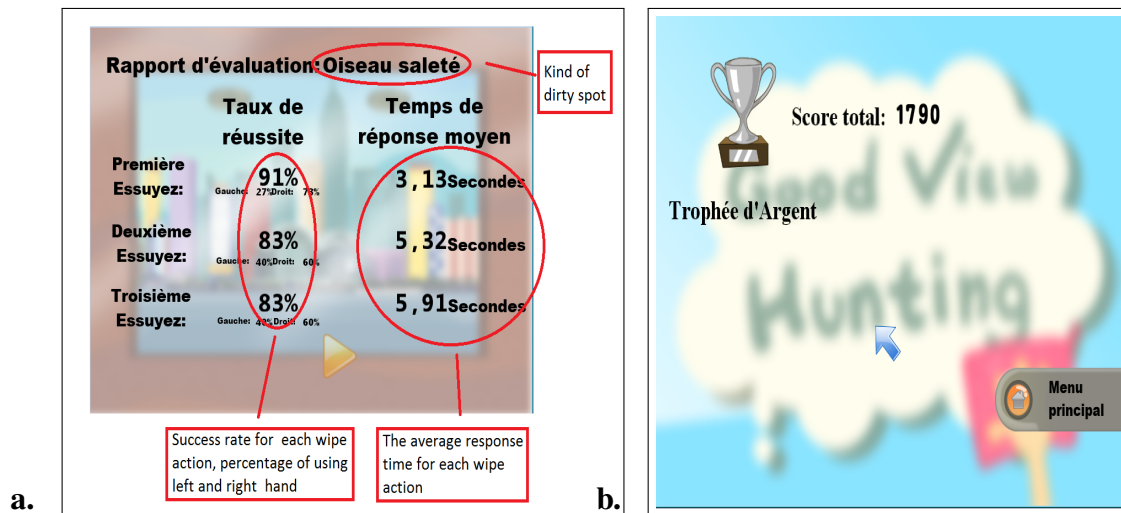


Figure 4.11 – a) Evaluation report on the success rate and the average response time of wiping actions. b) Final score .

#### 4.2.4 Implementation of the support system

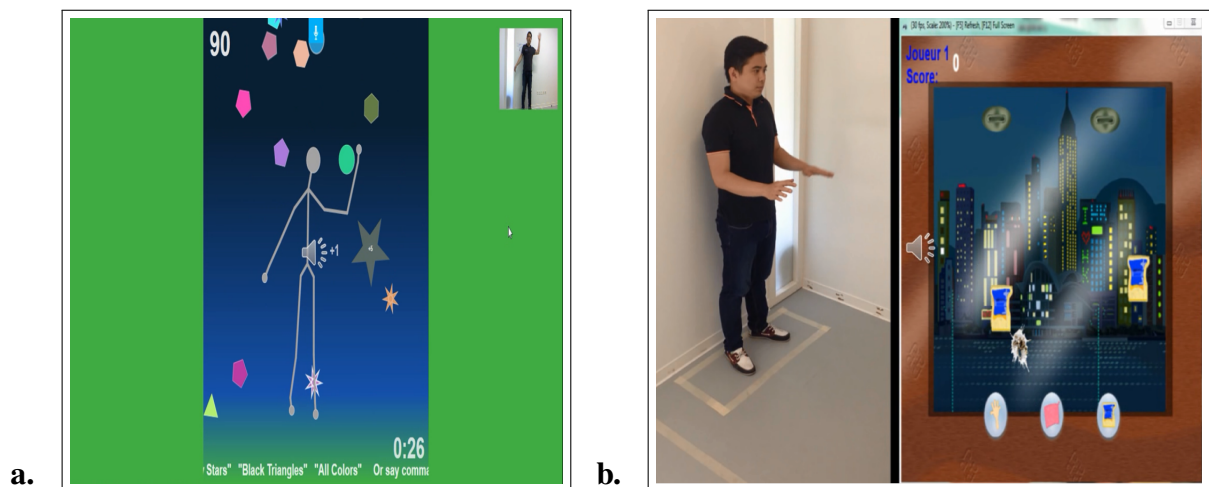


Figure 4.12 – Extraction of tutoring videos: a) Shape Game tutorial b) Good View Hunting tutorial.

The support system installed in the last pre-study is reused with some improvements. The system is still implemented in two kits of desktop computer and RGB-D sensor because the recognition component is not adapted yet on Windows OS. The young girl agent takes again the role of the direct interlocutor of the support system with the users. In order to make her more human-like, she has now a real human voice recorded by a female nurse. This choice is not really dynamic, on the grounds that if her speech contents need to be updated (modifications or additions), then new records have to be realized. But in our context, that

is acceptable and our choice is probably the good one. The participants in the experiment do not have enough time to familiarize with a "robot" voice. That is why using a real human voice can probably have more positive influence on their first impressions. In parallel, the speech contents are checked and validated by a psychiatrist to avoid some surprising words or expressions which can get the user engagement down in case of errors or poor results.

The second pre-study provides an interesting remark: few explaining sentences of "how-to-play" the Shape Game can not help older people to understand immediately that they have to stand in front of the Kinect sensor and move the arms to play. Indeed, this is the first time, for most of them, that they interact with the sensor and they have not the same capacity of adaptation to new technology as young people. They take a lot of time to understand and move the arms to play. To help older people to understand easily, two video tutorials are made and added before the games (Figure. 4.12). In each video tutorials, a person shows step by step how to browse the menu, select a scene and play the game, in support of the agent's voice.

The space to play is divided into two areas: *zone\_playing* and *zone\_stimulating* (Figure. 4.13). Therefore, a set of events allowing to track the user positions and movement relative to the screen are defined (Figure. 4.13):

- *Person\_Inside\_Zone\_Stimulant\_Long* (i.e the person is in the *zone\_stimulating* more than 4 seconds.)
- *Person\_Inside\_Zone\_Playing\_Long* (i.e the person is in the *zone\_playing* more than 3 seconds.)
- *Person\_Outside\_Long* (i.e the person is outside these two zones more than 3 seconds.)
- *Person\_Change\_From\_Zone\_Stimulant\_To\_Zone\_Play* (i.e the person moves from the *zone\_stimulant* to *zone\_play*.)
- *Person\_Change\_From\_Zone\_Play\_To\_Zone\_Stimulant* (i.e the person moves from *zone\_play* to *zone\_stimulant*.)
- *Person\_Change\_From\_Zone\_Stimulant\_To\_Outside* (i.e the person moves from *zone\_stimulant* to outside.)
- *Person\_Change\_From\_Zone\_Play\_To\_Outside* (i.e the person moves from *zone\_play* to outside.)

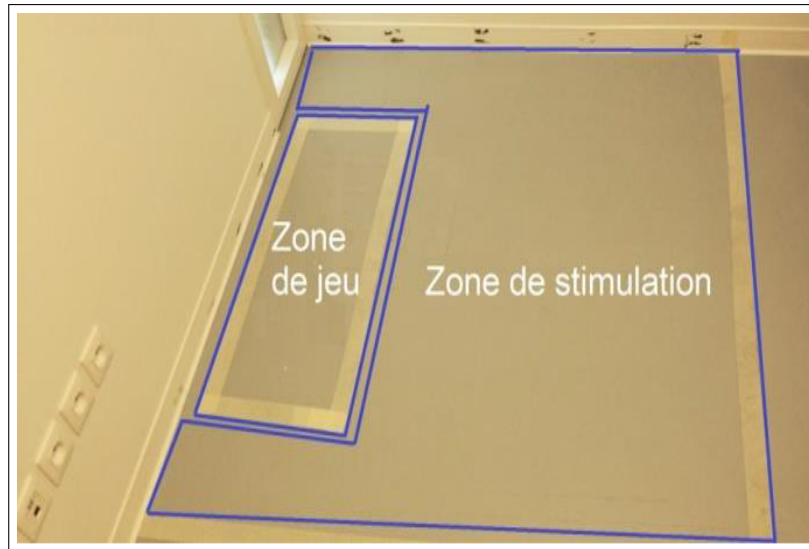


Figure 4.13 – The space to play is divided into two virtual zones.

```

CompositeEvent (Person_Inside_Zone_Play_Long,
  PhysicalObjects((p1: Person) (z1: Zone))
  Component((c1:PrimitiveState Person_Inside_Zone_Play(p1,z1)))
  Constraint((duration (c1) > 5))
  Alarm((Level: URGENT))
)
CompositeEvent (Person_Inside_Zone_Stimulant_Long,
  PhysicalObjects((p1: Person) (z1: Zone))
  Component((c1:PrimitiveState Person_Inside_Zone_Stimulant(p1,z1)))
  Constraint((duration (c1) > 5))
  Alarm((Level: URGENT))
)
CompositeEvent (Person_Outside_Long,
  PhysicalObjects((p1: Person) (z1: Zone) (z2: Zone))
  Component((c1:PrimitiveState Person_Outside(p1,z1,z2)))
  Constraint((duration (c1) > 3))
  Alarm((Level: URGENT))
)
CompositeState (Person_Change_From_Zone_Stimulant_To_Zone_Play,
  PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
  Component((c1:PrimitiveState Person_Inside_Zone_Stimulant(p1,z1))
    (c2:PrimitiveState Person_Inside_Zone_Play(p1,z2)))
  Constraint((c1 meet c2)
    (duration(c1) >0.5)
    (duration(c2) <3))
  Alarm((Level:URGENT))
)

```



```

CompositeState (Person_Change_From_Zone_Play_To_Zone_Stimulant,
  PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
  Component((c1:PrimitiveState Person_Inside_Zone_Play(p1,z1))
    (c2:PrimitiveState Person_Inside_Zone_Stimulant(p1,z2))))
  Constraint((c1 meet c2)
    (duration(c1) >0.5)
    (duration(c2) <3))
  Alarm((Level:URGENT))
)
CompositeState (Person_Change_From_Zone_Stimulant_To_Outside,
  PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
  Component((c1:PrimitiveState Person_Outside(p1,z1,z2))
    (c2:PrimitiveState Person_Inside_Zone_Stimulant(p1,z2))))
  Constraint((c1 meet c2)
    (duration(c1) >0.5)
    (duration(c2) <3))
  Alarm((Level:URGENT))
)
CompositeState (Person_Change_From_Zone_Play_To_Outside,
  PhysicalObjects((p1: Person)(z1:Zone)(z2:Zone))
  Component((c1:PrimitiveState Person_Outside(p1,z1,z2))
    (c2:PrimitiveState Person_Inside_Zone_Play(p1,z2))))
  Constraint((c1 meet c2)
    (duration(c1) >0.5)
    (duration(c2) <3))
  Alarm((Level:URGENT))
)

```

Figure 4.13 – Set of events to recognize of experiment 1 to track the user positions and movements relative to the screen.

## 4.2.5 Protocol and Interaction Scenarios

### Protocol

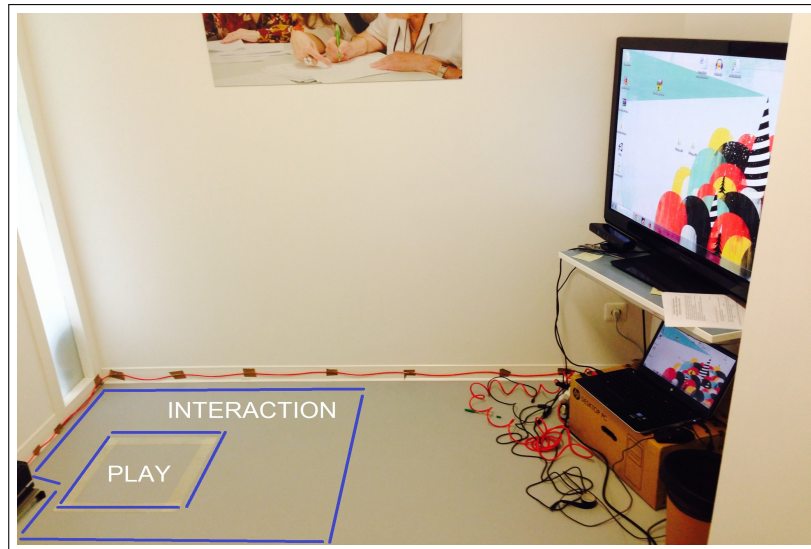


Figure 4.14 – The private room of experiment is equipped with a screen, the support system, the game and a playing space.

- The doctor recommends to the person that they participate in a therapeutic training with video games.
- If the person accepts, he / she is placed in a private room away from the public. The room is equipped with a screen, the support system and a playing space.
- The person plays the game with the presence of a therapist whose responsibility is to observe, assess, take care of the security of the person and not intervene during the game activities.
- The person is asked to approach near the screen and to follow the scenario of interaction thanks to the instructions displayed on the screen and the information provided by the agent.
- The person is free to stop playing the game at any moment.
- At the end of the training, the person is invited to fill in an evaluation form about the agent's properties.
- No personal information is stored.

### Interaction Scenario

- The user gets close to the screen and reads the information.
- When the user stays in place more than 5 seconds, the agent appears and starts to interact with the user.
- If the current position of the user is in the *zone\_stimulating*, the agent asks the user to step back into the *zone\_playing*. Otherwise, the agent asks the user to wait in few seconds.
- The user moves correctly in the indicated space. The agent appears, introduces herself and invites the user to play a game. If he / she accepts, he / she just needs to stay in place and wait patiently. A video tutorial is launched to explain the gameplay and

guiding how to play the game with the Kinect sensor. At the end of the video, the Shape Game started. The person is invited to gain up to 600 points before ending the game. The user is informed that he / she is free to stop playing at his / her convenience by simply leaving the space reserved to play.

- When the user ends the Shape Game or decides to stop playing, the agent re-appears and retains the user by suggesting another game.
  - If the user agrees, he / she turns back to the previous space. A video of the Good View Hunting Game is launched. At the end of the second game or another interruption, the agent say "thanks you", puts the Shape Game on standby mode and the user quits the space.
  - Otherwise, the user gets completely out of the space and the session is finished.

## 4.2.6 Collection of data

## 4.2.7 Results

Table 4.3 – Results of interaction

Successful Interactions	Pursuing with the second game
16/19	14/16

Table 4.4 – Results of subjective evaluation about the agent properties.

Question	Yes	No	Neutral
Is the agent's appearance cute?	14	2	0
Are the agent's animations fluid and natural?	12	3	1
Is the agent's voice clear and sharp?	16	0	0
Is the agent's speech understandable?	16	0	0

Among 19 older participants, 16 participants interacted successfully with the support system (Table. 4.3). Only 3 participants failed to move despite the instructions of the agent. The first participant had difficulties with walking and decided to immediately stop the test. The other had a significant cognitive impairment and could not correctly follow the instructions of the agent. Nonetheless, these results are very encouraging despite the users' lack of experience with video games. Among them, 14 participants agreed to play a second game after the suggestion of the agent. Their subjective evaluation (Table. 4.4) gives an positive appreciation on the agent properties. The agent has established a collaborative relationship and has accompanied the user throughout the interaction. These results have been communicated in a conference of Gerontechnology in 2014 [57].

## 4.2.8 Discussion

The results presented in Table 4.3 show the success of the support system in interacting with older people. The failure cases of 3 participants do not cause serious concerns about the functionality of the system, because their problems are independent from the proposed solution and due to the advanced stage of the disease. The support system provides to the older people new experiences in cognitive training with Serious Games. Indeed, the support system facilitates the initiation into the game for older people. They can start the game and learn to play thanks to the support of the agent and the video tutorial without using any device such as a mouse or a keyboard. At the same time, the new improvements brought many contributions. Passing the test and playing the game in a room allow the users to feel tranquil and preserve their privacy and concentration as much as possible. New video tutorials displayed before starting game help the user to better understand the game rules and to successfully play the game. The new interaction mode "*vocal - movement*" is natural and does not require the user to employ a lot of muscles. The voice, recorded by a real human, and the new animation of the avatar enhance the impression of the users towards the interaction with the support system. The newly added game evokes the curiosity of the users to try another session. This is quite easy to understand since they just finished the first game successfully and their joy and motivation still remain.

The usefulness of the support system makes it applicable in other contexts. For example, doctors can suggest the users that they play a serious game at home. The user would have to play one session of one hour per day to benefit from all positive effects of the game. With the additional information about the timetable (e.g, resting time, time of lunch and diner) or the habits of the users, new interaction strategies can be added in order to explore new appropriate moments to interact with the person, which are always based mainly on the user properties (position, movement, posture). In the case that the user forgets to play because of memory disorders or after a series of refused invitations, the support system can remind the users or send alert message to doctor. More interesting, the agent can establish many quick exchanges with the user during the day. The content of the exchanges can be about various usual topics such as weather, health or family. The objective of the exchanges is to improve the relationship between the user and the agent.

During the experiment, some remarks underline a new problem on the game performance of the user. Some users, while playing, tend to forget the control mode and the objective of the second game. They make consecutive errors and quickly stop playing. This embarrassing situation may induce the user performance to decrease and discourage the user to play the game afterwards. The cases of 3 users who failed to interact with the agent also need to be discussed. 2 users with advanced cognitive disorders could not follow correctly the instructions of the agent. What is the main reason of the failure? Are the way of speaking and the speech of the agent which are not adapted to this type of user? Can the situation be better if that is the therapist who presents instructions instead of the agent? Regarding the user who

had the difficulty of walking, he / she could accept to play the game if, instead of walking, he / she just needed to touch buttons to interact. It is really regrettable to exclude this type of user. They may be still able to play a game adapted to their disadvantages.

The results of the experiment show the success of the interactivity of the support system. However, one of the main questions of the thesis is not satisfied yet: are the users engaged in the game? Many factors can provide information about the issue such as the active time during the game or the performance of the user. Unfortunately, the game controller does not have access inside of the Good View Hunting game. The controller can only run and close the game and does not catch any information about the user's activities in game in real time.

These problems lead the research direction to the new challenge. Now, the system needs to be improved and capable of recognizing the situation where the user realizes a bad performance, identifying the cause of the situation, and providing appropriate solutions to the user (e.g. [58] ). This new functionality of the support system would reduce the impression of a complicated process to control, strengthen the engagement and stimulate the user to adopt the game in their habit life as a new therapeutic training tool. The more the user plays the game regularly without interruption and with a good performance, the more he/she benefits from the advantages of the game and understands the positive impacts of the game on his/her health. Furthermore, it is important to prove that this new functionality is really useful and can help older people with dementia compensate for the disadvantages caused by their cognitive disorders. In other words, can get a similar game performance to healthy older people thanks to the support system. Also, their game performance is better than the one of the older people playing the game without the support system.

In parallel, the participants further contributed to some improvements for the next experiment. 2 female participants desire to play the game in a musical ambiance in order to feel more comfortable. Indeed, other factors, apart from the ones proposed in the support system, could significantly influence the user engagement. Thus, a male player could prefer to play a "male" game, such as battle game or sports game, rather than other types of game. An agent with a doctor appearance can seem more trustworthy to the user, and thus more convincing to play the game.

## **Experiment 2: Can the support system improve the game performance of the older adults in Serious Game ?**

---

### **5.1 Context and Objective**

The previous experiment proved that on the one hand the support system is capable of determining appropriate moments to interact with the users. On the other hand, the users can interact successfully with the support system. In parallel, many problems are noticed to improve the support system which has, to remain, a principal objective that is maintaining the users engagement with the game. The improvement can base on one of the factors which can determine the users engagement: their performance in game. This factor can be related to other factors:

1. It is a complete participation of the user. When the user finished a game session, it is hardly conforming that the user was engaged completely in the game. But if the user abandoned before the end of the game, it can conclude at least that the user is not engaged playing any more.
2. The performance can be related also to the active time during game session. The active time is defined as the time that the user takes to react to a given task. The longer the user take time, the more there is a chance that the user is not encouraged any more. There are two possible cases in this situation. Either the user need more time to search a solution or the user is simply distracted by other things around. If the user reacts instantly on demanded tasks, it means the user is engaged and concentrated to the game.
3. Another factor which can link with the user engagement is the errors. Of course, if the user performs a lot of errors or a significant series of consecutive errors, either the user get serious problems (cognitive disorders or motor disabilities) or the user is distracted.

4. The last factor is the final score / result at the end of the game. Using of this factor to assess the user engagement with the game is quite confident despite of different cases in reality. A healthy user can realize a high score maybe because the difficulty level of game is still easy compared to cognitive capacity of the user and the user does not need to be really engaged to the game. But if a older user with cognitive disorders successes to finish the game with a good score, the user must be engaged with the game.

To maintain the engagement of the user, the support system must be capable of determining the situations in which the user performance can be lowed and providing an appropriate solution. Here, the new issue is discussed. Given that the support system is improved and can provide helps to the user to maintain the game performance, how to measure the usefulness of this new assistance of the support system ? In order to deal with the issue, the main objective of this experiment is proving that the users who benefit this assistance have a better performance than the others who do not.

A new context is applied to research this issue. In context reality, the older adults with dementia come to consult the doctors. They can be demanded to realize some cognitive exercises. In the most of cases, the doctor explains the rules of the game and plays with them in a short session. Then, they play new session by themselves. The support system is used in this context instead of the doctors. So, the users play mainly the game in two times: one time with the support system and another time by themselves. The results of these times could be compared to evaluate the interest of the support system. Normally, this evaluation must show expectantly that playing the game with the support system can get a better performance than playing the game alone.

## 5.2 Target Population

The experiment continues being tested with the same types of participants than the previous. The older participants in the experiment are recruited in Claude Pompidou Institute during their medical consultation. Inclusion criteria are their age and their Mini-Mental State Exam (MMSE). The participants who have the motor disabilities or the MMSE under 16 are excluded. 30 older adults, including 15 men and 15 women, gave their agreement to participate in the experiment. Compared with the previous target population, new groups of MCI and Alzheimer participants have moderately an MMS Score less than the previous ones.

Table 5.1 – Description of the target population in the experiment 2

Group	Average Age	Average MMS Score	Men	Women
Mnesic Complaints	76.6 ±4.2	28.8 ±0.7	4	6
Mild Cognitive Impairment (MCI)	77.9 ±4.7	23.3 ±2.7	4	6
Alzheimer	80.9 ±6.3	15.1 ±1.2	7	3

## 5.3 Game used with the support system

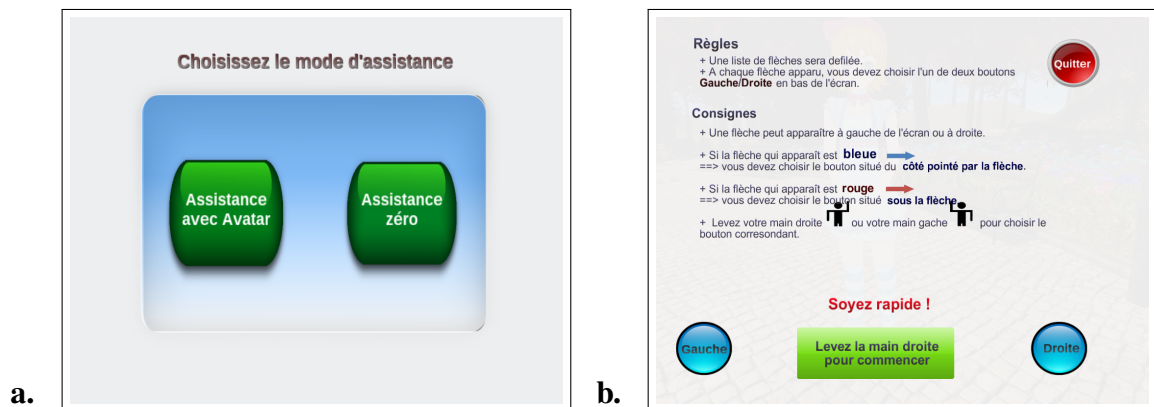


Figure 5.1 – a) Two versions of the game are used in the experiment 2. At left, the game is built with assistance of the support system. At right, the game is devoid of the support system. b) Notice page presenting the rules and the advices before playing.

The results of the previous experiment remarks an important trouble. The game controller does not have access inside of the game. Then, none of the situations related with the user performance can be computed by the support manager. Taking the objective into account, a game is built exceptionally to control all of access into the game parameters. The game is a simplified version of the original developed by CobTek team (ref missing). The original is inspired from a test of attentional focus including different parameters to train different cognitive functions. The user interacts in the original version by mouse click or by touches in case of touch pads. In the simplified version applied in the experiment, the interaction mode is changed. The users now interact with the game by gestures using the Kinect sensors. The interactions comprise of browsing menu and playing. Because of the time limit of the participants (they come to Institute to consult the doctor and most of them accept only about 30 minutes to play), the game using in the experiment is devoid of many parameters and difficulty levels.

The game disposes of two game modes: "*with assistance*" and "*without assistance*" (Figure. 5.1 a). In the "*with assistance*", the game is integrated with the support system. All of details is presented in the next section. In the "*without assistance*" mode, a notice page is displayed to inform the rules of the game. The rules are as follow:

- A set of 22 arrows is displayed randomly (on the left, on the right or in the midst) on the screen.
- For each arrow appearing, the user must give an answer "*Left of Right*" by raising left hand or Right hand.
- The choice of answer depends on the arrow colors. There are two colors: red and blue.
  - When the color is red, the answer is corresponding with the side where the arrow appears. For example in the Figure 5.2a, the red arrow appears in the right side



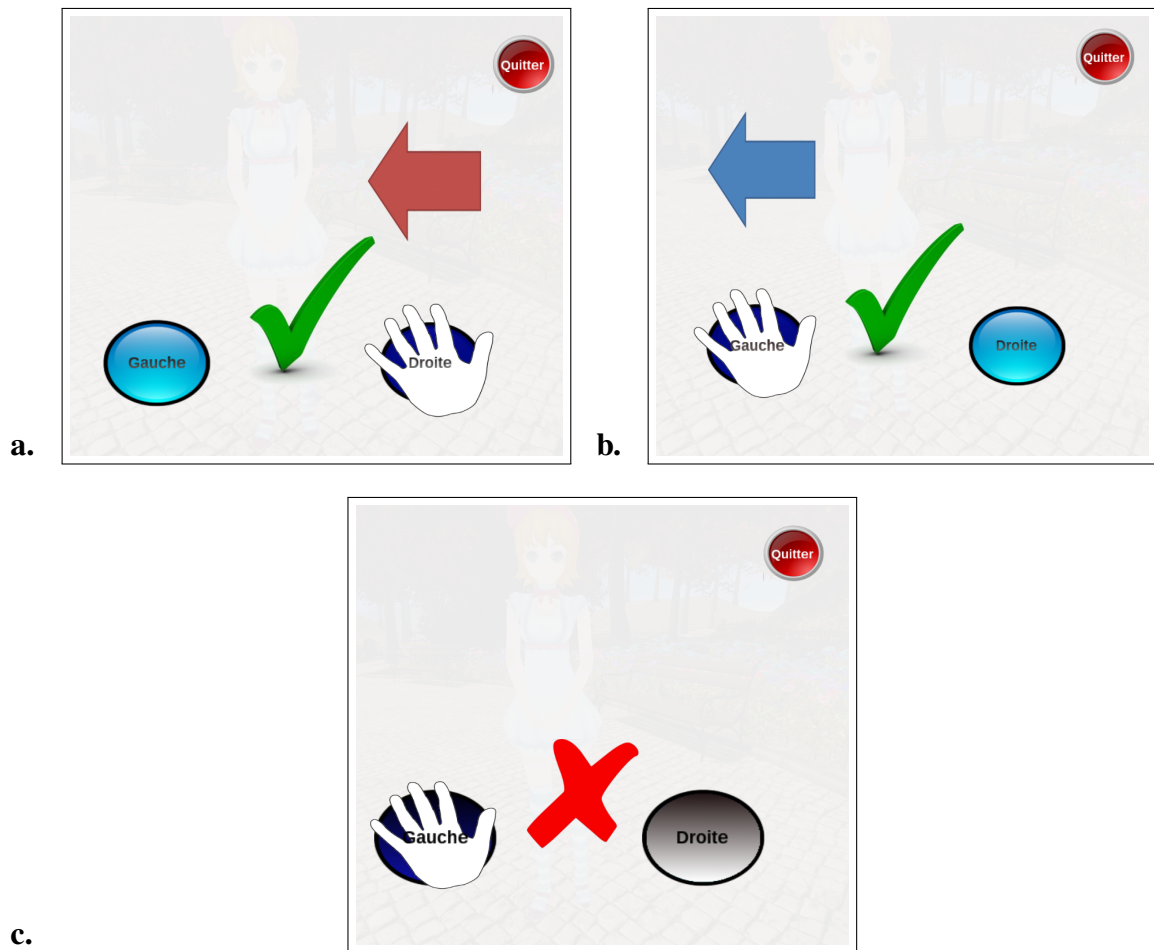


Figure 5.2 – Examples of the choice of answer: a) a correct answer with a red arrow b) a correct answer for a blue arrow c) symbol for a wrong answer.

then the correct answer is "*Right*" even that the arrows points to the left. The user raises the right hand to answer.

- When the color is blue, the answer is corresponding with the direction of the arrow. For example in the Figure 5.2b, the blue arrow points to the left then the correct answer is "*Left*" and the user must raise the left hand to answer.

- When the user gives a correct answer, a green symbol is displayed like in the Figure 5.2a,b. When it is a wrong answer, a red symbol is displayed like in the Figure 5.2c.

After giving 22 answers, the user can see the results detailing the number of the correct answers, the number of the wrong answers and accuracy rate being the ratio between the number of the correct answers on the total number of the answers (Figure 5.3).



Figure 5.3 – The results are presented at the end of the session including the number of the correct answers, the wrong answers and the success rate.

## 5.4 Implementation of the support system

In this experiment, the recognition of events is disable because of the main objective and the time constraint of the users participation. Indeed, the older adults come for the health consultation and precipitate to go home. They could refuse to participate if the session lasts a long time. Furthermore, the main objective concentrate on the user performance. So, the use of the recognition component in this experiment is not useful.



Figure 5.4 – The agent intervenes to recall the user attention

The novelty here is the integration of the support system with the game. Both applications are built by the Unity3D game engine. The game controller has now all access to values related with the user performance such as the active time, the errors and the scores computed during the game session. Thus, the support manager can determine the solutions to help the user thanks to these values. In parallel, the interaction component is merged with the

interface of the game, that allows to display easily the agent with the game interface in the *with assistance* mode. In this mode, the support manager observes permanently the users performance and sends interaction commands to the interaction component to provide helps to the users (Figure. 5.4). There are 3 types of helps proposed to the users:

- *Help for tutorial*: at the beginning of the mode, the user is guided to place correctly facing to the screen. Later, the agent asks to the user if he / she plays already the game. The user raises the left hand to answer "No" and right hand to answer "Yes". If yes, the agent displays the game menu. If not, the agent run the tutorial.
- *Help against inactivity*: For each task that the user must react (e.g. choosing menu, reading notice page, answering), a appropriate limit time is counted down. When the time is over and any reaction is not realized, the user is considered like "not active". Then the agent recalls the user attention and gives some expected guidelines according to the current game state.
- *Help against errors*: during the game, if the user makes 3 errors on the 4 last answers, the agent supposes that the user can forget the rules then recalls. The strategy of "3 errors on the 4 last answers" is chosen carefully here. The helps are provided to keep the user still staying in the game but should not depress progressively the user. For example, if the user is helped for each error, he / she can doubt his / her capacity. Therefore, it is important to let the user continuing to play and regaining the believe after the errors.

The tutorial is also improved in this experiment in order to render it more easier to understand. Unlike the last experiment that, the long video is split into many short videos. After each displayed short video, the user can practice the provided knowledge throughout a simple test, especially with the video on the arrow color (Figure 5.5). In parallel, the agent has new appearance. The agent still has girl body but changes the cloths style which is that of comics. Her moves are more natural than before. She can walk, speak with the moving lips, smile and blink. She is also placed in a autumn park to create a smooth ambiance.

## 5.5 Protocol and Interaction Scenarios

### Protocol

- The experiment takes place in a private room, equipped a screen, a game with Camera Kinect (Figure. 5.8) with the presence of a therapist.
- Each session lasts approximately 20 minutes.
- There are 3 phases of the game:
  - *Phase 1*: the user learns rapidly how to play the game with the therapist.
  - *Phase 2*: the user plays the game alone without any help.
  - *Phase 3*: the user plays the game with the support system.
- The order of phases for each user is as follows:
  - all the users begin with phase 1.

- Then, a randomization is made to determine between phase 2 and 3 in which one the user continues as described in Figure 5.7.

### Interaction Scenarios

- In the phase 3, the user is placed in front of the screen and the game is launched.
- The agent appears and asks the user if he / she plays already the game. The agent demands to the user raising the left hand to answer "No" or raising the right hand to answer "Yes".
  - The user raises the left hand. The agent confirms the choice and demands to the user waiting for the tutorial. Then, the agent launches the tutorial. During the tutorial, the user benefits also the helps against *inactivity and errors*. If the results of tutorial are not good, the agent suggests to the user trying again the tutorial.
  - The user raises the right hand. The agent launches the game at the game menu.
- During the phase 2 and 3, the therapist stays with the user to ensure the security but do not intervene to help.

## 5.6 Collection of data

According to the objective of the experiment which is evaluating the user performance to prove the effectiveness of the support system, two types of value are stored: the time to finish and the accuracy rate of the phase 2 and 3. In parallel, an evaluation form about the agent's properties is asked to the users to evaluate the appreciation of them towards the use of the agent.

Table 5.2 – Evaluation form about the agent's properties in the experiment 2.

- How do you evaluate the agent's voice?  
Fuzzy  Normal  Clear
- How do you evaluate the agent's speech?  
Unclear  Normal  Understanding
- How do you evaluate the agent's appearance?  
Ugly  Normal  Nice
- How do you evaluate the agent's animations?  
Dummy  Normal  Natural
- Do you want to try another interaction mode?  
Vocal  Move  Tangible Objects
- How do you evaluate the agent's helps?  
Not Enough  Enough  Frequent

## 5.7 Results

The Figure 5.9 presents the results of playing time of participants in phase 2 and 3. Each chart in the Figure displays a group. The blue line indicates the values in the phase 2 and the red line indicates the values in the phase 3. Visually, the blue line is, in most of time, above the red line. That means playing without helps of the agent takes more time playing with helps of the agent. Indeed, thanks to the assistance against inactivity the users can remember the rules of game, continue and finish the game. The conclusion seems really not convinced with the *Mnesic Complaints* group because the difference between the two lines is not actually important (only the fourth and the ninth user have a clear difference between two values), whereas among the *MCI* group, the difference is lighted a little more (only the seventh the ninth and the tenth have the similar values in both phases). Then, in the chart of *Alzheimer* group, the variation of the both lines is interesting. The case of the second and the tenth user, who abandoned the game, emphasize the interest of assistance against inactivity. Their motivation tumbles down quickly when they cannot remember the rules of game. Despite of the advanced cognitive disorders, the fourth, the sixth and the seventh show that the agent can help them finishing the game as fast as the second, the sixth, the eighth and the ninth user of the *MCI* group when the last ones play without helps. These differences are computed and showed in Table 5.3. The three columns from the right presents the difference of playing time between the phase 2 and 3, calculated in percentage by the formula  $\left(\frac{|PlayingTime_{phase3} - PlayingTime_{phase2}|}{PlayingTime_{phase3}}\right) * 100$ . The differences of playing time of the second and the ninth of the *Alzheimer* group are not computed because of their abandon in phase 2. The average result of each group confirms the influence of the support system on the users playing time. Among the *Mnesic Complaints* group, the users do not need the support system because they finish the game of phase 2 and 3 in similar time. Among the *MCI* group, some users benefit the helps of the system (the cases of the three first users in the group). Among the *Alzheimer* group, the support system can not help the fifth, the eighth and the ninth user to make a big difference.

Table 5.3 – Difference in percentage of playing time between the phase 2 and the phase 3

Groups Users	Mnesic Plaints	MCI	Alzheimer
1	3	10.8	12.8
2	0	12.8	#
3	6.9	15.6	11.5
4	12.1	5.5	35.7
5	0	7.7	5.2
6	3.5	7.6	32.1
7	3.4	2	27.5
8	3.4	8.3	4.8
9	10.9	5.12	0
10	0	0	#
Average	4.3	7	14.9

The accuracy rate of the users benefits also the helps of the support system (Figure. 5.11). Thanks to the helps against errors, the users can reduce the number of errors. Especially, the reduction in Alzheimer group is more important than in other groups.

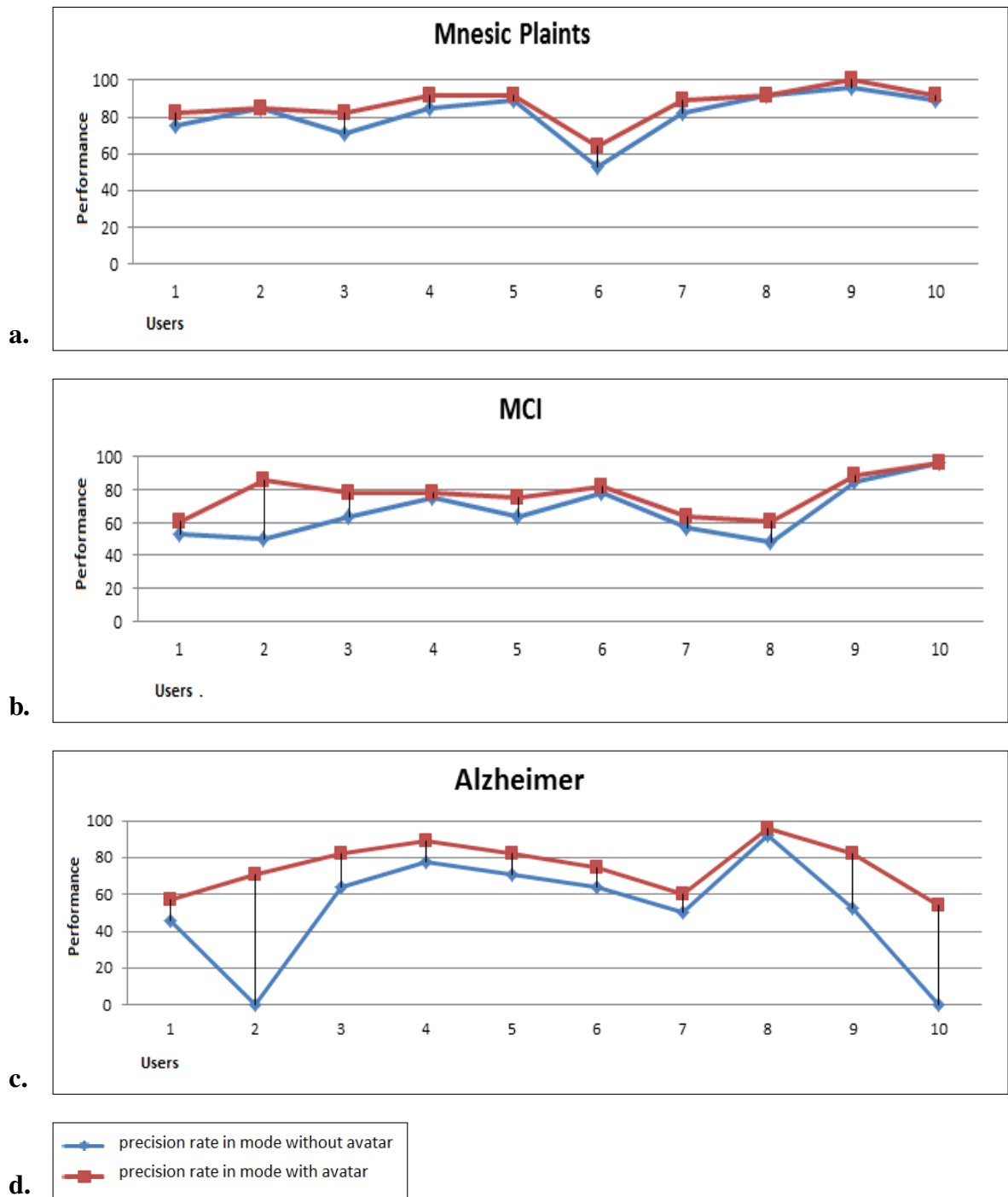


Figure 5.10 – Results of precision rate of 3 groups in two modes (with agent and without agent).

The results of subjective evaluation present a positive appreciation of the users toward the agent. All of the users agree that agent’s voice is clear and the communication is understandable. 27 users think that the appearance is pleasant and the other three find it normal. Moreover, agent’s animation is judged natural by 26 players, normal by 2 users and still dummy by the last two. Globally, the users appreciate positively the agent as well as its

Table 5.4 – Difference in percentage of accuracy rate between the phase 2 and the phase 3

Groups Users	Mnesic Complaints	MCI	Alzheimer
1	8.5	13.1	19.2
2	0	41.8	#
3	13.4	17.9	21.9
4	7.6	3.8	12.3
5	3.2	14.6	13.4
6	17.1	4.8	14.6
7	7.8	10.9	16.6
8	0	21.3	4.1
9	4	4.4	35.3
10	3.2	0	#
Average	0.65	7	17.2

interactions during the game. These results have been published in the Game and Learning Alliance Conference in 2015 [59].

## 5.8 Discussion

The results above confirmed the interest of using the support system for older adults with dementia in playing the video games. Playing the game with the helps of the support system is better than playing without any help. Indeed, 3 modes of help (tutorial, against inactivity and errors) allow the users to compensate their disadvantages, especially with the *Alzheimer* group users. The users finish the game faster with an accuracy rate higher. That means they play actively in the game and use effectively the rules and guidelines of the game. Therefore, these results can be also an argument to conclude that the engagement level of the users is maintained during their game activities. Moreover, the users appreciate positively the assistance of the agent as well as her properties.

However, there are some points to discuss. These results proved that playing with the assistance of the agent is better than playing without helps to older adults with dementia. But the results do not show if this gained performance is enough. Do this good performance is expected sufficiently according to the doctor? How is the efficiency of the support system comparing with a therapist? Does the support system can replace the therapist in the daily cognitive trainings ? In parallel, do the helps of the support system take care correctly the factors cited in Section 5.1? That is also the interesting points to discuss. The helps against *inactivity* and *errors* can cover the factors 2 and 4 in most of the cases. In reality, it is possible that the user plays carefully and want to take a certain time to think about the answer. So, if the user is recalled the attention in each time the user thinks, this help can become a disturbing element. Thus, the user can make a lot of errors just because of being distracted by other external events. So, the helps against *errors* are not conform to bring the user back to the



game. Regarding the factors 1 and 4, it seems that these factors can be also influenced by the user profile. Of course, the male user can always finish a sports game and can be not concentrated if the user must play a "female" game. Anyway, playing an appropriate game according to the user profile can also take care these factors like the support system.

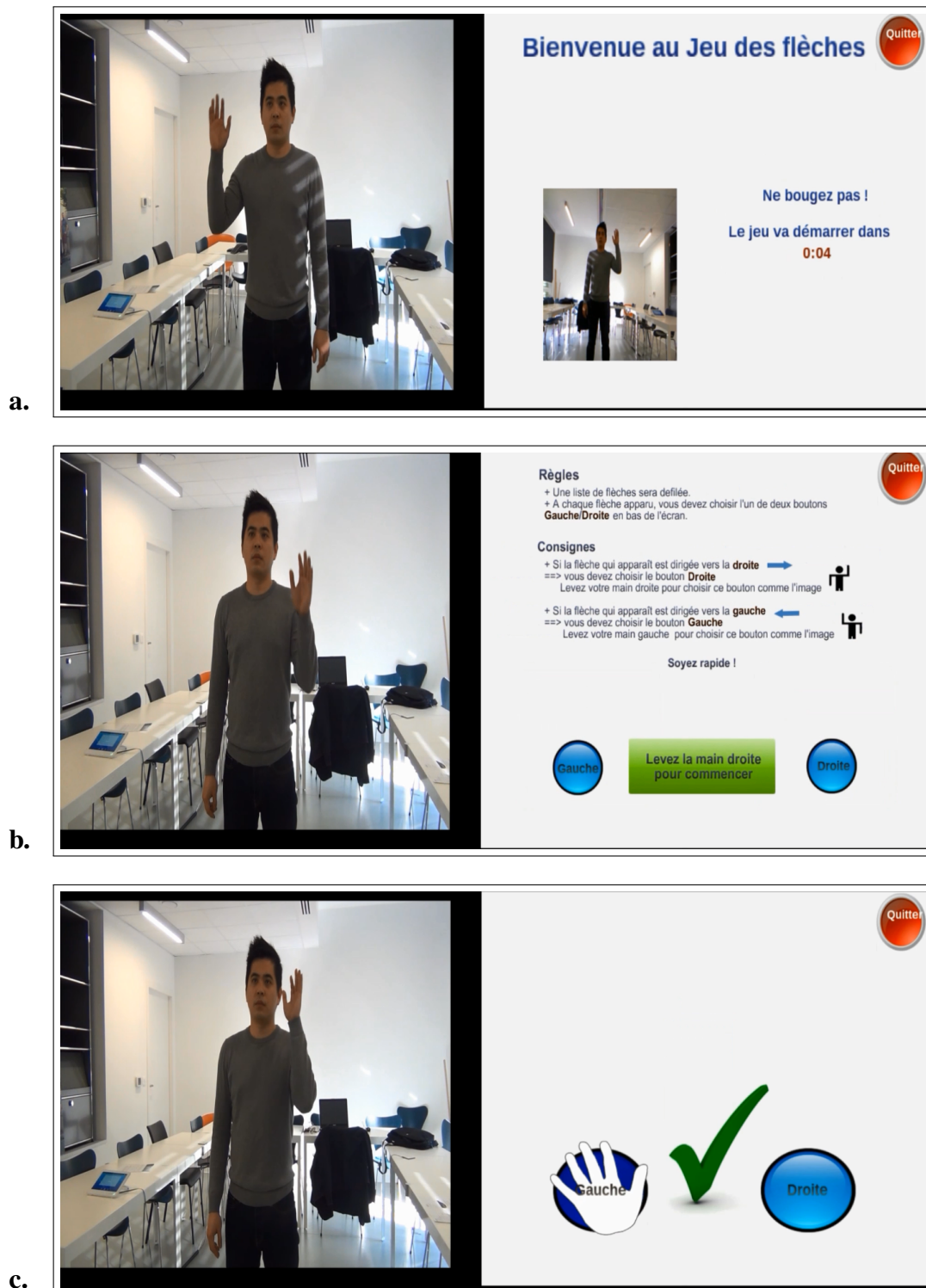


Figure 5.5 – Extraction of tutoring video: a) checking the user position facing to the sensor b) learning the rules and instructions of the current difficulty level c) practicing the rules



Figure 5.6 – The agent is improved with new cloths style and animations.

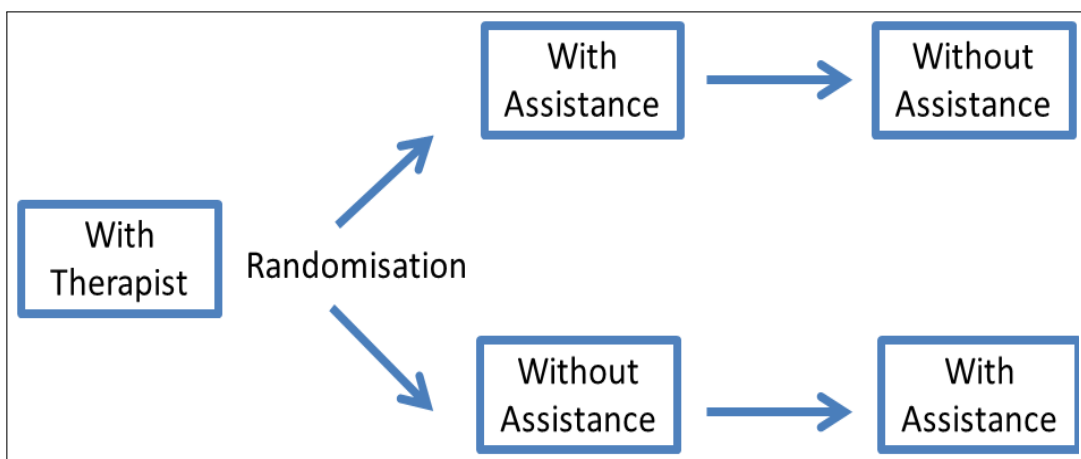


Figure 5.7 – Protocol of the experiment 2

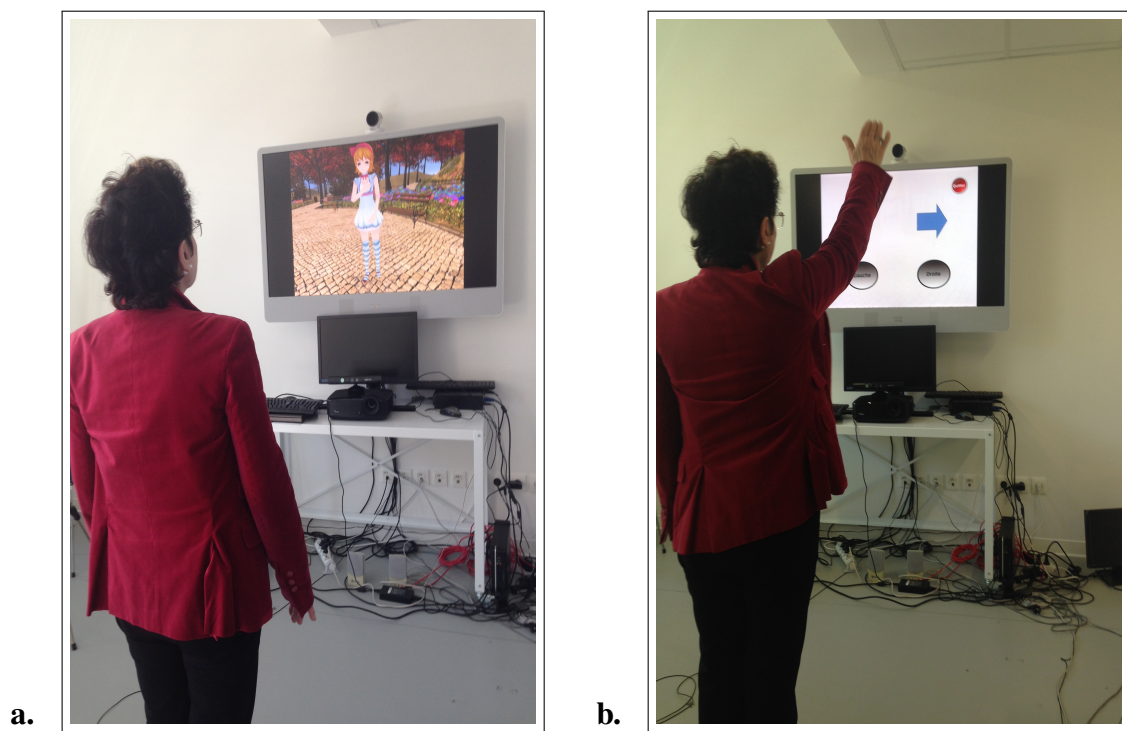


Figure 5.8 – a) The user interacts with the agent b) The user plays game

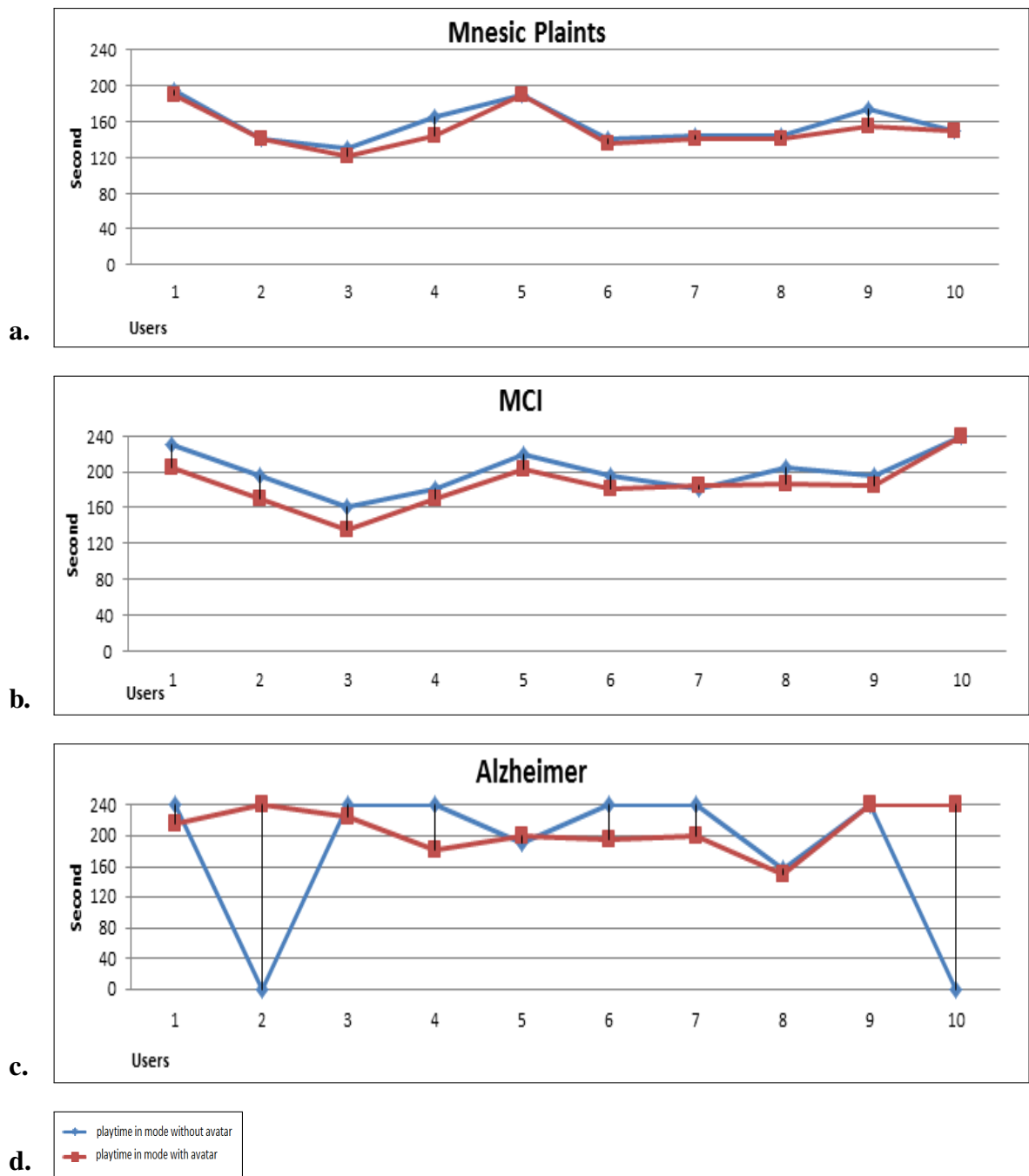


Figure 5.9 – Results of playtime of 3 groups in phase 2 and 3 (playing with agent and without agent).

Voice			
a)	Fuzzy	Normal	Clear
	0	0	30

Speech			
b)	Unclear	Normal	Understanding
	0	0	30

Appearance			
c)	Ugly	Normal	Nice
	0	3	27

Animations			
d)	Dummy	Normal	Natural
	2	2	26

New interaction mode			
e)	Vocal	Move	Tangible Objects
	12	0	0

Helps of the agent			
f)	Not Enough	Enough	Frequent
	0	3	27

Figure 5.11 – Results of subjective evaluation of the player on the agent’s properties.

# Experiment 3: Assessing the efficiency of the support system compared to the therapist

---

## 6.1 Context and Objective

The previous experiment proved that first, the users always finish the game while playing with the virtual agent accompaniment whereas two users in Alzheimer group abandoned the game while playing without the helps of the agent. Also, all users in Alzheimer group perform significantly much better while playing with the agent. In short, playing with the agent is better than playing without help. However, these results can not evaluate how much is the efficiency of the support system compared with a therapist. Therefore, the main objective of this experiment is trying to prove this incompleteness. Through the experiment, some hypotheses must be satisfied:

1. The users occur a better performance while playing the game with the agent helps than while playing the game alone, without any help.
  2. This performance can be similar than the one realized while playing with therapist helps.
  3. The occurred performance means:
    - the final score.
    - the accuracy rate (ratio between the final score and the errors)
    - the learning effect (the score and the accuracy rate after playing the game one time)
- Testing the support system with new game and new interaction mode.
  - Analyzing the users performance and their behaviour toward these changes.

## 6.2 Target Population

The conduct of recruitment of the participants in the experiment is similar than the previous one. The older adults with dementia are invited to participate in the experiment during their health consultation in Claude Pompidou Institut. 47 cognition-impaired older adults distributed in 2 groups (*MCI* and *Alzheimer*) are recruited during their consultation in Memory Center. (Table 6.1). The only inclusion criteria are their mini-mental state examination scores (MMSE). In this experiment, the number of Alzheimer participants is more than the one of MCI participants because the results of previous study have reported that normal control people do not need the agent's help and the performance of MCI participants is not significantly better than playing with the agent. Only Alzheimer participants have a better performance thanks to the agent's helps.

Table 6.1 – Description of the target population in the experiment 3

	Number	Average of Age	Average of MMS Score
MCI	17	76.5 $\pm$ 7.5	24 $\pm$ 1.7
Alzheimer	30	79.2 $\pm$ 8.5	17.7 $\pm$ 2

## 6.3 Game used with the support system

As the previous experiment, a new game is built to control total access inside of the game and to change the interaction mode. The game content is a numeric version of the *Digit Symbol Substitution* test [60] which is a common neuropsychological test sensitive to brain damage used by the doctors in the Memory center. The first version of the game is built based on the paper version of the test. But a second version with many changes is demanded by the doctors in order to avoid the learning effect of the game for the users who can have the same test with the doctor lately. Finally, the last version transforms the test become an exercise. In this numeric version, the game is built on a new device type that is totally different to the previous experiment: a big tactile table (Figure. 6.1). This new device allows the users to interact easier with the game by touching directly on the screen.





Figure 6.1 – The user plays the digit symbol substitution game on the touch table.

The game is built generally in two mode: *with the support system* and *without support system* (Figure. 6.2). The mode with the support system is described in the next Section. Before starting the game, the user is asked if he / she plays already the game. If not, the user is brought to a tutorial to learn how to play the game. If yes, the games is started (Figure. 6.3). Here is the rules:

- the game requires an exercise of matching the two same symbols.
- a set of 9 symbol is displayed in a table at the bottom of the screen.
- for each symbol appeared in the center of the screen, the user must match the same symbol by touching touch on the corresponding symbol in the table (Figure 6.4).
- the final score is the number of the symbols matched.

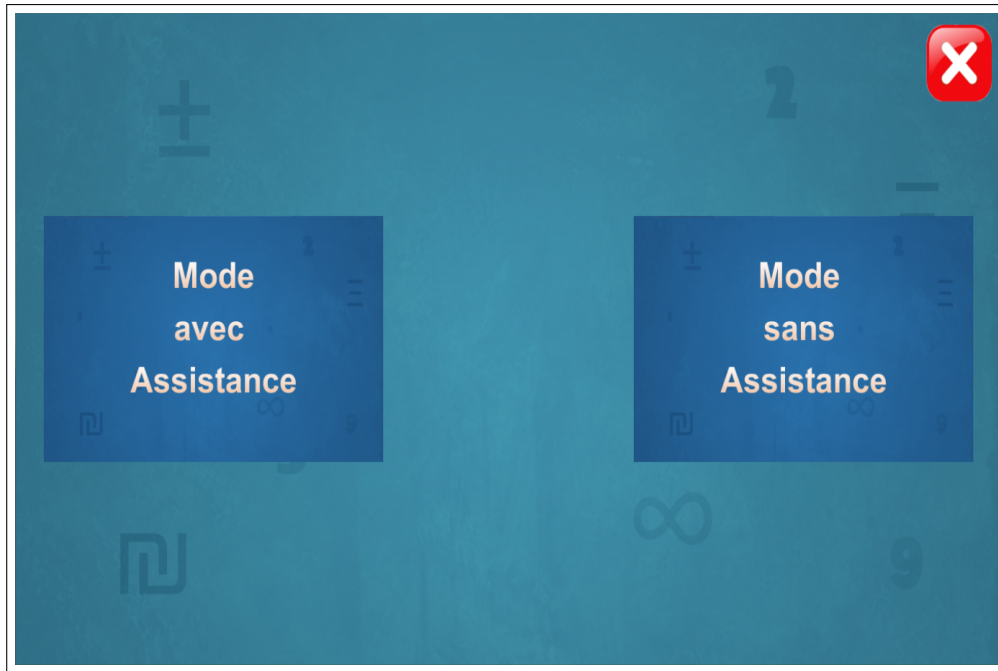


Figure 6.2 – The game is build in two mode: mode with the support system and mode without the support system.

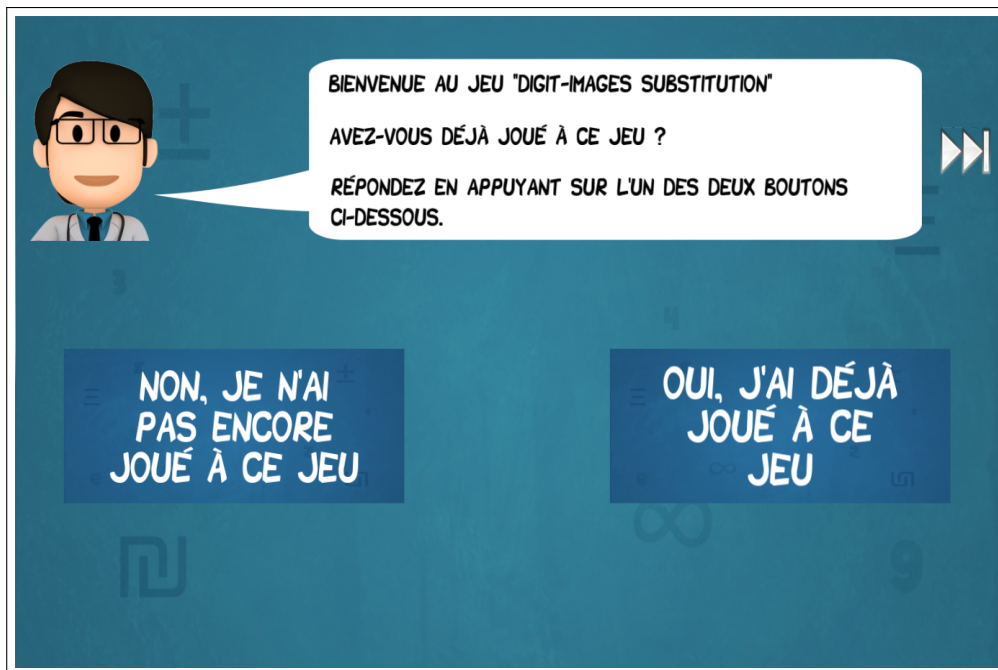


Figure 6.3 – Before playing, the user is asked if he / she plays already the game. If not, a tutorial is launched to help the user to learn the rules of the game.

In the tutorial, the users read the rules and test with a set of 5 symbols. When the user touches a symbol to match, a text is displayed above this one to indicate if the matching is correct or false (Figure. 6.5). At the end of the tutorial, the user has possibility of either retrying the tutorial or passing to the game (Figure. 6.6).



Figure 6.4 – Extract of the tutorial.



Figure 6.5 – a) Right matching b) Wrong matching



Figure 6.6 – At the end of the tutorial, the user has possibility of either retrying the tutorial or passing to the game.

In the game, the set of symbol to match contains now 10 symbols. A countdown timer of 120 seconds is also added. When the set is matched totally, a new one enchains. So, the objective of the game is to match the symbols as much as possible for 120 seconds (Figure. 6.7). At the end of the game, the number of the matched symbols and of the error are displayed. The user has possibility of retrying the game or getting away (Figure. 6.8).



Figure 6.7 – The main game interface with a countdown timer.

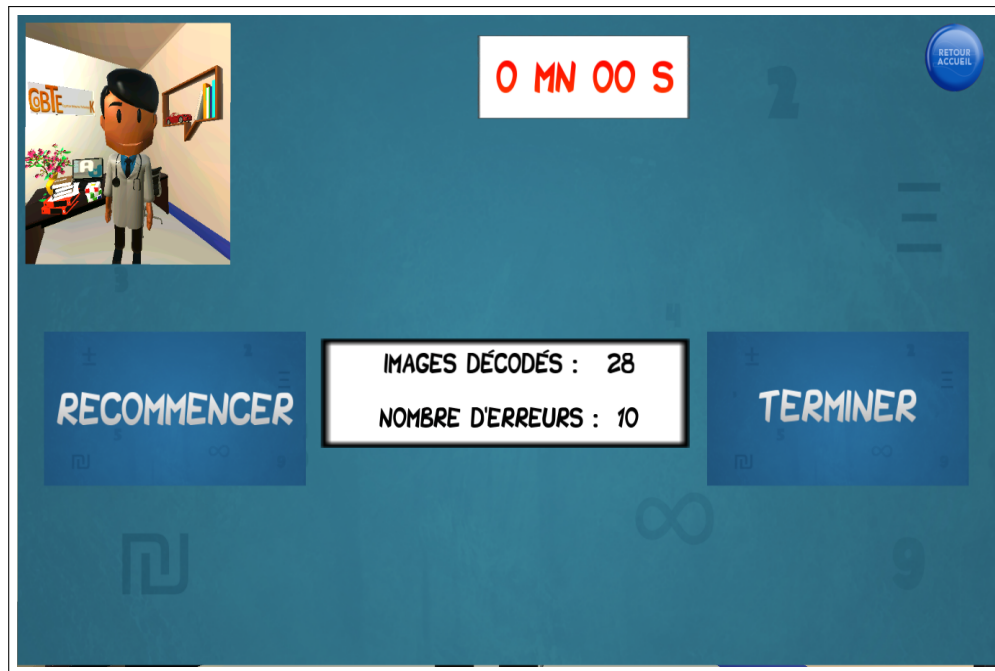


Figure 6.8 – At the end of the game, the number of the matched symbols and of the errors are displayed. The user has possibility of retrying the game or getting away.

## 6.4 Implementation of the support system

The implementation of the support system is quite similar as the one in the previous experiment. The recognition of events is still disable because of the main objective and the time constraint of the users participation. With the new controlled game, the game controller has now all access to values related with the user performance such as the active time, the errors and the scores computed during the game session. Thus, the support manager can determine the solutions to help the user thanks to these values. There are 3 types of helps proposed to the users:

- *Help for tutorial*: the user is invited to perform a tutorial to learn how to play.
- *Help against inactivity*: the users have 15 seconds to react to the current interaction; otherwise the agent intervenes first to recall his attention. If the inactivity still occurs, the agent supposes that the users can have other problems apart from the distraction. He displays on the screen four cases (Figure. 6.11) and the users touch on the cases corresponding with the situation.
- *Help against errors*: the users can make errors and the agent does not intervene for each error in order to avoid the pressure on them. However, only when participants make three consecutive errors, the situation become serious and the agent intervenes to recall their attention and remind the rules of game. Indeed, one correct answer after two consecutive wrong answers can keep engagement level of users. The

However, there are some novelties here. Unlike the last experiment that, since the touch is pretty intuitive for the users to interact with the game, the video for tutorial is not necessary.

The users are placed directly in the tutorial. The helps against *inactivity* and *errors* are also applied for the tutorial. In this game, the agent is omnipresent to provide to the users a sentiment of accompany. In parallel, the agent has new appearance. The agent appearance become a doctor who is placed in his office. These choices of appearance and 3D environment is made to simulate the similar real context in which the users go to the Memory Center to consult the heath with the doctor.



Figure 6.9 – New virtual agent with an appearance of doctor is placed in a doctor office.



Figure 6.10 – The agent guides the user for the tutorial: a) the agent asks if the user plays already the game b) the agent explains the rules and helps the user to match the symbols c) the agent asks if the user want to retry the tutorial of to pass to the game.

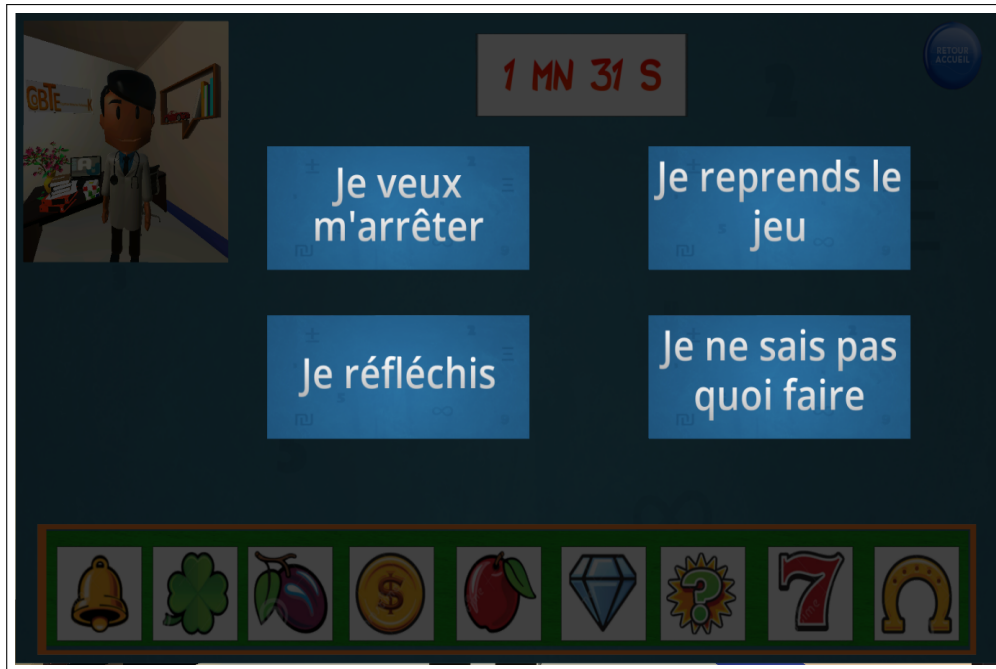


Figure 6.11 – The agent asks to the user more information when the inactivity is recognized more than 2 times.

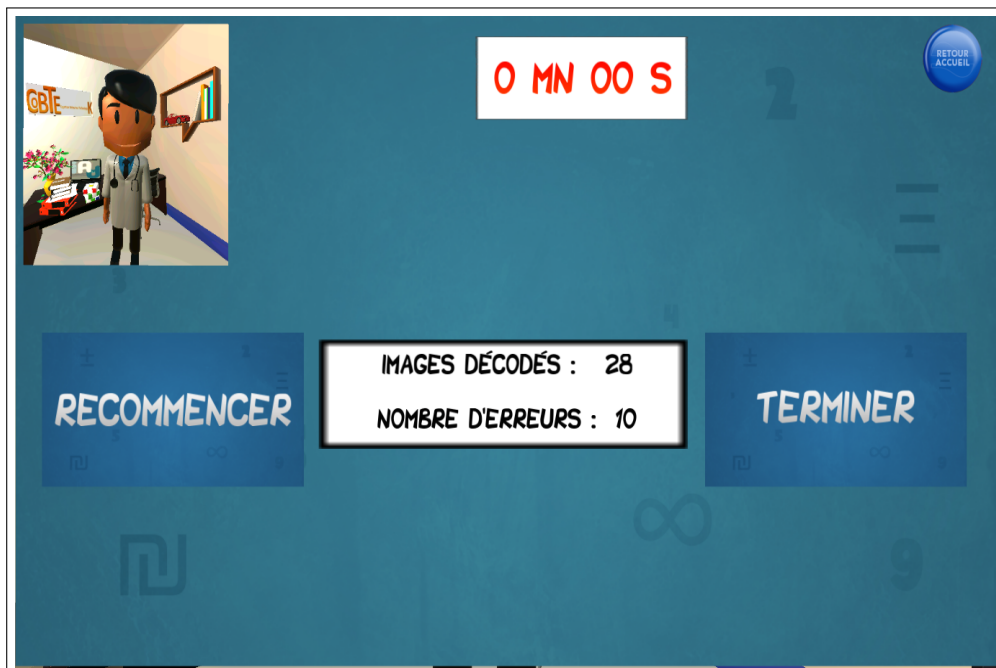


Figure 6.12 – The agent explains to the user the mean of the displayed results.

## 6.5 Protocol and Interaction Scenarios

### Protocol

- The users are placed in a private room facing to the touch table.
- The therapist explains first to the users how to use interaction mode of the table. Next, he introduces the protocol. None of the users plays already the game.



- There are 3 modes of game:
  1. *Mode 1*: the user plays the game in mode *without support system* with the therapist (Figure. 6.14).
  2. *Mode 2*: the user plays the game in mode *with support system* alone.
  3. *Mode 3*: the user plays the game in mode *without support system* alone.
- Each user must play two of three phases. The order of phases is as follows:
  1. a first randomization on the three phases to choose the first phase.
  2. a second randomization excluding the first chosen phase for the second phase (Figure. 6.13).
- Except the phase 1, the users play the game by staying alone in the room in order to avoid the distraction. For some special cases, when the user does not want to stay alone, the therapist stays but do not give any intervention with the user until he / she finishes the phase.
- At the end of each phase, the results were stored to assess cited hypotheses above.
- After two phases, the participants have been instructed to answer a questionnaire on their satisfaction on the game and the agent assistance.

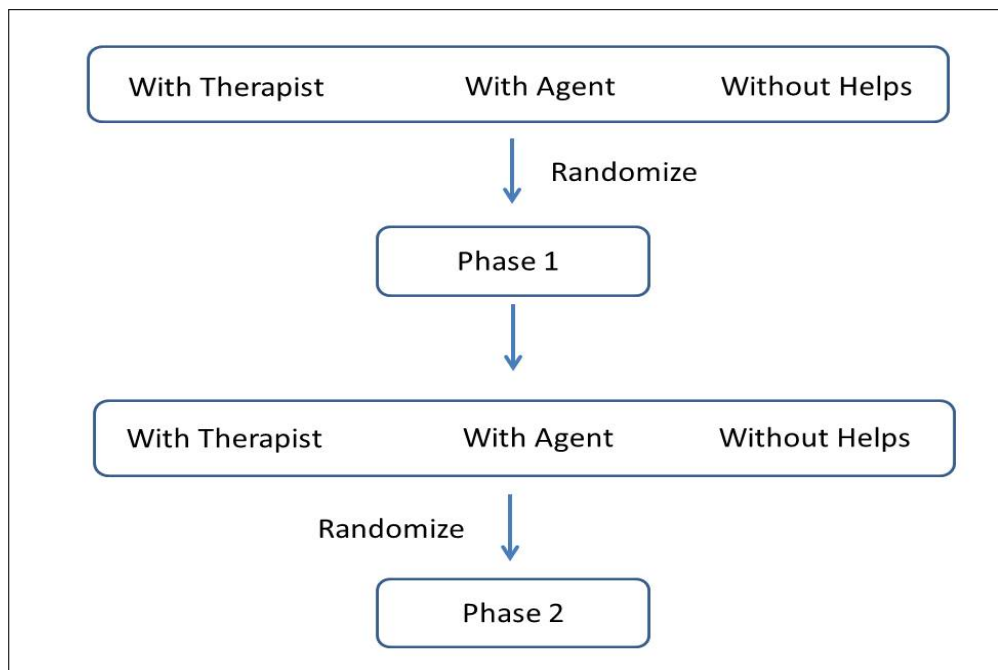


Figure 6.13 – Protocol of the experiment 3



Figure 6.14 – The therapist uses the game mode without the support system for playing with the user.

## 6.6 Collection of data

According to the objective of the experiment which is to evaluate the user performance to prove the effectiveness of the support system, two types of value are stored: the number of matched symbols and the accuracy rate. In parallel, an evaluation form about the agent properties is asked to the users to evaluating the appreciation of them towards the use of the agent.

Table 6.2 – Evaluation form about the agent properties in the experiment 3.

- a) How do you evaluate the agent voice?  
Fuzzy  Normal  Clear
- b) How do you evaluate the agent speech?  
Unclear  Normal  Understanding
- c) How do you evaluate the agent appearance?  
Ugly  Normal  Nice
- d) How do you evaluate the agent animations?  
Dummy  Normal  Natural
- e) Do you want to try another interaction mode?  
Vocal  Move  Tangible Objects
- f) How do you evaluate the agent helps?  
Not Enough  Enough  Frequent

## 6.7 Results

To validate the hypothesis 1, the scores (e.g. the number of matched images) of the user in the first phase (Table 6.3). The choice is objective because 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 the agent or therapist do not make great impact on the performance of the users in MCI group. In the other hand, the users in Alzheimer group can benefit totally the helps of the agent and the therapist. Moreover, the users playing with agent achieve only 4 matched images in two minutes, by means, less than the users playing with therapist.

Table 6.3 – Average score of MCI and Alzheimer group in three phases

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

Table 6.4 – Average accuracy of MCI and Alzheimer group in three phases

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

The accuracy of the uses is assessed to validate the hypothesis 2. The accuracy was computed as the ratio of correct answers and the number of answers in total included wrong answers. Again, the same results are occurred (see Table 6.4). The users in MCI group make some errors during the first phase and they play with equivalent ratios of errors in three phases. It can be explained by the tolerance of the strategy of helps against errors. The agent and therapist do not intervene on each error and the users continue making correct answers after few errors. Regarding the users in Alzheimer group, the different of accuracy between “playing without helps” with two others phases is significant. In fact, adaptivity of Alzheimer users with the game for the first time while playing without any help is not easily accomplished. Once again, the agent performs a similar efficiency compared with the results with therapist. To validate the last hypothesis, the performances in second phase of all user who either play “with therapist” or play “with agent” in first phase are assessed. The results are encouraged (Table 6.5 and 6.5). Most of users in “playing with agent” phase acquire learning effects close enough than other users in “playing with therapist” phase despite a slight difference in accuracy of Alzheimer group.

Table 6.5 – Average score of MCI and Alzheimer group in second phase with “*Without help*”

Without Helps	With agent	With therapist
MCI	64.40	64.47
Alzheimer	36.36	35.7

Table 6.6 – Average accuracy of MCI and Alzheimer group in second passage with “*Without help*”

Without Helps	With agent	With therapist
MCI	90.1%	83%
Alzheimer	87.69%	74.52%

To acknowledge more information about user’s perception, the questionnaires asked at the end of two passages are analyzed. The content has been divided in two parts: about the game and about the agent. Here are the results resumed from the questionnaires: 92 % users have never played a video game before. Only 4 users have already used Ipad touch-screen with their little children. 96% users 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 users don’t like to play game in their daily activities so they found the game “normal”.

Most of users assess the agent “friendly” and appreciate the agent properties (voice, speech, animation and appearance) 96% of users think that the agent can temporarily play with them instead of therapist. The results have been presented in Workshop Artificial Compagnon-Affect-Interaction in 2016 [61].

## 6.8 Conclusion and Discussion

The results reported that participants can product similar performances (score, accuracy, learning effects) while playing with the agent than while playing with the therapist. Further, subjective results reported that agent characteristics were greatly appreciated and the agent can temporarily accompany the users 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 to explore more strategies for enhancing user engagement with Serious Game in long-term.

# Conclusion and Discussion

---

## 7.1 Contributions and Limits

### 7.1.1 Approach

The thesis takes an interest in the engagement of the older adults with dementia in using Serious Game. Most of the times, they cannot play independently the games designed especially for their cognitive disorders, which propose the cognitive and physical trainings using various new sensors. They always need to play with the presence of a person (e.g., therapist, nurse) together. The reasons come from the lack of gaming experiences and the memory and cognitive disorders caused by the Alzheimer's disease. Indeed, the older adults do not have the basic knowledge of the gaming and take a lot of time to understand the meaning of various game elements (e.g. menu, button, character, game interactions,...). Moreover, memory disorders can make them forget the game control or the rules of game. Cognitive impairments can provoke distraction or low understanding of the current situation. Therefore, they cannot have the good results. Being frustrated by these difficulties and the bad results, they can stop playing quickly the games and refuse to replay that again. In other words, the older adults discourage quickly while facing to many problem and doing not have the appropriate helps at time. They will be not encouraged to play again the games. This is a critical situation for the game designers because the games are not usable any more.

To avoid this undesirable situation, an approach is proposed with the objective of bringing older adults with dementia in the best conditions to play video game. The main idea of the proposed approach is to provide at the right time the appropriate helps corresponding to the problems they are facing. The current undesirable situation can be computed thanks to the information outside or inside the game of the older adults. The appropriate helps can be deducted from an interaction strategy related to the computed situation. Once all of the problems are treated, the users can finish the games without interruptions, even realize a good performance. Now, they feel the game playable and they are engaged to continue playing the games.

A support system is built to apply the proposed approach. The support system consists of 4 components: the Activity Recognition, the Game Controller, the Interaction and the Support Manager.

1. **The Activity Recognition:** the component is used to understand what the users are doing around the games. The component contains an event recognition framework developed by the Stars team. The framework uses, first, different algorithms to detect and track people in the scene. Then, these results concerning the users properties such as the positions and the postures are served as input to compute the event using a constraint-based event ontology. The use of this component allows the support system to determine the interactions related with the users activities outside the games. For example: the support system can guide the users in the correct positions for playing. This help is particularly useful for the games using RGB-D sensors such as the Kinect sensor. Many errors are caused by a bad position of the players on the scene. The support system can also use the recognized activities of the user to stimulate and keep them in the games. There are two related situations in which the users need the support system. A Serious Game is installed at their home and they have to play a game session at least 20 minutes per day, according to the advices of the doctor. Because of the consequences of the Alzheimer's disease, they can forget the session or be often in bad mood for playing. In these two cases, the support system can track their positions during the day, thanks to the Activity Recognition component emerged in a multi-sensors system, then stimulate them to play the games just after the lunch which is the moment that the users are usually free and in good mood. In another situation, the users can be interrupted while playing the games because of external events such as a call, a visit of someone or the time of cooking. The support system can pause the games and invite them to resume the games after the events or in other appropriate moment in the day.

Besides the contributions of the component within the support system, the component has also some disadvantages while being used in the thesis. First, the event recognition framework run only on the Fedora OS but most of the Serious Game are designed for older users on the Windows OS. Therefore, a second computer is needed to host the framework in parallel with the first one which hosts the games. That can complicate the implementation of the support system at the living home of the users and the interchange between the component with the Support Manager component. Second, the framework cannot recognize yet the activities related with other properties such as the face or the gaze. So, the support system cannot taking into account some specific situations. For example: the user position is recognized in front of the screen but the users turn their back on screen. In another situation, they are facing to the screen but do not look at the screen.

2. **The Game Controller:** the component is used to collect the game states and the game performance of the users. The component receives too the commands from the Support

Manager to adapt new behaviours to the game. In the thesis, the component considers 4 game states (*starting, pausing, resuming and ending*) and two values related with the game performance of the users (the reaction time of a task (which allows to determine the inactivity) and the errors).

3. **The Interaction:** the component is used to communicate directly with the users using a 3D-animated avatar. Besides the animations designed for being-like-human, the avatar is equipped also other specific animations and sounds adapted with the appropriate interactions. During 3 experiments of the thesis, the use of an animated avatar is appreciated well by the users. Most of them enjoy with the avatar appearance. However, only 3 avatar appearances are used to communicate with the users. The users do not have right to choose the avatar they want. Some male users in the second experiment prefer interact with a male avatar than a female avatar. In parallel, the speech content of the avatar is recorded with a real human voice before and not generalized by a vocal synthesizer, which render the speech content more emotional but less dynamic.
4. **The Support Manager:** is the main brain of the support system, which decides how the support system takes care the current situation. The functioning of the component occurs throughout 3 tasks: "Current Situation Estimation", "Interaction Strategy Selection" and "Interaction Commands".
  - "Current Situation Estimation": the task consists of estimating the current situation by computing the data provided by the two previous components. 21 situations are defined and categorized in 4 groups (the situations related to the game states, the situations related to the game performance of the users, the situations related to the position of the users towards the screen and the situations related to the game modes).
  - "Interaction Strategy Selection": once the current situation is estimated, the support manager can determine the appropriate interactions by selecting an interaction strategy which is a rule defining a set of interactions allowing to transfer a situation to another situation. 10 direct interactions with the users and 3 others interactions are defined, which are combined with the defined situations above to define a set of 11 strategies.
  - "Interaction Commands": the last task consist of sending the commands containing the appropriate interactions to the Game Controller and the Interaction in order that these components realize these interactions with the users or the games.

In the context of playing the game in the hospital or in the nursing home, these sets of interaction, situation and strategy can cover the problems which disturb the user engagement. On the one hand, the suggestion and the encouragement of the doctor can enhance significantly the user engagement. The users accept easily to interact with the support system. They are engaged and concentrated quickly to play the games because they believe that is advantageous for their memory and cognitive state. On the other hand, they are often placed in a private place while playing the game. So, there are

not so much the situations which can interrupt the game session, except the problems related with their memory and cognitive impairments. However, if the users desire to play the game at home, these sets of interaction and strategy need to be enriched to cover more situations. For example, the Support Manager needs the definition of the new situations, especially the ones in which the users can be free to play or in which the users can interrupt the game session and forget to resume the session later. Here are some possible new definitions:

- *While the game is suspended because of a call phone*: the users interrupt the game to pick up the telephone / make a phone call. The situation can be recognized while the users leave the playing zone and stay in a long time in the zone for the call.
- *While the game is suspended because of the lunch time*: the situation can be recognized while the users leave the playing zone and stay in a long time in the kitchen room. A time value provided by a schedule of the daily activities of the users can be added to give more the precision to the recognition of the situation.
- *While the game is suspended because of a visit*: the situation can be recognized while the users leave the playing zone and go to the entrance door and a second person is detected.
- *While sitting on the couch after lunch*: the situation can be recognized while the users are detected sitting on the couch after lunch.

In parallel, the Support Manager needs also the definition of new interaction strategies in order to provide more support to the users. For example, the interaction "*Adapting the difficulty level*" can be added in the set of interactions to adjust the difficulty level of the games based on the last game performance of the user. In this case, the Support Manager can send a command to the Game Controller to alleviate the difficulty level of the session. This dynamic setting can make the users always feel the game "playable".

## 7.1.2 Experiments

3 experiments are realized to validate the functionality of the support system. The results confirm favorably the usefulness of the support system in maintaining the engagement of the older adults with dementia in Serious Game.

- for the first time of interacting with the support system, most of the participants do not have the difficulty to understand and follow the interactions provided by the support system.
- thanks to the appropriate helps of the support system, the participants can finish the game and perform the good results of the game.
- the usefulness of the support system is quietly similar than the one of a therapist.

In parallel, many limits are remarked during these experiments.

- The results of these experiments reply on the initial experiences of the users while



playing the games for the first time. However, these results need to be proved also in long period. Would the system still be useful when the users have already gained the experiences with the games?

- it seems that the success of the interactions between the participants and the users and the maintain of their engagement depend not only on the support system but also on the general context and the environment. The fact that playing the games within the memory center makes their point of view toward the games becoming less severe. In parallel, the suggestions of the doctor offer more of the credibility for the support system and the games. Thus, playing the games in a private room allows to the users getting their tranquility and preserves in maximum their privacy and concentration. So, the context is already optimized in order that the participants can face to less problems. In parallel, the general context and the environment limit the choice of game to use for the experiments. In fact, there are many attractive video games which make the users play in public place.
- the number of the participants in each experiment is not yet sufficiently large to conclude the results of these experiments on a large scale. Moreover, other the participant profiles, apart from the MMS Score, are not taken into account in the assessment of the results. Of course, the level of study, the profession or the sex could be great factors influencing on the engagement. For example, a participant with high university degree can have a capacity of analyzing and understanding the problems better and faster than the participant with a primary or middle school level. The participant who worked in the computer science or related field can control quickly the game devices. A female participant can be motivated to play the game related with the cooking and a male participant can realize a good performance in sport game. Therefore, it is necessary to propose to the users a selection of the game matching with different profiles of users.
- the type of game used in the experiments is also a considered limit. Two games designed in the experiments 2 and 3 are quietly simple and not attractive in terms of gaming, that proposes only the short memory and cognitive trainings. These games do not have been integrated any story or scenario. So, the support system must be tested with the games more complex in terms of the gaming and the interaction mode. For example, it could be a game which is a combination of an exergame and a memory game. The users have to enchain various physical actions in memorising the game rules and follow a game story.
- these 2 games used in the experiments have not been validated yet its benefits of training through clinical trials. The user can be motivated and have more confidence to play the video game if they knew that they can benefit the positive effects, proved scientifically, from the games. These games miss also the evidence of the number of training that the user have to practice to benefit totally the training effects. If this information would have integrated in the experiments, the obtained results could be different.
- in the experiments, the issues of safety and ethic are not studied. If the inclusion criteria

can exclude some risks such as falling or fatigue, but any research on the risks that the users can be faced while playing these games is not done. In parallel, some ethic aspect has not been studied. Could the avatar replace the therapist? Would the users accept the presence of the avatar and the support system at home?

### **7.1.3 Conclusion**

Despite of the cited limits in the previous part, the proposed approach to maintain the engagement of the older adults in playing the Serious Game satisfies the main objective of the thesis. Throughout the three experiments, the results report that, on the one hand, the support system, applied the proposed approach, is capable of helping the users to initiate the game without using any device and to play actively the game with a good performance. On the other hand, the users do not have the difficulty to interact with the support system. The success of the support system is due to its structure which is similar to a human being. The support system determines the problems thanks to the understandings outside and inside the game, decides the appropriate interactions from a set of strategies of interaction and communicates throughout a 3D animated avatar.

If the usefulness of the support system is not proved yet in the long term and in other contexts, the support system is already operational and provides many contributions within the Memory Center. Some older adults having participated in the experiment 3 make many comebacks to the Memory Center to play the game with the support system. The interesting thing is that they do not start with the tutorial test but go directly to the game. In parallel, the game with the support system is already used by some therapists in the cognitive training sessions with their patients.

## **7.2 Perspective**

This section consists of proposing some future works to improve the support system. The works include the context of application of the support system, the support system and the game used with the support system.

### **1. New context**

To expand the usefulness of the support system, a new experiment can be realized in which the support system is tested in the living home of the users during 3 - 6 months. The objective of the experiment is to maintain the user engagement in playing the game. There are many challenges to the support system:

- the support system has to determine the appropriate moments during the day to stimulate the users to play a game session, either to do the session according to the suggestion of the doctor or to resume the session they do not yet finish before.
- the support system has to help the user to finish the game session with a good performance.

- the support system has to recognize different situations which can reduce the game performance or disturb the user engagement and propose the appropriate interactions to help the user to get out of the situations.
- the users accept to interact with the support system during the experiment and do not have the difficulty with the interaction mode.

## 2. **The game used with the support system**

The choice of the game is also important to maintain the user engagement. Indeed, the game should be neither too simple nor too difficult. If the game is so simple, the users can easily finish the game and become quickly less attracted. Thus, if the game is so long to finish the session, the users can abandon the game and they hesitate to play again another game session. So, the idea here is that the game can contain a set of mini-games, each one does not take more than 20 minutes to finish. The users can play a mini-game in everyday. Moreover, the mini-games can be organized in 2 possible ways: either the users have to finish one mini game to unlock another one or all mini games are unlocked and the users can choose the one they want to play. To enhance the engagement of the users, the mini-games' content have to match with the user profile. In parallel, the interaction mode of these mini-games must also be accorded with the physical abilities of the users.

## 3. **The support system**

The support system needs to be improved to take care the new context. Here, the support system must be capable of recognizing new situations and defining the new appropriate interactions. To realize this objective, 3 components of the support system need new improvements.

### a) *the Activity Recognition*

the component can link with a multi-sensor network installed in the living house to detect the position and the posture of the users as well as tracking their movement and uses these data as input to recognize their activities with new models of events. The component needs also to detect new body properties (e.g. hands, head and eyes) of the users (either by linking to other specific system or by improving itself) to offer to the Support Manager more useful information. The first improvements are already done in the VISIONUM project <sup>1</sup>. In this project, new algorithm is applied to detect and track the head of the users. The computed information are used to satisfy some constraints. The depth information provides the distance between the head position and the RGB-D sensors in order to guide the users in good distance ( $60 \text{ cm} < \text{distance} < 3\text{m}$ ). The x and y value of head is used to guide the users in good position at the screen. From the computed information of the head, the 3D information of the eyes are deduced, which are use to compute the angle of the head toward the screen. The bigger is the angle, the

---

<sup>1</sup><http://www.projet-visionum.com/>

more precise the user is not looking to the scree. It could be a source information to determine of the distraction.

b) *the Interaction*

Throughout three experiments in the thesis, the influence of the avatar appearance is not really decisive to the user engagement. The users appreciate the avatar appearances but any information can confirm that they will accept to interact with the same avatar in long term. It can explain that on the one hand, the users are attracted by the therapist and the game, and on the other hand, they do not have enough time to nourish a close relationship with the avatar. So, in this new experiment, as the users will exchange with the avatar throughout the experiment, it is important to establish a regular relationship between them. The first idea is to let a possibility to the users to choose an appearance for the avatar. The second idea is to improve the avatar to be more emotional in exchanging with the users. Many approaches in the field of Conversational Agent can be applied to realize this idea.

The interface of the support system can be also improved. New factors can be added in the interface to enhance the attractiveness. The example of the SAFEE project <sup>2</sup> can be cited. A combination of aroma, music and 3D screen is integrated in the interface.

c) *the Support Manager*

Nowadays, the Support Manager determines the current situation based on the predefined set of situations. A possible improvement can rely on the autonomy of the component: the Support Manager can learn and define the situation by itself, as the work of Negin and al. [62].

---

<sup>2</sup><http://www.innovation-alzheimer.fr/safee-en/>

## Appendix A

# Annexes : Az@Game Partners

Genious Group, the CMRR from Nice teaching hospital through its research team (EA Cob Tek), INRIA/Pulsar and IDATE have set up a partnership (Fig. A.1) to propose the Az@GAME project in which each partner contributes their competences. Genious Group offers their specialized knowledges in Serious Game design, CoBTeK team adds their expertise in Alzheimer's Disease while Stars team provides their speciality in activities recognition and IDATE brings their consulting service inside of project. Here are some details about these partners extracted from the project website.

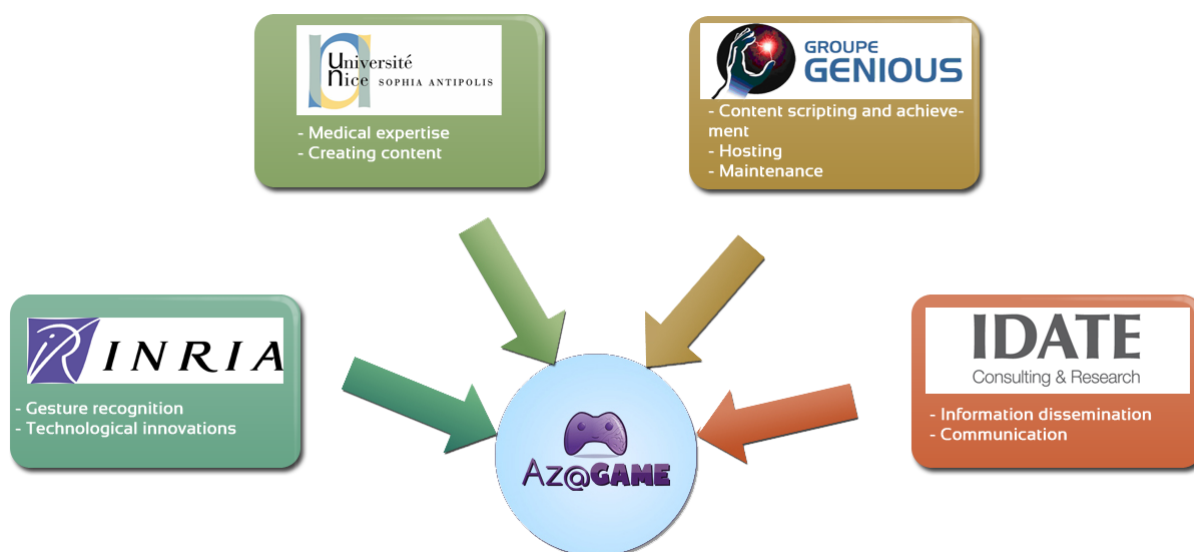


Figure A.1 – Partners of Az@Game project

### Genious Group<sup>1</sup>

Created in 1983, Genious Group is a human scale computing group. 155 people work for the Group and has a turnover of 15 million in 2010. The group targets information systems, freewares, e-learning, serious gaming and web next generation. This company specializes in:

- Computer engineering, consulting services, expertise and technical support.

<sup>1</sup><http://www.genious.com>

- Digital teaching:
  - Serious Games, EduGames,
  - E-learning, e-training, ODL,
- Skills diagnostic tools and HR positioning
- Interactive and creative web solutions:
  - Next generation web application,
  - Mobile applications,
  - Social and marketing Games.

**Inria - Pulsar**<sup>2</sup> The project team Pulsar has been launched in January 2008 within INRIA Sophia Antipolis research centre. François Bremond has been appointed manager of this team in September 2009. Pulsar project team is focused on activities recognition and more precisely on semantic interpretation in real time of dynamic scenes observed with sensors (video camera). Studies focus on spatiotemporal activities on the long term by human beings, animals or vehicles.

The main problem about the semantic interpretation of dynamic scenes relies in the considerable difference between the subjective interpretation of data and objective measures given by sensors. The team's approach to solve this problem is to keep a clear frontier between the subjective interpretation linked to implementation and the objective analysis of videos.

Pulsar team puts forward new techniques in the fields of vision and cognitive systems to recognize physical objects, activity learning, systems design and assessment. It focuses on two fields of application:

- video-surveillance,
- home care for elderly people

### **CHU of Nice - CoBTeK**<sup>3</sup>

The CMRR, which means Memory Resource and Research Centre from Nice teaching hospital has been labelled on December 19th 2002. Its 4 assignments are: care, teaching, Research and network coordination. The research activity of the CMRR is centered on behaviours, emotions and their disorders. The CMRR is really involved in several French research networks (IFRAD, IM2A, CenGeps, BNA). This illustrates why these activities are based on clinical research but also on translational research. The CMRR has obtained the creation of an academic welcoming team CoBTek (Cognition – Behaviour Technology) and its assignments are meant to promote:

---

<sup>2</sup><https://team.inria.fr/stars/>

<sup>3</sup><http://www.cmrr-nice.fr/>

- Diagnosis and care of cognitive and behavioural disorders in Alzheimer’s disease and related pathologies.
- Autonomy of elderly people presenting a normal or pathological ageing.

The promotion of the CMRR and CoBTek team’s research activity is carried out through Association Innovation Alzheimer (IA) whose objectives are:

- Promote innovation and research on prevention, diagnosis, treatment of Alzheimer’s disease and related pathologies;
- Extend knowledge on the use of Information and Communication Technologies for elderly people (during normal or pathological ageing) and in neuropsychiatric pathologies.

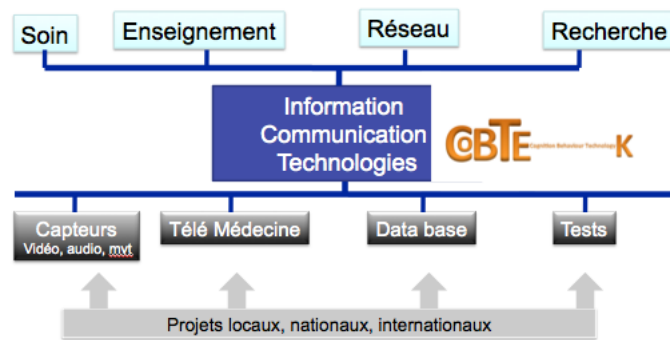


Figure A.2 – CoBTek team’s research activity

## IDATE

Since 1977, IDATE has been recognized as one of the first consulting service and study centre in Europe whose mission is to back up strategic decisions of its customers on telecom, internet, media sectors. IDATE’s main fields of action are:

- **Consulting:** Ability to intervene on strategic files. IDATE has established its credibility and independence by completing research and consulting assignments for its customers. Its multidisciplinary teams of economists and engineers can analyse the impact of market evolution, regulation and technologies on their profession and strategies.
- **Research:** Observer of the digital world. IDATE puts the skill of its specialized teams and its constant dedication at its customers’ disposal through an information system and a strategic monitoring through studies listed in the DigiWorld catalogue and its related services.
- **DigiWorld Programme:** European forum on the digital world. Over the years IDATE has been recognized as one of the first exchange and analysis centre within Europe. It specializes in industries and telecom markets, Internet and broadcasting media.

---

# Bibliography

---

- [1] Alzheimer's Disease International. World Alzheimer report 2015: The global impact of dementia, 2015.
- [2] H.L. O'Brien and E. G. Toms. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Journal of the American Society for Information Science and Technology*, 59(6), 2008.
- [3] K. Clough-Gorr T. Bickmore, D. Schulman and T. Heeren. Relational agents for older adults. *Interacting with Computers*, 17(6), 2005.
- [4] P. Chaudhuri Z. Kasap, M.B. Moussa and N. MagnenatThalmann. Making them remember – emotional virtual characters with memory. *IEEE Computer Graphics and Applications*, 29(2), 2009.
- [5] United Nations. The world population situation in 2014: A concise report. pages 24–25, 2014.
- [6] INSEE. Évolution de la structure de la population en France, 2014.
- [7] INSEE. Evolution de la structure de la population, France, 2014.
- [8] C.A.Morse S.Carmel and F.M.Torres-Gil. *The art of aging well*. NY Baywood Publishing, 2007.
- [9] R.Fernández-Ballesteros. *Active aging: The contribution of psychology Cambridge*. MS: Hogrefe and Huber Publishing, 2008.
- [10] J.W.Rowe and R.L.Kahn. Successful aging. *The Gerontologist*, 37(4):433–440, 1997.
- [11] C.Neufils E.Polard S.Balliard S.Schuck, D.Bentue Ferrer and H.Allain. Effets indésirables et médicaments de la maladie d'Alzheimer. *Congrès National de la Société Française de Pharmacologie*, 54(2):237–242, 1999.



- [12] A.Von Gunten and A. Kung. Les limites de la prescription des inhibiteurs de l'acétylcholinestérase dans la maladie d'alzheimer. *Médecine et hygiène*, pages 302–308, 2000.
- [13] Pascale DORENLOT. Non pharmacological interventions in dementia: a review and prospect. *Psychol NeuroPsychiatr Vieil*, 4(2):135–44, 2006.
- [14] LT.Guey GW.Rebok, K.Ball and al. Ten-year effects of the active cognitive training trial on cognition and everyday functioning in older adult. *Journal of the American Geriatrics Society*, 64(1):16–24, 2014.
- [15] O.Olufuwa and T.Alemayehu. Improving elderly health care by using serious games: A systematic literature review. *Laurea University of Applied Sciences*, 2015.
- [16] H Mollenkopf. Assistive technology: Potential and preconditions of useful applications. *Impact of Technology on Successful Aging*, pages 203–214, 2003.
- [17] Fisk A.D.and Rogers A.R., Charness N, Czaja S.J., and Sharit J. *Designing for Older Adults – Principles and Creative Human Factors Approaches*. Boca Raton: CRC Press, 2004.
- [18] S.J. Czaja and C.C. Lee. Information technology and older adults. In *The Human-Computer Interaction Handbook*. Lawrence Erlbaum Associates, New York and London, 2006.
- [19] H.S. Becker. Notes on the concept of commitment. *The American Journal of Sociology*, 66(1), 1960.
- [20] M. Argyle and M. Cook. Gaze and mutual gaze. *Cambridge University Press*, 1976.
- [21] E.Z. McClave. Linguistic functions of head movements in the context of speech. *J. Pragmatics*, 32, 2000.
- [22] F.D. Davis. Perceived usefulness, perceived ease of use, and user acceptance of information technologies. *MIS Quarterly*, 13(3), 1989.
- [23] V. Venkatesh and F. D. David. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management science*, 46(2), 2000.
- [24] G. Kearsley and B.Shneiderman. Engagement theory: A framework for technology-based teaching and learning. *Educational technology*, 38(5), 1998.
- [25] L. Hedman P. Sharafi and H. Montgomery. Using information technology: engagement modes, flow experience and personality orientations. *Computers in Human Behavior*, 22(5), 2006.
- [26] M. Csikszentmihalyi. Flow: The psychology of optimal experience. 1990.

- [27] M. Jennings. Theory and models for creating engaging and immersive ecommerce web sites. In *Proceedings of the 2000 ACM SIGCPR Conference on Computer Personnel Research*, 2000.
- [28] P.L. Roth A.B. Woszczyński and A.H. Segars. Exploring the theoretical foundations of playfulness in computer interactions. *Computers in Human Behavior*, 18(4), 2002.
- [29] J. McCarthy and P. Wright. Technology as experience. *Cambridge, Massachusetts: MIT Press*, 2004.
- [30] J.M. Morris. User interface design for older adults. *Interacting with Computers*, 6(4), 1994.
- [31] Sri Kurniawan and Panayiotis Zaphiris. Research-derived web design guidelines for older people. pages 129–135, 2005.
- [32] M. Zajicek. Interface design for older adults. *Proceedings of the 2001 EC/NSF Workshop on Universal Accessibility of Ubiquitous Computing: Providing for the Elderly*, 2001.
- [33] Juha Häikiö, Arto Wallin, Minna Isomursu, Heikki Ailisto, Tapio Matinmikko, and Tua Huomo. Touch-based user interface for elderly users. In *Proceedings of the 9th International Conference on Human Computer Interaction with Mobile Devices and Services, MobileHCI '07*, pages 289–296, New York, NY, USA, 2007. ACM.
- [34] Alma L. Culén and Tone Bratteteig. Touch-Screens and Elderly users: A Perfect Match? In *ACHI 2013, The Sixth International Conference on Advances in Computer-Human Interactions*, pages 460–465, 2013.
- [35] Judy Kay Apted, Trent and Aaron Quigley. Tabletop sharing of digital photographs for the elderly. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 781–790. ACM, 2006.
- [36] Bruno Loureiro and Rui Rodrigues. Design guidelines and design recommendations of multi-touch interfaces for elders. *The Seventh International Conference on Advances in Computer-Human Interactions*, 2014.
- [37] Caroline Golanski-Camille Roux Francois Portet, Michel Vacher and Brigitte Meillon. Design and evaluation of a smart home voice interface for the elderly. In *Acceptability and objection aspects. Personal and Ubiquitous Computing, Springer Verlag*, volume 17, page 127. ACM, 2013.
- [38] M. Doris. The impact of animated interface agents: a review of empirical research. *Human-Computer Studies Journal*, 52, 2000.
- [39] M.N. Grimshaw R.H. Campbell and G.M. Green. Relational agents: A critical review. *The Open Virtual Reality Journal*, 1(1), 2009.

- [40] D. Schulman T. Bickmore and L. Yin. Maintaining engagement in long-term interventions with relational agents. *Applied Artificial Intelligence: An International Journal*, 24(6), 2010.
- [41] D. Oyarzun J. J. Yanguas C. Buiza M. F. Gonzalez A. Ortiz, M. del Puy Carretero and I. Etxeberria. Elderly users in ambient intelligence: Does an avatar improve the interaction? *Universal access in ambient intelligence environments. Springer Berlin Heidelberg*, 2007.
- [42] J. I. Aoe Kiyoshi Yasuda and Masao Fuketa. Development of an agent system for conversing with individuals with dementia. *The 27th Annual Conference of the Japanese Society for Artificial Intelligence*, 2013.
- [43] Y. Laurent-Corniquet S. Benveniste P. Jouvelot P. Wargnier, G. Carletti and A. S. Rigaud. Field evaluation with cognitively-impaired older adults of attention management in the embodied conversational agent louise. *4th International Conference on Serious Games and Applications for Health*, 2016.
- [44] Nap H. H. de Kort Y. Ijsselsteijn, W. and K. Poels. Digital game design for elderly users. In *In Proceedings of the 2007 conference on Future Play*, pages 17–22. ACM, 2007.
- [45] J. W. Lee and S. J Park. A study on interface design of serious game for the elderly. In *Advanced Science and Technology Letters*, volume 39, pages 159–163, 2015.
- [46] Mubin O. Shahid S. Al Mahmud, A. and J. B. Martens. Designing and evaluating the tabletop game experience for senior citizens. In *In Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, volume 4, pages 285–308, 2006.
- [47] Miao C. Yu H. Leung C. Pan, Z. and J. J. Chin. The effects of familiarity design on the adoption of wellness games by the elderly. In *IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT)*, volume 2, pages 387–390. IEEE, 2015.
- [48] Schild Jonas Gerling, Kathrin M. and Maic Masuch. Exergame design for elderly users: The case study of silverbalance. In *Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology, ACE '10*, pages 66–69, New York, NY, USA, 2010. ACM.
- [49] Kathrin M. Gerling, Regan L. Mandryk, and Michael R. Kalyn. Wheelchair-based game design for older adults. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*, pages 27:1–27:8, New York, NY, USA, 2013. ACM.

- [50] Nghiem.A.T and F.Bremond. Background subtraction in people detection framework for rgb-d cameras. *the 11th IEEE International Conference on Advanced Video and Signal-Based Surveillance (Seoul: AVSS)*, 2014.
- [51] F.Bremond Chau.D.P and M.Thonnat. A multi-featuretracking algorithm enabling adaptation to context variation. *the International Conference on Imaging for Crime Detection and Prevention*, 2011.
- [52] B.Fosty. A.Konig. R.Romdhane. M.Thonnat Crispim-Junior.C., V.Bathrinarayanan. and F.Bremond. Evaluation of a monitoring system for event recognition of older people. *The 10th IEEE International Conference on Advanced Video and Signal-Based Surveillance*, 2013.
- [53] F. Sascha M. Morandell. Martin, H. Andreas and W.Siegfried. Avatars in assistive homes for the elderly. *HCI and usability for education and work*, 2013.
- [54] L.S. Candace B. Timothy P.V. Laura, B. Barbara. Designing relational agents as long term social companions for older adults. *The 12th international conference on Intelligent Virtual Agents*, 2012.
- [55] O. David J.Y Jose B. Cristina M. Feli Gonzalez O. Amalia, D.P.C María and E. Igone. Elderly users in ambient intelligence: does an avatar improve the interaction? *The 9th conference on User interfaces for all*, 2006.
- [56] L.M. Robins M.F. Folstein and J.E. Helzer. The mini-mental state examination. *Arch Gen. Psychiatry*, 40(7), 1983.
- [57] Phan Tran Minh Khue, Bremond François, and Robert Philippe. Comment intéresser les personnes âgées aux serious game ? In *Journée Annuelle SFTAG 2014*, Nov 2014.
- [58] V. B. Axel C. Tammy B. Craig H. Jesse, P. Pascal and M. Alex. Automated handwashing assistance for persons with dementia using video and a partially observable markov decision process. *Computer Vision and Image Understanding (CVIU)*, 2010.
- [59] Phan Tran Minh Khue, Bremond François, and Philippe Robert. Assistance for older adults in serious game using an interactive system. In *GALA 2015 - 4th International Game and Learning Alliance Conference*. Springer, 9599, pp.6, LNCS - Lecture Notes in Computer Science, Dec 2015.
- [60] Brianne Magouirk Bettcher, David J. Libon, Edith Kaplan, Rod Swenson, and Dana L. Penney. *Digit Symbol Substitution Test*, pages 849–853. Springer New York, New York, NY, 2011.
- [61] Phan Tran Minh Khue, Robert Philippe, and Bremond François. A virtual agent for enhancing performance and engagement of older people with dementia in serious games. In *Workshop Artificial Compagnon-Affect-Interaction 2016*, 2016.

- [62] Farhood Negin, Serhan Cosar, Michal Koperski, and François Bremond. Generating unsupervised models for online long-term daily living activity recognition. In *Asian conference on pattern recognition (ACPR 2015)*, 2015.