A Computational Framework for Planning Therapeutical Sessions aimed to Support the Prevention and Treatment of Mental Health Disorders using Emotional Virtual Agents

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Abstract

Interaction is defined as the realization of a reciprocal action between two or more people or things. Particularly in computer science, the term *interaction* refers to the discipline that studies the exchange of information between people and computers, and is generally known by the term Human-Computer Interaction (HCI). The HCI is a multidisciplinary research area that includes findings not only from computer sciences, but also from social sciences, engineering and design.

Good design decisions and an adequate development of the software is required for efficient HCI to facilitate the acceptability of computer-based applications by the users. In clinical settings it is essential to eliminate any barrier and facilitate the interaction between patients and the system. A smooth communication between the users (i.e. patients) and the computer-based application is fundamental to maximise the advantages and functionalities offered by the system. The design of these applications must consider the personal and current needs of the user by applying a User-Centered Design (USD) methodology.

The main purpose of this research work is to contribute in the improvement of HCI-based applications addressed to the clinical context, particularly to enhance computer-based interactive sessions to support people suffering from a mental disorder such as major depression. Thanks to the advances in Artificial Intelligence techniques, it is now possible to partially automate complex tasks such as the continuous provision of Cognitive-Behavioural Therapies (CBTs) to patients. These computer-based therapies require good levels of **adaptability** and **variability** during the interaction with the patient that facilitates the **acceptability** in the user, an optimal **usability** and good level of **engagement** for a successful mid/-long term use of the application and treatment **adherence**. The modelling of complex deliberative and affective processes in artificial systems can be applied to support the prevention and treatment of mental health related issues, enhancing the continuous and remote assistance of patients, saving some economical and clinical resources and reducing the waiting lists in the health services. In this regard, the efforts of this Thesis have been concentrated on the research of two main lines: (1) the generation and planning of adequate contents in an interactive system to support the prevention and treatment of depression based on the dynamic and individual characteristics of the user; and (2) the modelling of relevant affective processes able to communicate the contents in an emotional effective way taking into account the importance of the affective conditions associated with the depression in the users.

Rule Based Systems and the appraisal theory of emotions have been the roots used to develop the main two modules of the computational Framework presented in this thesis: the Contents Management and the Emotional Modules. RBS are able to simulate the knowledge of a human expert in a particular domain. Regarding the modelling of affective processes, the work presented in this Thesis has been extended an existing computational architecture of emotions. In both cases, the continuous interaction with the user and his/her environment, causes a process of reasoning that customizes and adapts the interaction with the goal of improve the user experience, to promote the acceptability and usability of a system which uses the computational Framework presented in this Thesis as the core mechanism to produce the interactive sessions.

The design and development of the computational Framework presented in this Thesis has followed a prototyping methodology, which has allowed an incremental evaluation of the different versions of the incremental prototypes. The last version of the prototype included an evaluation based on massive simulations to assess the level of variability and adaptability of the session contents taking into account the clinical requirements and the simulated user status. The developed computational Framework was integrated into two interactive systems to evaluate the achievement of the research objectives. The first system where the Framework was integrated has been developed in the context of the "Help4Mood" European research project [FP7-ICT-2009-4; 248765] and its main aim was to support the remote treatment of patients with major depression. The second scenario was a system developed to prevent depression and suicidal thoughts in the University community. This second system was developed in the context of the local one-year duration "PrevenDep" research project. The evaluation of the Framework in this second case was conducted in three Spanish universities and in a Mexican research center.

The evaluations carried out in both scenarios (treatment and prevention), have indicated that the proposed Framework has reached good levels of usability and acceptability in the target users thanks to the personalizations and adaptation capabilities of the contents and in the way how these contents are communicated to the user.

The research work and the obtained results in this Thesis has contributed to the state of the art in HCI-based systems used as support in therapeutic interventions for the prevention and treatment of depression. This was obtained by the combination of a personalized content management to the patient, and the management

of the affective processes associated to these pathologies. The developed work also identifies some research lines that need to be addressed in future works to get better computer-based interactive systems used for therapeutic purposes.

Resumen

Interactuar se define como la realización de una acción recíproca entre dos o más personas o cosas. Particularmente en informática, el término *interacción* se refiere a la disciplina que estudia el intercambio de información entre las personas y computadoras, y suele conocerse por el término anglosajón *Human-Computer Interaction* (HCI). Con la finalidad de cubrir los conocimientos necesarios de ambas partes, esta disciplina concentra principalmente los conocimientos de tres áreas: ciencias sociales, de ingeniería y del diseño.

Un buen diseño y un adecuado desarrollo del software es necesario para lograr una HCI eficiente que facilite la aceptabilidad del sistema por el usuario. En entornos clínicos es fundamental eliminar cualquier tipo de barrera y facilitar la interacción entre los pacientes y el computador. Es de vital importancia que haya una buena comunicación entre usuario (o paciente) y computador, por este motivo el sistema debe de estar diseñado pensando en las necesidades actuales, cambiantes y personales del usuario, basándose en la metodología de diseño centrado en el usuario (USD, del inglés User-Centred Design).

El propósito principal de esta investigación es la identificación de mejoras en HCI aplicada en entornos clínicos, en concreto para dar soporte a personas con trastornos mentales como la depresión mayor y que precisan de terapias psicológicas adecuadas y continuas. Gracias a técnicas de Inteligencia Artificial, es posible automatizar eficientemente ciertas acciones asociadas a los procesos de las terapias cognitivo-conductuales (CBTs, del inglés Cognitive-Behavioural Therapies). Los sistemas computacionales de ayuda a la CBT, requieren de una **adaptabilidad** y **variabilidad** en la interacción para favorecer la **usabilidad** del sistema y asegurar la continuidad de la **motivación** del paciente. Una buena gestión de esta automatización influiría en la **aceptabilidad** de los pacientes y podría mejorar su **adherencia** a los tratamientos y por consiguiente mejorar su estado de salud. Adicionalmente, la unión de procesos deliberativos dinámicos pueden liberar recursos clínicos, mejorando el control de los pacientes, y reduciendo los tiempos de espera y los costes económicos.

En este sentido, los esfuerzos de esta Tesis se han centrado en la investigación de dos líneas diferentes: (1) la selección y planificación adecuada de los contenidos presentados durante la interacción a través de una planificación dinámica y personalizada, y (2) la adecuación de la comunicación de los contenidos hacia el paciente tomando en cuenta la importancia de los procesos afectivos asociados a estas patologías.

Los Sistemas Basados en Reglas (SBR) han sido la herramienta utilizada para dar soporte a los dos módulos principales que componen el Framework presentado en esta Tesis: el módulo de gestión de los contenidos ofrecidos al usuario; y el módulo emocional. Los SBR son capaces de simular ciertas características de un ser humano experto en un dominio de conocimiento determinado, mediante la representación del conocimiento a través de reglas. Respecto a la gestión de emociones, el trabajo presentado en esta Tesis incluye el modelado de procesos afectivos en sistemas artificiales mediante la extensión de una arquitectura computacional de emociones ya existente. En ambos casos, la continua interacción con el usuario y su entorno, provoca un proceso de razonamiento que personaliza y adecua la interacción con el objetivo de mejorar la experiencia del usuario, favoreciendo la aceptación y usabilidad del Framework presentado.

La fase de diseño y desarrollo del Framework computacional descrito en esta Tesis ha seguido una metodología de prototipado, la cual ha permitido realizar diferentes evaluaciones sobre las diferentes versiones de prototipos incrementales. Sobre el último prototipo completo de la fase de desarrollo se realizó una evaluación basada en simulaciones masivas, la cual se centró en la variabilidad y adaptación del módulo de planificación en función de los requerimientos clínicos y estado del usuario. Concluida la fase de diseño y desarrollo, el Framework fue adaptado a los dominios correspondientes e integrado en sistemas maduros para ser evaluado en dos escenarios reales, para validar la viabilidad y la adecuación del marco de trabajo de esta Tesis. En primer lugar, el sistema se aplicó durante tres años en el tratamiento de la depresión mayor en varios centros clínicos europeos en el contexto del Proyecto Europeo de investigación Help4Mood [FP7-ICT-2009-4; 248765]. Finalmente, el sistema fue evaluado en la tarea de prevención de la depresión y del suicidio en el Proyecto Local de investigación PrevenDep, de un año de duración. Esta última evaluación se llevó a cabo en tres universidades españolas y un centro de investigación mexicano para valorar su usabilidad y aceptabilidad.

El feedback de las evaluaciones llevadas a cabo, tanto en el escenario de tratamiento como en el de prevención, han demostrado que el HCI del Framework tiene unos niveles altos de usabilidad y aceptación, gracias a la personalización y adaptación de los contenidos y de la comunicación de los mismos.

Los experimentos computacionales llevados a cabo en esta Tesis han permitido avanzar el estado del arte de sistemas computacionales emocionales aplicados en entornos terapéuticos para la prevención y tratamiento de la depresión. Principalmente, gracias a la combinación de una gestión personalizada de los contenidos hacia el paciente tomando en cuenta la importancia de los procesos afectivos asociados a estas patologías. Este trabajo abre nuevas líneas de investigación, como la aplicación de este sistema en otras patologías de salud mental en las que sea recomendable la aplicación de sesiones terapéuticas.

Resum

Interactuar es defineix com la realització d'una acció recíproca entre dos o més persones o coses. Particularment en informàtica, el terme *interacció* es refereix a la disciplina que estudia l'intercanvi d'informació entre les persones i computadores, i es sol conèixer pel terme anglosaxó Human-Computer Interaction (HCI). Amb la finalitat de cobrir els coneixements necessaris de les dues parts, aquesta disciplina concentra principalment els coneixements de tres àrees: ciències socials, d'enginyeria i del disseny.

Un bon disseny i un adequat desenvolupament del software és necessari per aconseguir una HCI eficient que faciliti l'acceptabilitat del sistema per l'usuari. En entorns clínics és fonamental eliminar qualsevol tipus de barrera i facilitar la interacció entre els pacients i el computador. És de vital importància que hi hagi una bona comunicació entre l'usuari (o pacient) i el computador, per aquest motiu el sistema ha d'estar dissenyat pensant en les necessitats actuals, cambiants i personals de l'usuari, basant-se en la metodologia de disseny centrat en l'usuari (USD, de l'anglès User-Centered Design).

El propòsit principal d'aquesta investigació és la identificació de millores en HCI aplicada en entorns clínics, en concret per donar suport a persones amb trastorns mentals com la depressió major i que precisen de teràpies psicològiques adequades i contínues. Gràcies a tècniques d'Intel·ligència Artificial, és possible automatitzar eficientment certes accions asociades al processos de les teràpies cognitiu-conductuals. Els sistemes computacionals de ajuda a la CBT, requereixen d'una **adaptabilitat** i **variabilitat** en la interacció per afavorir la **usabilitat** del sistema i assegurar la continuïtat de la **motiviació** del pacient. Una bona gestió d'aquesta automatització influiria en l'**acceptabilitat** dels pacients i podria millorar la seva **adherència** als tractaments i per tant millorar el seu estat de salut. Addicionalment, la unió de processos deliberatius dinàmics poden alliberar recursos clínics, millorant el control dels pacients, i reduint els temps d'espera i els costos econòmics. En aquest sentit, els esforços d'aquesta Tesi s'han centrat en la investigació de dues línies diferents: (1) la selecció i planificació adequada dels continguts presentats durant la interacció a través d'una planificació dinàmica i

personalitzada, i (2) l'adequació de la comunicació dels continguts cap al pacient tenint en compte la importància dels processos afectius associats a aquestes patologies.

Els Sistemes Basats en Regles (SBR) han estat la eina utilitzada per donar suport als dos mòduls principals que componen el Framework presentat en aquesta Tesi: el mòdul de gestió dels continguts oferits a l'usuari; i el mòdul emocional. Els SBR són capaços de simular certes característiques d'un ésser humà expert en un domini de coneixement determinat, mitjançant la representació del coneixement a través de regles. Respecte a la gestió d'emocions, el treball presentat en aquesta Tesi inclou el modelatge de processos afectius en sistemes artificials mitjançant l'extensió d'una arquitectura computacional d'emocions ja existent. En tots dos casos, la contínua interacció amb l'usuari i el seu entorn, provoca un procés de raonament que personalitza i adequa la interacció amb l'objectiu de millorar l'experiència de l'usuari, afavorint l'acceptació i usabilitat del Framework presentat.

La fase de disseny i desenvolupament del Framework computacional presentat a aquesta Tesi ha seguit una metodologia de prototipatge, la qual ha permès realitzar diferents avaluacions sobre les diferents versions de prototips incrementals. Sobre l'últim prototip complet de la fase de desenvolupament es va realitzar una avaluació basada en simulacions massives, la qual es va centrar en la variabilitat i adaptació del mòdul de planificació en funció dels requeriments clínics i estat de l'usuari. Conclosa la fase de disseny i desenvolupament, el Framework va ser adaptat als dominis corresponents i integrat en sistemes madurs per ser avaluat en dos escenaris reals, per validar la viabilitat i l'adequació del Framework d'aquesta tesi. Primerament, el sistema es va aplicar durant tres anys en el tractament de la depressió major en diversos centres clínics europeus en el context del Projecte Europeu d'investigació Help4Mood [FP7-ICT-2009-4; 248765]. Finalment, el sistema va ser avaluat en la tasca de prevenció de la depressió i del suïcidi al Projecte Local d'investigació PrevenDep, d'un any de durada. Aquesta última avaluació es va dur a terme en tres universitats espanyoles i un centre d'investigació mexicà per valorar la seva usabilitat i acceptabilitat.

El feedback de les avaluacions dutes a terme, tant en l'escenari de tractament com en el de prevenció, han demostrat que el HCI del Framework obté uns nivells alts d'usabilitat i acceptació, gràcies a la personalització i adaptació dels continguts i de la comunicació.

Els experiments computacionals duts a terme en aquesta Tesi han permès avançar l'estat de l'art de sistemes computacionals emocionals aplicats en entorns terapèutics per a la prevenció i tractament de la depressió. Principalment, gracies a la combinació d'una gestió personalitzada dels continguts cap al pacient tenint en compte la importància dels processos afectius associats a aquestes patologies. Aquest treball obre noves línies d'investigació, com l'aplicació d'aquest sistema en altres patologies de salut mental en què sigui recomanable l'aplicació de sessions terapèutiques.

Acronyms and Abbreviations

AC	Affective Computing
AI	Artificial Intelligence
ASD	Autism Spectrum Disorder
ATS	Adaptive Treatment Strategy
BDI	Beck Depression Inventory
BDI-II	Beck Depression Inventory II
BHS	Beck Hopeless Scale
BMI	Brief Motivational Intervention
CBR	Case-Based Reasoning
CCBT	Computerised Cognitive Behaviour Therapy
CDSS	Clinical Decision Support Systems
CET	Cue Exposure Therapy
DA	Data Analysis Module
DAS-SF2	Dysfunctional Attitude Scale Short Form 2
DM	Dialogue Manager
DSS	Decision Support System
ECA	Embodied Conversational Agent
EEG	Electroencephalogram
EEMML	Emotional Eye Movement Markup Language
EHR	Electronic Health Record
EQ-5D	Brief Quality of Life Assessment
eSmart-MH	Electronic Self-Management Resource Training for Mental Health
FDA	Functional Data Analysis
GUI	Graphical User Interface
GWT	Gaze Warping Transformation
H4M	Help4Mood
HCI	Human-Computer Interaction
IBIME	Biomedical Informatics Group
ITACA	Instituto Universitario de Aplicaciones de las Tecnologías de la Información
IVA	Intelligent Virtual Agent
KE	Knowledge Extraction Module

KI	Knowledge Inference Module
Knn	K nearest neighbour
MD	Major Depression
MDD	Major Depression Disorder
NLG	Natural Language Generator
OCC	Ortony, Clore, and Collins
ODVIC	On-Demand VIrtual Counselor
PHQ-9	Patient Health Questionnaire
PMC	PubMed Central
PMS	Personal Monitoring System
PSTD	Posttraumatic Stress Disorders
Px.y	Participant number y, in the pilot number x
QALY	Quality-adjusted life years
QIDS-SR	Quick Inventory of Depressive Symptoms Self-Report
RBS	Rule-Based System
RC2S	Coginitive Remediation Program to Improve Social Cognition
RCT	Randomized Controlled Trial
SAD	Social Anxiety Disorder
SCID	Structured Clinical Interview
SOA	Service Oriented Architecture
SP	Session Planner
SPARX	Smart, Positive, Active, Realistic, X-factor thoughts
SUS	System Usability Scale
SVM	Support Vector Machine
TAM	Technology Acceptance Model
TAU	Treatment As Usual
ToM	Theory of Mind
TMAP	Texas Medication Algorithm Project
TTS	Text-To-Speech
UCD	User Centered Design
UPV	Universitat Politècnica de València
USD	User-Centred Design
VA	Virtual Agent
VP	Virtual Patient
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
WHO	World Health Organization
WM	Working Memory

Preface

This Dissertation describes the research work performed in the context of the PhD program in *Technologies for Health and Wellbeing* that was carried out at *IBIME Biomedical Research Group* (`www.ibime.upv.es`) of the *Instituto Universitario de Aplicaciones de las Tecnologías de la Información* (ITACA) (`www.itaca.upv.es`) from the *Universitat Politècnica de València* (UPV) (`www.upv.es`).

The main focus of the Thesis is on the improvement of Human-Computer Interaction (HCI) techniques in the administration of computer-based therapeutic sessions through the development of a computational framework as the mechanism to produce the actions and emotions in a virtual agent, the main interface that provides the adequate content to the user. Although the developed Framework can be adapted to provide sessions addressing different mental disorders, the research performed in this Thesis has been concentrated in the major depression disorder. It could be applied in both the treatment (Case of Study I) and prevention (Case of Study II).

The research methodology presented in this Dissertation has been organized as follows:

Chapter 1 introduces the context of this research and some technical and clinical considerations necessary for the smooth reading and understanding of this Thesis. In this Chapter, the initial hypothesis and the scientific approach are defined in order to present the methodological research approach.The main goals of this research work and the process to achieve them are also presented in this Chapter. Moreover, the research contributions are presented.

Chapter 2 presents the **state of the art of the Intelligent Virtual Agents (IVA) applied to mental health care**. This Chapter defines the virtual agents technology and describes how it is used in applications of mental health. Next, a review is conducted in order to highlight the most relevant published works in this area. This review was performed in two scenarios: First, collected papers related with the use of synthetic characters in general to support the treatment of different mental disorders. The second scenario refines the previous results, focusing only on those research works in which the virtual agents were designed to produce an autonomous, intelligent behaviour and to provide a dialogue-based interaction with the user.

The content of this Chapter is under review for publishing in Bresó, Martínez-Miranda, and García-Gómez 2016.

Chapter 3 describes the design and implementation of one of the main components of the Framework presented in this Thesis: The **Content Management Module**. This module is the mechanism responsible to manage and select (i.e. plan) the specific content of the daily sessions based on the detected user's condition. In this Chapter, the performance of the module is described and evaluated in order to assess their levels of variability and adaptability to the user. This internal evaluation was conducted by massive simulations that represented two opposite configurations (restrictive Vs flexible) to compare the behaviour of the module for each of the scenarios. Restrictive configuration includes more clinical restrictions and more guided sessions. Instead, the flexible configuration allows more free and open session's content.

This Chapter has been published as journal paper in Bresó et al. 2016. More details can be found in other related publications (Bresó, Martínez-Miranda, and García-Gómez 2014; Fuster-García et al. 2013; Fuster-García et al. 2015a; Fuster-García et al. 2015b).

Chapter 4 shows the other main result obtained in this Thesis: **The Emotional Module**, which is the responsible to produce the adequate emotional behaviour in the virtual agent. The produced behaviour aims to simulate a useful therapeutical-based responses, so this module has been designed to model therapeutic empathy. This emotional modelling must simulate an useful therapeutic behaviour, so this module is designed to produce therapeutic empathy reactions. In this Chapter, the different computational strategies to model this behaviour are detailed.

The content of this Chapter corresponds to the following book section publication (Martínez-Miranda, Bresó, and García-Gómez 2014b). More details can be found in other related publications (Martínez-Miranda, Bresó, and García-Gómez 2014; Bresó, Martínez-Miranda, and García-Gómez 2014; Martínez-Miranda, Bresó, and García-Gómez 2012a; Martínez-Miranda, Bresó, and García-Gómez 2012b).

Chapter 5 shows the **evaluation of the Case of Study I**, which corresponds to evaluations with real users carried out in the context of Help4Mood European Project. The developed Framework was adapted and integrated in a full research Personal Health System (PHS). These evaluations were focused on the treatment of patients with (mild or moderate) major depression.

Some of the data showed in this Chapter, was published in (Wolters et al. 2014; Martínez-Miranda, Bresó, and García-Gómez 2014).

Chapter 6 presents the **Case of Study II** where the framework has been evaluated in a different scenario focused in the prevention of depression and suicide in University communities. In a similar fashion to the evaluation described in the Chapter 5, the Framework has been integrated in a computational system addressed to these communities.

This evaluation was conducted thanks to the PrevenDep research project, and the results have been considered for publishing as journal paper in Bresó et al. 2015a.

Chapter 7 concludes this Dissertation with a compilation of the obtained **results and contributions** as well as the identification of **further research directions**. Final outcomes are highlighted and discussed in order to evaluate the work described in this Thesis and to show the achievement of the objectives defined in Chapter 1.

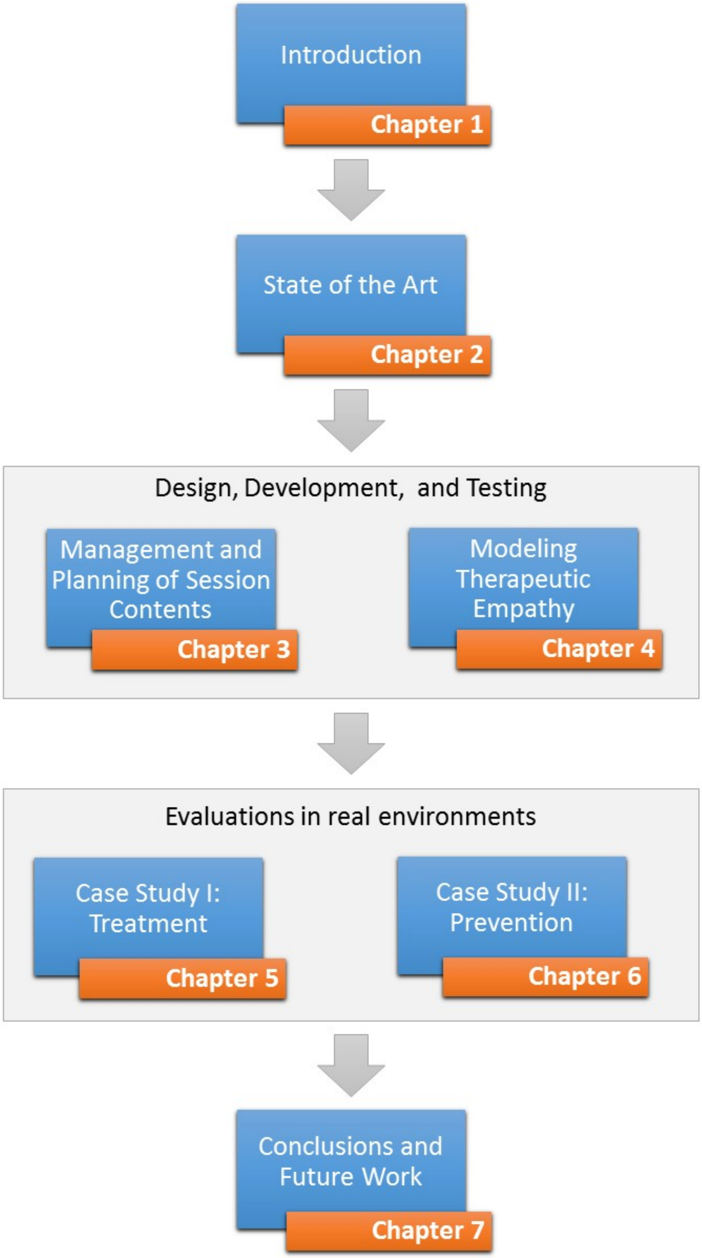


Figure 1: Diagram of the chapters

Contents

Chapter 1

Introduction

1.1 Motivation

Mental health disorders are one of the hottest topics in biomedical research due to their high impact in global population. More than 450 million people suffer from a mental or behavioral disorder, and four of the six leading causes of years lived with disability are due to neuropsychiatric disorders (such as depression, alcohol-use disorders, schizophrenia and bipolar disorder). In the Member States of the European Union the economic burden of mental illness is estimated between 3% and 4% of Gross National Product (GNP) due mainly to job absenteeism, decreased productivity at work, medical treatments (therapies and drugs), high prevalence, and hospitalizations (WHO et al. 2003).

Depression, also called **Major Depression** (MD), is a mood disorder that causes a persistent feeling of sadness and loss of interest. There are lot of scales and classifications, but in general, regarding on the number and severity of symptoms, a depressive episode can be categorized as *mild*, *moderate*, or *severe* (Hamilton 1960). Major Depression affects how an individual feels, thinks and behaves and can lead to a variety of emotional and physical problems. You may have trouble doing normal day-to-day activities, and sometimes you may feel as if life isn't worth living. Major Depression has been proved to be one of the most common mental health illness. According to the World Health Organization (WHO), 350 million people worldwide suffer from depression (that's 5% of the world's population). Unfortunately, many people with major depression can not be effectively treated and recover with adequate treatment. These impersonal treatments are a great economic burden, besides a great saturation of services which impairs the quality of life of patients and their families.

The techniques of Artificial Intelligence (AI) are a powerful tool to assist in the prevention and treatment of many diseases. AI technologies have promoted the development of eHealth applications, which have expanded hugely over the last decades and continues to evolve, providing greater benefits to patients (Good and Sambhanthan 2013) and therapists (Wright et al. 2014). Specifically, in mental health disorders, since 1990 we can find different systems based on Virtual Reality (VR), Augmented Reality techniques, and Telepsychology applications based on the internet (Arbona et al. 2009) that have changed the way that people communicate, sense and interact. The AI also has provided tools for the acquisition, representation and processing of clinical expert knowledge (called as cognitive science) in order to support and guide users in the mental health area. Other aspect to emphasize about benefits of using AI tools is the ability to simulate human emotions and behaviours in interactions. All of these have allowed the increment of understanding the patient requirements and needs in order to provide realistic new ways to envisage healthcare, improving the quality of life of the patients, whether it is by providing new diagnostic tools, or by developing innovative therapeutic approaches. Nowadays, many of these advances have been improved and evolved, showing that they are able to improve health outcomes, the well-being of the patient, and the cost-effective healthcare systems.

In the complex scenario of health, specifically in mental health, we need to provide **useful and usable evidence-based systems**. We need to ensure the adequate quality in clinical content and easy interaction with the users in order to get effective health Information Technology (IT) solutions. The patients with MD are people very prone to suffer anxiety and frustration. Even, they may stop the treatment if they encounter some difficulties (Safford and Worthington 1999; Martin et al. 2005). It is very important that computer systems do not cause any inconvenience to patients because this could lead to a deterioration in the patient's health condition. It is critical to provide them an adequate clinical contents, avoiding inappropriate, unnecessary repeated, or incorrect information. Regarding graphical interface, it is very important to allow as smooth and pleasant interaction as possible. The interface is very important because it is the bearer of the content to be offered to the patient. If the interaction fails, all the benefits that an ICT-based solution offers will not be fully exploited.

The discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them, is known as HCI (Human-Computer Interaction). Currently, there have been many advances in HCI that create more realistic and enjoyable experiences as the use of **Virtual Agents** (VA). Coyle et al. 2007 suggested that introducing VA as complement of human interventions might have a strong positive impact on users. The VA are conversational characters generated by a computer system able to maintain interaction with a human. The components of a VA are two: (1) the appearance or its graphical appearance, and (2) the intelligence (or the knowledge base) in its behavior. The advances in computational graphics have allowed that the appearance of VAs will become increasingly realistic and fluid. Regarding the intelligence of the VA, advances in artificial intelligence have achieved to provide the VA with certain behaviors and skills increasingly humans: speech, gesture recognition, modelling of emotions, etc.

Other key feature that highly influences the acceptability of HCI applications is the personalization. One of the latest and most popular definition of personalization was proposed by Montgomery and Smith 2009 as *the adaptation of products and services by the producer for the consumer using information that has been inferred from the consumer's behavior or transactions.* The **personalization of information and the adaptive interaction** of clinical tools encourage the motivation and patient adherence. Martin et al. 2005 reviewed the challenge of the patient adherence and he highlits the most relevant key factors that affect the treatment adherence as follows:

- **Cognitive factors** that are related with the understanding of the clinical message information by the patients. Often, patients do not understand the medical indications because the message is not clear or it does not contains the adequate information.
- **Interpersonal factors** in the physician-patient relationship. Patients need to be motivated, trust and feel that the health providers communicate well with them to be involved in their own care.
- **Participative factor** such as collaborative decision making in the treatment. The reciprocal exchange of information is critical. The patients must understand the illness problem and contribute in some physician-patient negotiation, for example, the patient should choose some recommended tasks, or he should be able to refuse or repeat certain activities.
- **Patient's attitudes**, as the thinking, the influence of the family, etc. It is a difficult factor to assess.
- **Cultural factor**. It is necessary that the doctor knows and understands the cultural details to adapt the behavior and treatment.

In addition to improving patient adherence, the personalized and adaptive patient's treatments strategies have the potential to improve treatment outcomes and to reduce economical and clinical resources (Gunlicks-Stoessel et al. 2015; Murphy and Collins 2007). Adaptive treatment strategies (ATSs) is a new paradigm that tailors time-varying treatments when critical checkpoint is assessed. Typically, ATSs are implemented by decision rules, which take as input patient characteristics and outcomes collected during treatment, such as patient response, and provide as output a treatment update. Variables as dosage pills are managed in order to influence the health condition of the patient. These systems are recommended for long term treatments, specifically when they are combined with medication and behavioral intervention. In this Thesis, the focus is on the achievement of adaptive sessions or interventions. Our Framework is not updating the treatment, it is updating the content of the session which mainly is composed by pre-defined CBT (Cognitive Behavioral Therapy) activities. Besides, we are not evaluating the patients' health condition, but their well-being instead. The Framework assessments are based on patient mood and other variables stored in a period of less than 4 weeks.

The work developed in this PhD focuses on improving the interaction of computational based solutions applied to support the people in the treatment and prevention of Major Depression. This Framework, which will be described in the following chapters, is able to generate the contents of the daily sessions provided to the users. In these sessions, an emotional AV interacts with the users to provide them with a sets of recommendations and to collect specific data used to assess the users' condition. So, the presented Framework is composed of two main components: the **Content Management Module** as the mechanism to generate the adaptive and variable content for the daily sessions (see Chapter 3), and the **Emotional Module** responsible to generate the adequate emotional responses (based on therapeutic empathy) during the interaction with the user (see Chapter 4).

1.2 Research Approach

1.2.1 Hypothesis

The main aim of this research work is to contribute in the development of an HCI-based Framework that, based on a set of clinical requirements, offers to the users a personalized support for the treatment and prevention of mental health related problems and in particular of major depression. Our focus is to provide a mechanism that, using the clinical requirements, generates the most adequate therapy-related content and communicate it effectively to the users.

In therapeutic mental health sessions, the provision of personalized, adaptive and emotional interaction in the mid-long time can lead to promote stronger rapport and engagement; rather than the generation of random-based content's sessions or the personalisation of the contents only at the beginning of the interaction and keep the same contents along the execution of the interactions.

The hypothesis that guides the development of this work is the following: "***the development of a HCI-based framework able to generate adaptive and variable contents, and to provide adequate emotional responses to the user in computer-based therapy sessions, will promote the adherence,***

engagement, usability and acceptability of therapy-based applications in people with problems of major depression".

1.2.2 Objectives

Based on the above hypothesis, we have defined six main objectives, which must be achieved with the developed Framework described in this PhD. All of them are related with key features for the improvement of the HCI-based framework. These goals are listed as follows:

- **Obj1-Adaptability**: To obtain a framework that ensures the adaptability of the behavior according to the patient condition and clinical restrictions. If necessary, the framework must allow to generate different behaviour from the same input or event, in order to respond intelligently in every situation.

- **Obj2-Variability**: To achieve a framework that offers variability in the management of sessions, in order to avoid repetitive and routine executions. The framework must allow to generate different planned sessions every day.

- **Obj3-Usability**: For the developed framework, to achieve good rates of usability which is a quality attribute that assesses how easy user interfaces are to use (Nielsen 2003).

- **Obj4-Acceptability**: To achieve high values regarding the acceptability of users about the developed framework. The acceptability is a combination of its social acceptability and its practical acceptability, in which is included the usability (Nielsen 1994) .

- **Obj5-Engagement**: To get engagement patients to maintain their interest in using the framework.

- **Obj6-Adherence**: To get positive values regarding adherence of users who uses the framework. Clinicians should establish guidelines such as in traditional treatments, in order to monitor its compliance. The adherence is very related to the engagement or commitment of the patients, so similar results in Obj5 and Obj6 are expected.

Table 1.1 shows how these objectives are addressed in the different chapters of this Dissertation. Chapters 1, 2 and 7 are not included in this Table because they are the introduction, the review of the state of the art, and the conclusions respectively. The main two developed modules of the presented Framework (described in Chapters 3 and 4) were addressed mainly to achieve the above objectives. In general, the evaluation of the objectives, was carried out in Chapters 5 and 6.

Table 1.1: Summary list of the modelling and evaluation of the objectives in the chapters of the Dissertation.

Chapters	Objectives					
	Obj1	Obj2	Obj3	Obj4	Obj5	Obj6
Chapter 3	⚙ 📋	⚙ 📋	⚙	—	—	⚙
Chapter 4	—	—	⚙	⚙	⚙	⚙
Chapter 5	—	—	—	📋	📋	📋
Chapter 6	—	—	📋	📋	—	—

Legend	
⚙	Modelling
📋	Evaluation

1.2.3 Limitations

Although this research work has reached its main aims and contributed with advances in the area of Human-Computer Interaction, it also presents some limitations. The main limitation is related to the evaluation results: there is no enough evidence about the clinical efficacy of the Framework. The influence of the computational system, where the Framework has been integrated, in the improvement of the clinical condition in the participants of the pilots has been not conclusive. The execution of a full randomised clinical trial (RCT) during a longer period of time and with a bigger number of patients is required to get better conclusions. The preparation and execution of such RCT need to carry out different steps (clinical requirements, security measures, ethics committee approvals, patient recruitment process, etc.) that has been really difficult to implement within the period of execution of this PhD. Thought the assessment of the clinical efficacy has never been a primary goal of this research work, our Framework has been assessed by the clinicians of the Help4Mood and PrevenDep research projects as adequate, safe, and useful to support patients with mild to moderate major depression whose live in the community, and it is ready to be used in a further RCT.

1.3 Methodology

The definition of a methodology allows the identification of the needed steps to be followed by the researcher to address a particular problem. In this case, with the hypothesis defined above as a reference and the objectives set as a goal, the author began his research in the field of HCI applied to mental health working in *IBIME*, one of the pioneering research group of biomedical informatics reported in Spain. During this period, the acquired knowledge in multidisciplinary research and international collaborations have made possible the development of this PhD.

The creation of a self-contained software is required, with a defined functionality, focusing on non-clinical staff, and support in the field of mental disorders based on medical evidence. This Framework has been structured in two modules: the **Content Management Module** (see Chapter 3) and the **Emotional Module** (see Chapter 4). We based this modular architecture of the Framework attending the philosophy of the Service Oriented Architecture (SOA): Each module (or sub-module) produces services to other module (or sub-module), providing adaptability, flexibility, and maintainability. The combination of all the modules is able to provide full and complex functionality.

The Content Management Module is responsible for carrying out the inference of the most appropriate contents and the management of a session content according to the current situation of the patient and pre-defined clinical guidelines. This module is required to be reactive and intelligent. It must be able to represent and manage the necessary clinical knowledge and to adjust their behavior to the specific circumstances every time. From these conditions, we have opted for the use of Rule Based System (RBS) in which clinical conditions are coded as if-then rules. Regarding the selection of the technology to carry out this planning, some heuristic methods from classical planning were evaluated such as Graphplan (Blum and Furst 1997) (PDDL4J, JPLAN, or PL-PLAN) and Metric-FF (Hoffmann 2003) (SAPA (Do and Kambhampati 2003), JavaFF) using the language PDDL (planning domain definition language)(Fox and Long 2003); and other more recent problem solving such as genetic algorithm (JGAP) and Grasp methods. In any case, the obtained results were the expected due to the inability to encode the necessary restrictions and the optimization function, which should ensure that the maximum number of tasks are planned, taking into account the clinical restrictions and user behavior. Finally, a custom planning algorithm was programmed to this domain, capable of delivering a variable and adaptive planning content. Additionally, this module will leverage the usability of the Framework and the treatment adherence.

The second module presented, the Emotional Module, is able to adapt the behavior of the VA to be as efficient and realistic as possible. Due to the particular characteristics of the application domain, the use of therapeutic empathy is essential. The modelling of this module is based on the most accepted emotional theories such as Gross theory (Gross 2001). From the technological point of view we selected the FAtiMA computational architecture of emotions (Dias, Mascarenhas, and Paiva 2014) which is based in the cognitive appraisal theory of emotions (Scherer, Schorr, and Johnstone 2001). The developed emotional module extends FAtiMA, as one of the main contributions of this PhD, in order to model two emotion regulation strategies: *cognitive change (reappraisal)* and *response modulation (suppression)*. This module is focused on the improvement of the acceptability and the usability of the Framework, the engagement of the user, and the treatment adherence.

The Framework has been evaluated according to the achievement of the defined objectives. The initial evaluation of the Framework functionality was through a set of massive simulations to assess the adaptability and variability levels of the planning module (see Chapter 3). After this internal evaluation, the developed Framework was evaluated in two clinical scenarios in the context of the **Help4Mood** and **PrevenDep** projects, which will be introduced in Section 1.5. During more than three years, the Framework was adapted and integrated into the Help4Mood system, focused to support the treatment of patients with major depression at home. In the Help4Mood project, the Framework was evaluated in three incremental pilots supervised by the clinical staff of the project in order to assess its acceptability, user engagement, and adherence. This evaluation is described in Chapter 5.

The second evaluation scenario was performed for the prevention of depression and suicidal behaviour in the University community. In This Project, the Framework was adapted to the requirements of the project under the supervision of the clinical partners. Sixty members of the University community were enrolled to take part in the evaluation of the usability and acceptability levels of the Framework.

During the performance of this PhD, some research works were published (see next Section 1.4). We highlight the Master Final Thesis in which some of the evaluations of the Help4Mood project were presented (Bresó 2014); and the achieved award for the best research Thesis project presented in the doctoral consortium of the 6th International Conference on Agents and Artificial Intelligence (ICAART) (Bresó, Martínez-Miranda, and García-Gómez 2014).

1.4 Contributions

During the research work of this Dissertation, the author was contributed in the publications listed below:

- Title: *Intelligent Virtual Agents Applied to Mental Health Care: A Survey*
  Authors: **Adrián Bresó**, Juan Martínez-Miranda, Juan Miguel García-Gómez

Type publication: Journal (under review) - *Journal of Medical Systems*
Year: -
Related Chapter: 2

- Title: *A Novel Approach to Improve the Planning of Adaptive and Interactive Sessions for the treatment of Major Depression*
Authors: **Adrián Bresó**, Juan Martínez-Miranda, Elies Fuster-García, Juan Miguel García-Gómez
Type publication: Journal - *International Journal of Human-Computer Studies*
Year: 2016
Related Chapter: 3

- Title: *Fusing actigraphy signals for outpatient monitoring*
Authors: Elies Fuster-García, **Adrián Bresó**, Juan Martínez-Miranda, Javier Rosell-Ferrer, Colin Matheson, Juan Miguel García-Gómez
Type publication: Journal - *Information Fusion*
Year: 2014
Related Chapter: 3

- Title: *Monitoring changes in daily actigraphy patterns of free-living patients*
Authors: Elies Fuster-García, Javier Juan-Albarracín, **Adrián Bresó**, Juan Miguel García-Gómez.
Type publication: Congress - *International Work-Conference on Bioinformatics and Biomedical Engineering (IWBBIO)*
Year: 2013
Related Chapter: 3

- Title: *Actigraphy Pattern Analysis For Outpatient Monitoring*
Authors: Elies Fuster-García, **Adrián Bresó**, Juan Martínez-Miranda, Juan Miguel García-Gómez
Type publication: Book Section - *Data Mining in Clinical Medicine*
Year: 2014
Related Chapter: 3

- Title: *Modelling Two Emotion Regulation Strategies as Key Features of Therapeutic Empathy*
Authors: Juan Martínez-Miranda, **Adrián Bresó**, Juan Miguel García-Gómez
Type publication: Book Section - *Emotion Modeling: Towards Pragmatic Computational Models of Affective Processes*
Year: 2014
Related Chapter: 4

- Title: *Modelling Therapeutic Empathy in a Virtual Agent to Support the Remote Treatment of Major Depression*
  Authors: Juan Martínez-Miranda, **Adrián Bresó**, Juan Miguel García-Gómez
  Type publication: Congress - *International Conference on Agents and Artificial Intelligence (ICAART)*
  Year: 2012
  Related Chapter: 4

- Title: *The Construction of a Cognitive-Emotional Module for the Help4Mood's Virtual Agent*
  Authors: Juan Martínez-Miranda, **Adrián Bresó**, Juan Miguel García-Gómez
  Type publication: Congress - *Workshop on ICT applied to Mental Health*
  Year: 2012
  Related Chapter: 4, and 5

- Title: *Look on the Bright Side: A Model of Cognitive Change in Virtual Agents*
  Authors: Juan Martínez-Miranda, **Adrián Bresó**, Juan Miguel García-Gómez
  Type publication: Congress - *Intelligent Virtual Agents (IVA)*
  Year: 2014
  Related Chapters: 4, and 5

- Title: *Leveraging Adaptive Sessions Based on Therapeutic Empathy Through a Virtual Agent*
  Authors: **Adrián Bresó**, Juan Martínez-Miranda, Juan Miguel García-Gómez
  Type publication: Congress - *International Conference on Agents and Artificial Intelligence (ICAART)*
  Related Chapters: 3, 4, and 5
  Year: 2014
  Award: **Best PhD Project in the Doctoral Consortium**

- Title: *Help4Mood – Supporting Joint Sense Making in the Treatment of Major Depressive Disorder*
  Authors: Maria K. Wolters, Christopher D. Burton, Colin Matheson, **Adrián Bresó**, Aurora Szentagotai, Juan Martínez-Miranda, Javier Rosell-Ferrer, Elies Fuster-García, Claudia Pagliari, Brian McKinstry for the Help4Mood Consortium
  Type publication: Congress - *Workshop on Interactive Systems in Healthcare (WISH)*
  Year: 2013
  Related Chapter: 5

- Title: *Assessment of Usability and Acceptability in a User-Adapted System Addressing Depression and Suicide*
  Authors: **Adrián Bresó**, Juan Martínez-Miranda, Cristina Botella, Rosa Maria Baños, Juan Miguel García-Gómez
  Type publication: Journal (accepted with minor changes) - *Expert Systems*
  Year: -
  Related Chapter: 6

Additionally, the author was involved in other publications in topics not directly related with the current Dissertation. The author wants to highlight his participation in the awarded journal article titled "*An HL7-CDA wrapper for facilitating semantic interoperability to rule-based Clinical Decision Support Systems*" (Sáez et al. 2013), which was selected as one of the four best articles from the literature in the 'Health Information Systems' in 2013 by IMIAYearbook of Medical Informatics.

1.5 Research Projects and Partners

Much of the developed work in this Thesis has been possible thanks to the participation in two research projects. In both, the author of this Thesis has been involved working at full time.

The two research projects are listed below:

- **Acronym: Help4Mood**:
  Title: A Computational Distributed System to Support the Treatment of Patients with Major Depression. (FP7-ICT-2009-4; 248765)
  Financial organization: European Commission. VII Framework Program
  Project budget: 580.919,75 €
  Date of end: 31-12-2013
  Date of start: 01-01-2011
  Main researcher: Colin Matheson
  Summary: Help4Mood project aims to address and significantly advance the state-of-the-art in the research and development of Personal Health Systems through the design and implementation of a distributed computer system to support the treatment and assessment of people with Major Depression. The project will focus on Major Depression in its moderate form, supporting people who are significantly affected but are still able to live at home and may also be working. Help4Mood will focus in particular on reducing depressive symptoms, improving functioning, and preventing the recurrence of symptoms in the future.
  Partners: UEDIN Edinburgh's School of Informatics, I2CAT, Babes-Bolyai University (UBB), FVA new media design, Universitat Politècnica de València

(UPVLC), OBS Medical, Universitat Politècnica de Catalunya (UPC), HWU The School of Mathematical and Computer Sciences (MACS).
Web: `www.help4mood.info`

- **Acronym: PrevenDep**:
  Title: Sistema computacional de ayuda a la prevención de episodios de depresión y suicidio
  Financial organization: Consellería de Sanidad – Generalitat Valenciana
  Project budget: 10.923 €
  Date of end: 31/12/2014
  Date of start: 01/01/2014
  Main researcher: Juan Miguel García Gómez
  Summary: The main objective of PrevenDep is to prevent episodes of depression and suicide. This will be achieved through the continued collection of information self-reported by the patient to identify risk factors and provide information, suggestions and recommendations of activities that contribute to minimize these risks. To achieve this objective the adaptation of an existing computer system developed to help the remote support of major depression is proposed. This adaptation will focus on the contents of the interactive sessions provided by the system which will include material (eg standardized questionnaires) for relevant patient information that allows reliable identification of the clinical condition of the patient and identify particular risks future episodes of depression and suicide. When these risks are identified, the system will provide specific information and recommendations for minimizing the risks identified. In high-risk situations, the system will alert the clinician to establish a direct contact with the patient.
  Partners: Universitat Politècnica de València (UPVLC), Laboratorio de Psicología y Tecnología de la Universidad Jaume I de Castellón (Labpsitec).

Additionally, the author of this Thesis has been working since 2010 in the Biomedical Data Mining research line of the **research group of biomedical informatics (IBIME)**. IBIME was founded in 2000 and it belongs to ITACA Institute of the *Universitat Politècnica de València*. IBIME focuses its research on real problems in the field of biomedical computer by means of advanced pattern recognition and machine learning techniques, modelling, computational prediction and development of tools for biomedical data processing to support biomedical research, health care professionals and their patients.

Chapter 2

State of the art

The research and use of Intelligent Virtual Agents (IVAs; a.k.a. Embodied Conversational Agents, ECAs) as an enhanced tool for Human-Computer Interaction has increased enormously in the last years. One of the fields where this technology has concentrated its efforts is in the mental health care domain. Several advances and applications have emerged focused on how to better interact with and support people in coping with particular issues associated with different mental disorders.

The aim of this Chapter is to present a literature review on the current state in research and applications of IVAs in the mental health care domain, which is the approach of the current Thesis.

This Chapter starts with a brief introduction about the use and functionalities that IVAs can offer, putting emphasis on those especially relevant for applications in the field of mental health. After that, we present an overview of different works that use IVAs as HCI tools to support different mental health disorders.

The search has been focused on two scenarios: Scenario 1 collects papers related to the use of synthetic characters (e.g. avatars and virtual agents) to support the treatment of different disorders. For this Scenario 1 we have selected 146 works (46.05%). Scenario 2 refines the above results, focusing only on those research works in which the IVA is designed to produce an autonomous, intelligent behaviour and to provide a dialogue-based interaction with the user. For Scenario 2 only 9 (2.83%) works fulfil the requirements. The works from the second scenario are close related with the work presented in this Thesis work.

From this review we observed a huge increment in the use of this technology in the scientific community, including new applications in the mental health domain. This increment could be due to common reported benefits of this technology such as that IVA-based systems are capable to empower the user through the promotion of healthy behaviours anytime-anywhere generating new opportunities for patients and caregivers. Clearly, the state of the art in this topic and proposed lines of future work focus on improving the interaction through (1) improved graphical representation of the IVAs; (2) more natural language capabilities; and (3) an adequate non-verbal communication to convey adequate emotions aimed to produce therapeutically useful empathic interactions with the users. Moreover, it is necessary to strengthen the user-centred approach to better provide real time user-adapted content of the sessions provided by IVAs.

> *This chapter is based on a paper that has been sent for publishing as journal paper in (Bresó, Martínez-Miranda, and García-Gómez 2016), which has been focused on clinical research literature published in the PubMed Central (PMC) online database from January 2000 to January 2015 (a total of 317 publications were found)*

2.1 Introduction

The convergence between technology and medicine is providing new tools and methods that aim to improve and optimise clinical resources. A very popular trend in recent years is the use of Virtual Agents (VAs) which represent an advanced form of Human–Computer Interaction (HCI) allowing the users to interact naturalistically with, and become immersed in, a computer-generated Virtual Environment (VE). VAs are usually human-like, animated graphical chat bots designed to interact with humans. For decades, growing interest in the development of VAs has encouraged improvements in the realism of graphics and agent behaviour. These improvements have resulted in better HCI tools and strategies. The use of VAs has been traditionally applied in different fields such as military (Johnsen et al. 2005), entertainment (Ji, Pan, and Li 2003; Gebhard et al. 2008; Mateas and Stern 2003; Andrist, Leite, and Lehman 2013), and education (Paiva et al. 2005; Core et al. 2006; Martínez-Miranda et al. 2008; Castellano et al. 2013).

Regarding the eHealth context, there is a growing need for VA-based systems that can dynamically interact with patients in order to gather/provide personalised information, monitor their health status, and support remote treatments. In the general health context there is a good number of VAs developed for different purposes ranging from the training of clinical professionals (Raij et al. 2007; Kenny et al. 2007) (Wu et al. 2014; Pantziaras, Fors, and Ekblad 2015), to applications that support patient adherence to medication (Bickmore and Pfeifer 2008) and motivating and encouraging the user to do physical exercise (Bickmore et al. 2006). There are also VAs applied to Mental Health (which is the focus of this Chapter) supporting patients with the treatment of phobias (Krijn et al. 2004) (Brinkman, Mast, and Vliegher 2008), posttraumatic stress disorder (Paddock 2002), applications used in the treatment of children with autism (Aresti-Bartolome and García-Zapirain 2014; Tartaro and Cassell 2008; Bernardini, Porayska-Pomsta, and Sampath 2013), interventions to reduce alcohol consumption (Lisetti et al. 2013; Amini, Lisetti, and Yasavur 2014; Yasavur, Lisetti, and Rishe 2013), the implementation of standardized questionnaires for the assessment of depression (Pontier and Siddiqui 2008), and remote systems for the treatment of depression (Martínez-Miranda and Lluch-Ariet 2010).

Results from Atlas 2011 (WHO et al. 2012) confirm findings from prior editions that resources remain insufficient to meet the growing burden of neuropsychiatric disorders. One strategy to address this challenge is the use of computer-based solutions that can reach a greater number of users. In particular, the use of IVAs is suitable for people with mental disorders due to the fact that these patients typically need a durable, constant, encouraging, friendly, personalized solution located "at home" that helps to improve their health conditions. Several efforts have been dedicated to the design and development of better IVAs to support the treatment of different mental health disorders, some of them putting emphasis on some particular characteristics that believable and effective IVAs would implement.

The following sections describe the compilation of representative research works that apply IVAs in the mental health domain. In section 2.2 we describe the main characteristics of an IVA and its advantages of use in the mental health domain. Section 2.3 presents the method used for the selection of the research works presented in this survey. A deeper analysis of the most representative applications is presented in Section 2.4, and section 2.5 presents final conclusions.

2.2 Background

2.2.1 Virtual Agents

Virtual Agents are a combination of Virtual Reality (VR) and agent technology that represents an advanced form of HCI, allowing the user to interact naturalistically with, and become immersed in, a computer-generated environment through complex (such as natural speech, gestures, facial expressions, and gaze) or simple (such as pre-defined questionnaires) communication, engaging face-to-face relationships. IVAs are autonomous and intelligent entities immersed in a VE designed with human-like, animal or cartoonish appearance. In most of the applications, IVAs are the leading actors of the VR or VE, which is a valuable technology for generating virtual spaces or scenarios where the users are located and different stimuli are produced allowing interactions with recreational, educational or clinical purposes (such as rehabilitation, control of phobias and addictions) to be conducted. The goal of this method is to give users the perception of being somewhere else, influencing their feelings using another –virtual– reality. Using these techniques it is possible to represent situations that the users can react to in a controlled way, without exposing the users to face real events. Thus, users can experience extreme situations without the risk of using immersive scenarios.

Depending on the purpose of the designed system, the development of the VE and the VA can vary widely. It can engage the same effort and resources to develop the VE and VA, but depending on the resources and needs it is also possible to develop an agentless virtual environment (Freeman et al. 2010; Jäger et al. 2012; Carter et al. 2008), or an agent without being immersed in a VE (Burton et al. 2012). In some cases we can find VE with VAs, but these VAs only form part of the scene. In these scenarios the VA is a decorative element of the scene, with a passive stimulus and without providing a direct interaction with the user (Yoon et al. 2013; Jarrold et al. 2013). In these cases the virtual characters do not have the capabilities to be considered autonomous or intelligent. On the other hand, there are several scenarios where the VA takes the main role as the peer of the user. These types of VAs currently implement more complex social and cognitive behaviours and are built with a high level of realism in their physical appearance. Recent developments have produced IVAs able to interact taking different roles and personalities with a varied representation of cultural knowledge, emotional reactions, adapting the verbal and nonverbal communication, and learning from past experiences.

2.2.2 Virtual Agents in mental health Care

Perhaps the earliest and most famous VA applied in the mental health domain is the chat bot known as ELIZA created in 1964, which aimed to emulate a Rogerian psychotherapist with capabilities of natural language processing (Weizenbaum 1966). Colby, Weber, and Hilf 1971 presented a conversational paranoid schizophrenic chat bot, in order to simulate a real human interaction. None of these developments had graphical representation of the VA nor provided real intelligent behaviour because the interactions were based on static databases or in the generation of the dialogues using generic responses (for example, responding to "My head hurts" with "Why do you say your head hurts?"). More complex VA technology has been available since the early 1990s and we can find a lot of examples in the literature, many of them developed with clinical purposes. VA and VE technologies have been successfully applied in mental health care for prevention, coaching, training, evaluation, treatment and rehabilitation. The popularity and use of these tools in the mental health domain has grown rapidly and there are several examples of these systems applied to the treatment of different disorders. VAs can enhance cognitive-behavioural therapies simulating a real world with real interactions, and assuring the full clinical control of all the parameters involved during the session. VAs cover different functions such as assessments, psychological interviews, diagnosis, therapies and professional training.

In mental health applications the patient-VA relationship is critical because patients need to feel comfortable and safe, in order to build a good level of trust with the virtual agent. A trustworthy relationship and a good level of intimacy and alliance are required for the patients to feel comfortable disclosing their feelings and to optimise the results of the therapy. Another critical aspect is the VA's capability to empower and motivate patients in order to improve treatment adherence. Over the past years many improvements in VAs technology have been achieved including more realistic appearance (using 3D technology), better emotional reactions (i.e. empathy), and the use of more complex verbal and nonverbal communication, combined with the emergence of new and improved sensor devices (such as body tracking, or emotion recognition) used to detect the affective state in the users. All these developments play a critical role in increasing the believability of VA and promoting better acceptance, which in turn can increase the success of a VA-supported treatment. The role of a VA in mental health applications differs depending on the clinical purposes, sometimes acting as a virtual counsellor, a virtual nurse or a virtual doctor and even as virtual patients (Bickmore and Pfeifer 2008) if they are designed to emulate the symptoms presented in a patient. An overview of these different applications of VAs is presented in more detail in the following sections.

2.3 Survey Method

2.3.1 Goal definition

The overall objective of this study was to collect published journal articles that report the use of VAs (with or without VR) in the mental health domain. We have concentrated on identifying the most representative works published in this topic and drawing attention to the evidence of the growing trend in the use of VA-based systems applied to the selected domain.

2.3.2 Search Strategy

We have performed a search in PubMed Central (PMC) repository from January 2000 until January 2015. In order to filter the most adequate content for our purposes, we defined the following query:

((("virtual coach"[All Fields] OR "virtual agent"[All Fields] OR "avatar"[All Fields]) AND ("mental health"[All Fields] OR "mental illness"[All Fields] OR "substance abuse"[All Fields] OR "psychoses"[All Fields] OR "depression"[All Fields] OR "anxiety"[All Fields] OR "eating disorder"[All Fields]))) AND ("2000/01/01"[PMC Live Date]: "2015/01/01"[PMC Live Date]).

We included in the query the most adequate concepts that ensured us to obtain the maximum number of relevant works. We included in the query the five most common mental health disorders as indicated by the WHO (Campkin 2002): substance abuse, psychosis, depression, anxiety and eating disorders.

2.3.3 Eligibility criteria

In this research work, two scenarios were defined: (1) applications where VAs are used in a mental health disorder acting as part of the scene or acting as an avatar; and (2) IVAs designed to be the main virtual peer of the user with the capability of providing an intelligent and autonomous interaction, which refines the first scenario. In the first scenario we clustered the selected works according to the mental disorder in which VAs are applied including those applications where VAs are part of a virtual reality environment where other synthetic characters also appear.

For the second scenario we added an additional criteria to filter those applications that design IVAs with more complex intelligent and social behaviours that are used as the main character to interact with. Therefore the interaction with the VA should influence and be influenced by the user's actions and should not be limited to the role of an observer (Broome et al. 2013; Freeman et al. 2008) (such as virtual audiences used with users with social phobias (Cornwell et al. 2006)), a puppet or servant of someone else (such as a clinician speaking through an avatar (Hartanto et al. 2014), avatars representing users who do not interact with other characters (Cesa et al. 2013; Hall, Conboy-Hill, and Taylor 2011), or users in Second Life (*second life*) using an avatar to talk with the avatar of other users (Vallance et al. 2014)). For the second scenario we also excluded those applications where virtual agents are used only to provoke a reaction in the user but without a long-term interaction, as in the work by Freeman et al. 2014, in which the use of avatars were concentrated on representing several everyday scenes on the London underground to see how it affects the level of paranoia in some patients. Another example is the work by Staugaard and Rosenberg 2011, in which patients are exposed to different facial expressions in the avatars to measure the reactions in patients with social phobia. The use of virtual agents as first person in eating disorders and obesity is high, mainly due to the fact that this technology makes it possible to show different appearances of the patient's body (Coons, Roehrig, and Spring 2011), but if no real intelligent interaction exists we excluded these works (Normand et al. 2011).

2.4 Results

The execution of the defined query produced 317 articles. The clustering of results by year shows an incremental trend. In 2014, 125 related papers were published compared to the 6 published in 2008. Therefore, we can say that the use of agent technologies applied in mental health disorders is a topic of growing interest (see Figure 2.1).

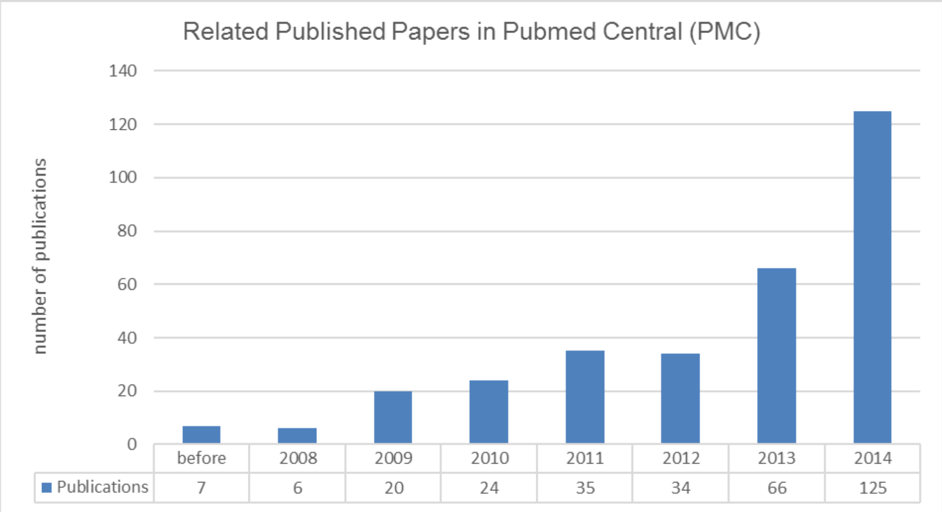


Figure 2.1: Papers published in PubMed Central by year, concerning to the use of Virtual Agents applied in mental health

As illustrated in Figure 2.2, the 317 were reduced to 146 full-text articles for the Scenario 1 (46.32%) in which a set of the most representative are briefly introduced in Section 4.1. We discarded duplicate papers and those that were out of the scope of the main topic of this review. From this pre-selection we discarded a further 137 dealing with the eligibility criteria of the Scenario 2, getting a total of 9 papers (2.83%) which are described in more detail in Section 4.2. For the Scenario 2, three works have been included in addition to the results obtained from the query. Although these works are not in the PMC repository, the three of them have been cited in the papers obtained from the query and have been considered due that their main research objectives and developments are close related with the focus of this review. These three additional works are JUST-TALK (Frank et al. 2002) cited in Hubal et al. 2008; OVDIC (Yasavur, Lisetti, and Rishe 2013; Amini, Lisetti, and Yasavur 2014; Lisetti et al. 2013) cited in Pelachaud 2009; and *European Project Help4Mood* cited in Kartsakli et al. 2014. In the architecture of the Help4Mood system is integrated the Framework presented in this PhD. Hence, this work is not presented in detail in this review chapter and is not considerate as current state of the art. The Help4Mood system is presented as a Case of Study of this Thesis in the Chapter 5.

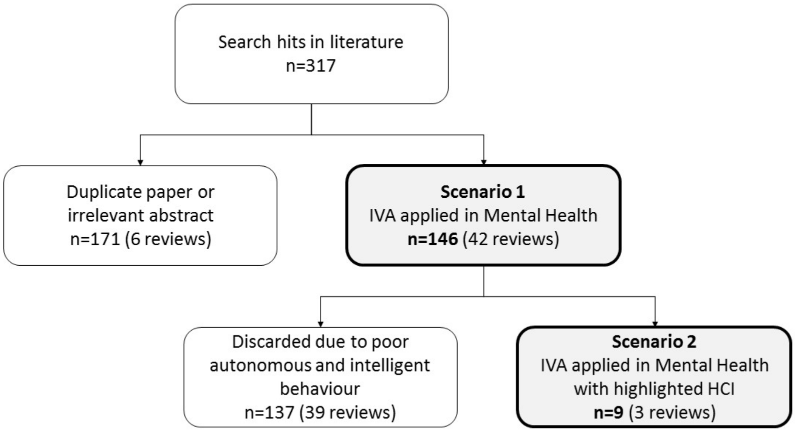


Figure 2.2: Review flow diagram that shows the obtained results in the both defined scenarios. The Scenario 1 includes VAs applied in the mental health disorder domain. The Scenario 2 refines previous results and only selects works where VAs provided intelligent and autonomous interaction with the user. Help4Mood is included in the final nine results, but in this Chapter it is not taken into account. The Help4Mood system will be detailed in Chapter 5, as an evaluation Case of Study in a real environment of the work presented in this Dissertation.

2.4.1 Scenario 1: Mental health disorders supported by virtual agents and virtual environments

In this section we grouped the most representative works obtained from the query, dealing with the WHO classification of mental and behavioural disorders identifying 99 different categories such as dementia, schizophrenia, schizotypal disorder, manic episode, schizoaffective disorder, depressive episode, bipolar affective disorder, persistent mood disorder or phobic anxiety disorder (WHO et al. 1992). There is a significant number of published papers in which VAs are used in many of these disorders providing efficient clinical outcomes (García-Palacios et al. 2002; Castro et al. 2008).

One of the most targeted disorders through the use of VAs is anxiety. In the treatment of anxiety disorder it is necessary to activate and update the fear structure and to improve symptoms of anxiety. In a previous review performed by Powers and Emmelkamp (Powers and Emmelkamp 2008) they identified and compared 13 studies. One of the conclusions reported in (Powers and Emmelkamp 2008) is that patients had a small preference for Virtual Reality Exposure Therapy (VRET) over the vivo exposure therapy for treatments such as phobias. Moreover, VRET produces better outcomes than imagined exposure. Additionally, VRET sessions showed longer effects. Parsons and Rizzo 2008 presented another meta-analysis of 21 VRETs for the treatment of anxiety disorders and specific phobias (i.e agoraphobia, acrophobia, aviophobia, and arachnophobia). This study reveals that VRET has potential for the treatment of anxiety and several specific phobias reducing symptoms and strengthening the affectivity. Lee et al. 2004 developed and assessed a VRET for the treatment of nicotine addiction. This system was based on Cue Exposure Therapy (CET), which consists in exposing the patient to cues associated with their addiction in order to extinguish this association. The VE represented a virtual bar and some characters such as a virtual smoking barman. The conclusion about this work, revealed that VRET produces better outcomes than other devices and that these kind of tools helps in nicotine dependence therapy. Hartanto et al. (Hartanto et al. 2014) also agrees with the benefits of VRET. In particular, he asserted that the social dialogue situation, and the dialogue feedback responses (negative or positive) between a human and a VA could be effectively manipulated for therapeutic purposes. Freeman et al. 2008 used a London underground scenario as a VR social environment in order to study factors related to social anxiety and paranoid thoughts. Freeman concluded by asserting that social anxiety and persecutory ideation share many of the same predictive factors. In Gilboa's review (Gilboa-Schechtman and Shachar-Lavie 2013), she studied how some VA features may affect patients with Social Anxiety Disorder (SAD). For example, regarding VA gaze, Gilboa highlights that women with high levels of social anxiety exhibited greater increase in avoidance while responding to male avatars with direct gaze compared with averted gaze. Aymerich-Franch, Kizilcec, and Bailenson 2014 proposed a VR scenario with an avatar of the patient, with the objective of treating social anxiety generated when the patient has to speak in public. Wong Sarver, Beidel, and Spitalnick 2014 presented and evaluated the feasibility, acceptability and credibility of a virtual school environment focused in the treatment of social anxiety disorder in preadolescent children. In Wong Sarver, Beidel, and Spitalnick 2014, the user practice his social skills while interacts with different characters in a different school locations. All the iterations are based in a combination of preprogrammed verbal and non-verbal responses.

There is an important number of research works that use virtual reality in the treatment of phobias where the most treated are those related to insects (Michaliszyn et al. 2010) (Parsons and Rizzo 2008) (García-Palacios et al. 2002). Nevertheless we can also find the application of VAs in the treatment of unusual phobias such as gelotofobia. Gelotofobia is a type of social phobia of the fear of being laughed at.

Ruch et al. 2014 used a VA with different types and intensities of laughter in order to post-analyze the perception by the patient of the facial laughter expressions.

Autism in children is another hot topic in the use of this technology. Lahiri, Warren, and Sarkar 2011 used a talking VA in order to study the eye-tracking of the user. This VA did not react to user conditions so the communication remains unidirectional: only from the VA towards the user. The results obtained by Kandalaft et al. (Kandalaft et al. 2013) suggested that virtual reality platforms are a promising tool for improving social skills, cognition, and functioning in autism. In order to study social attention in children with autism, Jarrold et al. (Jarrold et al. 2013) carried out a study using a virtual classroom containing social avatars. Maskey et al. (Maskey et al. 2014) tried to reduce phobias and fears in young people with autism combining Cognitive Behavior Therapy (CBT) with graduated exposure in a Virtual Reality Environment (VRE) in which several VAs are present.

Related to Posttraumatic Stress Disorders (PTSD) we can find substantial literature especially those related to warlike scenarios such as the case study of Olasov Rothbaum and colleagues, (Rothbaum et al. 1999) focused on Vietnam veterans (Rothbaum et al. 2001) who were exposed in two virtual environments: riding a Huey helicopter and walking in a clearing surrounded by a jungle. Only one patient was involved in this study so the results were very limited though it was positive in terms of patient recovery. For American soldiers who returned from the Iraq and Afghanistan wars, Rizzo and colleagues (Rizzo et al. 2010) developed and evaluated a VRET application designed for the treatment of PTSD. Additionally, Rizzo (Paddock 2002) led the SimCoach project, in which a web-based VA helps military personnel and their family members with the management of multiple mental health disorders including depression, stress, brain injury, substance abuse, suicide, rehabilitation, reintegration and other relevant pathologies, offering expert advice and healthcare information. The main goal of SimCoach is to engage the user in order to gather user healthcare information, understand their situations, monitor their healthcare, give advice and assistance, and recommend initiating traditional treatment when needed. Another project developed to support the treatment of PSTD was the proposal by Difede et al. (Difede et al. 2007) where the authors evaluated the use of VRET in patients affected by the terrorist attack on the World Trade Center in September 11, 2001.

The goal of the VA in the system RC2S (Peyroux and Franck 2014) was to assist patients with schizophrenia, providing them with cognitive strategies to analyse different social contexts and emotional information in order to develop skills that will help them in their life. Park et al. 2014 conducted a study related to the emotional perception of patients with schizophrenia using intimate avatars versus distant avatars. This study helped to confirm that the patients with schizophrenia have a deficit in emotional perception and social decision-making. Freeman et al. (Freeman 2008) reviewed the works related to virtual social environments in schizophrenia. Specifically, he focused on the assessment of symptoms, identification of symptom markers, establishment of predictive factors, tests of putative causal factors, investigation of the differential prediction of symptoms, determination of toxic elements in the environment, and development of treatment.

Regarding depression, we highlight works as eSMART-MH which is an avatar-based system (Pinto et al. 2013) that tries to educate and inform young patients in order to provide them with self-management skills to reduce depressive symptoms and pre-empt future illness. We can find serious games such as SPARX (Merry et al. 2012), which is a treatment for adolescents with depressive symptoms that tries to apply interventions during the game levels.

Substance abuse is another topic that can be effectively treated with very good clinical outcomes using virtual agent technology (O'Donohue and Ferguson 2006) and e-Treat in general (VanDeMark et al. 2010). In a review presented in (Pelachaud 2009), the author referenced relevant authors in Affective Social Computing. One of these authors is Lisetti, who participated in the ODVIC project (Lisetti et al. 2013) (On-Demand VIrtual Counselor) developing an empathic virtual agent to help patients overcome alcohol addiction through the delivery of an evidence-based Brief Motivational Intervention. One of the most studied addictions is tobacco consumption (Selby et al. 2010). Yoon et al. 2013 used the Second Life platform in order to study the effects caused by being exposed to a virtual room with several avatars smoking, and other stimuli (packs of cigarette or ashtrays). A similar approach was published by Culbertson and colleagues (Culbertson et al. 2012) where Virtual Reality Cue Exposure Therapy was used to recreate various scenarios (including a modern apartment with an outdoor seating area, a driving simulation, a replica of Venice beach, or a bus stop in Los Angeles) with several stimuli (cigarette, lighter, music, or coffee).

Second Life is a free use software that easily allows users to interact with each other in a virtual world. People create representations of themselves using avatars. Individuals can customize their avatar and use its functionalities: verbal (the user can speak or write the dialogue shown by the avatar in the virtual world) and nonverbal communication (such as laughing, waving, falling or flinching), and movements through the scenery. Hoch et al. 2012 evaluate the feasibility and impact of translating traditional face-to-face stress reduction program into a Second Life world. He obtained a significant improvement in the clinical quantitative results of the participants. Second Life has become a popular and efficient platform for developing social clinical virtual solutions (e.g. Health 2.0). We can found several works to support and highlight the benefits of using this platform (Suomi, Mäntymäki, and Söderlund 2014; Conradi et al. 2009).

Riva and colleagues (Riva et al. 1998; Riva et al. 2003) are using experiential cognitive therapy (ECT), an integrated approach ranging from cognitive behavioural therapy (CBT) to virtual reality sessions in the treatment of eating disorders (such as bulimia or anorexic) and obesity. In general, these kinds of patients have a disturbed perception of their body image. In this approach virtual reality is mainly used to modify this perception in order to increase patients' body awareness. Results obtained by ECT were better than the results reported by the traditional CBT. The ETIOBE system (Baños et al. 2011) is an e-health platform for the treatment and prevention of obesity in children through a VA to support users with several recommended educational and physical games and other activities (i.e. filling self-report diaries). The goal of this personalised treatment is to teach new knowledge and new skills regarding nutritional and healthy food topics, in order to make patients better and well informed.

The use of VAs in mental health is not only focused on supporting patients but also on improving the training and skills of professionals working with the treatment of mental disorders. These kinds of VAs take the role of patients (Virtual Patients VPs) and are a powerful tool if they have a high level of immersion such as life-size displays, head-tracked rendering, and gesture recognition (Johnsen et al. 2005). JUST-TALK (Frank et al. 2002) is a system that uses natural language and virtual reality technology used to teach police officers basic techniques for managing encounters with individuals with a mental disorder such as schizophrenic, paranoid or depressive people. To achieve this, the system implements a VA in five VEs in which the learner may develop a dialogue and interview with the VP in order to stabilize the situation. Hoffman et al. 2008 provided the first available evidence from an immersive VR system that can be an effective non-pharmacologic pain reduction for burn patients experiencing severe pain during wound care. Regarding paediatric pain, Jeffrey et al. (Gold, Kant, Kim, et al. 2005) presented a literature review about the use of VR for pain distraction, called virtual anaesthesia. This technique can be used in dental pain (Hoffman et al. 2001), for post-operative pain in children (Steele et al. 2003).

2.4.2 Scenario 2: Intelligent, social and embodied conversational agents in mental health

For this second scenario we have focused on the selection of intelligent characters, such as a virtual representation of a person who interacts with the user/patient. The generated interaction needs to be sufficiently complex to allow long-term dialogues between the VA and the user. In some studies, an avatar approaches the user offering to share an alcoholic beverage or cigarettes (Yoon et al. 2013) (Lee et al. 2008), but since the user did not have the possibility to answer and to change the unfolding course of events, we considered this as a non-complex interaction and the avatar as being a singular part of the environment. In these cases, the system only measures the reaction of the patient and an adaptation or interaction between the patient and the virtual agent does not exist. So following the criteria defined for Scenario 2, nine representative works were selected in this review but only eight are commented in this section (we excluded Help4Mood system).

Excluding Help4Mood system, a deeper description of the main characteristics implemented in the VAs and how they are applied to the mental health domain are presented in this section. The summary of the selected works is presented in Table 2.1. The main features implemented in these applications related with the clinical and graphical approach, are summarized in Table 2.2. Focusing on the interaction features, Table 2.3 shows the communication and content planning aspects. Finally, Table 2.4 presents the evaluation method and obtained results of the systems.

eSmart-MH

Pinto and colleagues (Pinto et al. 2013) present the Electronic Self-Management Resource Training for Mental Health (eSmart-MH), which is an interactive and autonomous VA tailored for young adults with depressive symptoms (see Figure 2.3). The main aim of this system is to promote self-management for patient empowerment and education, contributing to the reduction of depressive symptoms in the user. During the interactions with the patient, the virtual health coach is represented in a virtual primary care office setting. The patient is immersed into a virtual primary care environment to interact with the IVA and get information about depression and how to enhance self-managements skills for facing depressive symptoms. The patient can select from a cognitive behavioural strategy called SBAR3, six different topics for interacting with the IVA ("*Share your story*", "*Bring your background*", "*Ask for what you want or need*", "*Review the plan*", "*Reflect on whether it is right for you*", and "*Repeat the plan*").

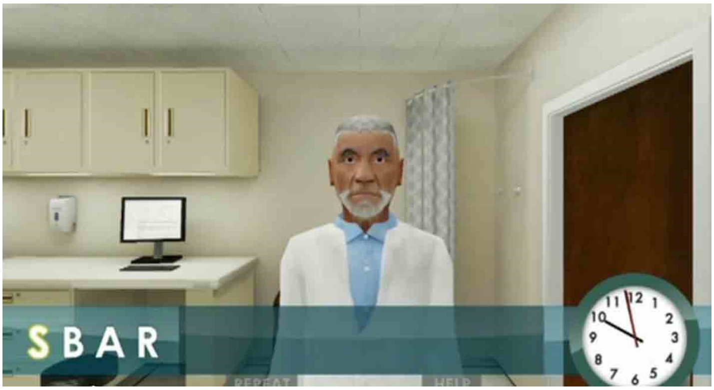


Figure 2.3: Screenshot of the virtual health coach introducing eSmart-MH

A first pilot study conducted by researchers at Case Western Reserve University in Cleveland showed a significant reduction of depressive symptoms over 3 months among young patients (aged 18 to 25 years) exposed to eSmart-MH when com-

Table 2.1: Summary of selected papers in Scenario 2

Work name	Description	Reference
eSmart	Role-play simulation of interactions with health providers for practice of skills, focused on depression in young adults	Pinto et al. 2013
ChangeTalk	Role-play simulation of interactions with patients and families for practice of skills, focused on childhood Obesity	Albright et al. 2012
Children-ASD	Conversational study for monitoring children with autism	Lahiri et al. 2013
RC2S	Role-play simulation of interactions with current daily situations for rehabilitation and practice of skills, focused on schizophrenia	Peyroux and Franck 2014
SPARX	Video game role-play simulation for practice of skills, focused on depression in adolescents	Merry et al. 2012
SimCoach	Therapeutic session provider for informing and detecting problems and recommending visits to a specialist, mainly focused on PSTD in military veterans	Rizzo et al. 2011
JUST-TALK	Role-play simulation of interactions with law enforcement and suspected subjects for practice conversational skills with people with mental disorders	Frank et al. 2002
ODVIC	Therapeutic sessions provider for behavior change intervention in patients with excessive alcohol consumption	Lisetti et al. 2013

Table 2.2: Summary of most relevant system features related with the clinical and visualization approach, in the selected works for Scenario 2 of our review. The categorical variable *Protagonism* indicates the protagonism of the VA in the scene, it can be assess as *High*, *Medium*, or *Low*.

Work name	User	Pathology	System	Appearance and Environment		
				VE	VA	Protagonism
eSmart	Clinicians	Depression	Role-Play	Clinical centre	Full-body VAs	High
ChangeTalk	Clinicians	Obesity	Role-Play	Clinical centre	Full-body VAs	High
Children-ASD	Patient	Autism	Conversational	Different scenarios	Full-body VAs	Medium
RC2S	Patient	Schizophrenia	Role-Play	Different scenarios	Full-body VAs	High
SPARX	Patient	Depression	Video Game	Different scenarios	Full-body VAs	High
SimCoach	Patient	PSTD	Conversational	Different scenarios	Sitting VAs	Medium
JUST-TALK	Law enforce	Some disorders	Role-Play	Different scenarios	Full-body VAs	High
ODVIC	Patient	Substance abuse	eTherapy	Clinical office	Sitting VA	High

Table 2.3: Summary of most relevant features related with the management of contents and iteration aspects, in the selected works for Scenario 2 of our review

Work name	Interaction				Sequence of contents
	Nonverbal communication		Verbal communication		
	Emotional	Gestures	Output	Input	
eSmart	NO	Facial expressions and body movements	Speech/Text	Text/Selection	Based on cognitive behavioral strategy (SBAR3)
ChangeTalk	YES	Facial expressions and body movements	Speech/Text	Text/Selection	—
Children-ASD	NO	Facial expressions and body movements	Speech/Text	Text/Selection	Predefined conversational menu-driven structure
RC2S	YES	Facial expressions and body movements	Speech/Text	Text/Selection	Predefined but flexible conversational decision tree
SPARX	YES	Facial expressions and body movements	Speech/Text	Text/Selection	Organized in seven predefined thematic modules
SimCoach	YES	Facial expressions and body movements	Speech/Text	Speech/Text	—
JUST-TALK	YES	Facial expressions and body movements	Speech/Text	Speech/Text	Based on the current user emotional state
ODVIC	Empathic	Facial expressions and body movements	Speech/Text	Text/Selection	Decision tree

Table 2.4: Summary of evaluation method and result for each selected work in Scenario 2

Work name	Evaluation	Result
eSmart	In this work is included a RCT with 28 young adults with depressive symptoms for 3 months.	The efficacy of the system was demonstrated: Intervention group had a significative reduction in depressive symptoms over control group
ChangeTalk	The study was performed with 35 physicians who tested a prototype for 10 minutes. They filled a pre- and post-questionnaire. Few weeks after, they responded a structured telephone interview focused on the acceptability and usability	A 97% of the participants were agreed that role-play simulations can be effective for learning Motivational Interviewing skills to address child weight
Children-ASD	Eight adolescents with ASD participated in acceptability and usability study, using a full version of this VR-based interactive system	Its adaptive response technology resulted a potential to be accepted by the target population and useful for social tasks. Additionally, it proved its efficiency detecting variations in one's eye-physiological features
RC2S	Not objective evaluation results are presented. Only a set of subjective reports from the participants	All the participants in every sessions reported good level of engagement in the therapy
SPARX	A RCT with 187 adolescents is presented	Remission rates were significantly higher in the intervention group. Hence, SPARX provides a potential alternate to usual care for the target population
SimCoach	A full RCT with 587 participants, focused on (1) software characteristics (flexibility, portability, modularity, use of open standards, reusability, avoiding dependencies on non-open standards, applying rapid development cycles with iterative evaluations, and findability); (2) system efficacy (when necessary, motivate intentions to seek help); (3) and user experience is described in Meeker et al. 2015	Study suggest that SimCoach aligns with best practices in software development; and users had a general satisfactory experience while using SimCoach Beta. SimCoach Beta users were more satisfied and more comfortable than users of a more conventional method. Unfortunately, this study did not show clearly the efficacy level of the SimCoach Beta version.
JUST-TALK	The primary objective was to assess reactions such as perceived utility, ease of use, comfort and learning enhancement associated with the virtual trainer. Seventeen law enforcement personnel who attended the three-day class were enrolled in the evaluation	A majority of the students said that the system was ease to use and the the virtual trainer enhanced their learning in the course. Additionally, they recommended update the scene appearance to a more realistic one
ODVIC	The RCT with 81 participants was performed in order to demonstrate the author hypothesis: characters with empathic abilities provide more positive effects than a non-empathic one (or text-only system) in terms of the users acceptance of the system. The participants answered 56 questions	In general, the most of defined measures were significant improved with the empathic counselor than others

pared to the attention control group. The use of this system demonstrated initial efficacy and a promising developmentally appropriate depression self-management intervention for young adults.

ChangeTalk

Kognito Interactive project is a company dedicated to the development of role-playing training simulations with avatars in several health pathologies such as PTSD (Albright et al. 2012) or obesity (Radecki et al. 2013). Specifically, Radecki et al. 2013 present the childhood obesity training system (called ChangeTalk) and its acceptability and feasibility evaluation. Childhood obesity is usually related to a mental health disorder such as anxiety or eating disorders. In order to prevent and treat this problem it is necessary to educate health providers with the required and effective skills and resources. The role-playing described by Radecki provides a realistic and conversational scenario for clinicians in order to obtain skills in Motivational Interviewing (MI) and other evidence-based communication techniques. MI is a patient-centered method for enhancing intrinsic motivation to change behaviour by exploring and resolving ambivalence. During the interaction, the VA of the scenario provides the users with immediate and personalized feedback according to user's behaviour. This feedback is provided through a spoken dialogue and through an indicator of the degree of motivation for behaviour change (see Figure 2.4).

Figure 2.4: Screenshot of the virtual scenario of ChangeTalk. The mother avatar shows an indicator of the motivation to change the behavior

Results of the evaluation of ChangeTalk showed a high interest from the clinicians in learning MI skills, thus proving to be a valuable review of this method. Finally, the author highlights that the use of ChangeTalk provides the potentially positive implications for patients and for paediatricians.

Virtual Reality Based Adaptive Response Technology for Children with Autism

Children with ASD present impairments in communication skills during social interactions. The Aresti-Bartolome review (Aresti-Bartolome and García-Zapirain 2014) asserted that the use of technologies such as VR and the use of virtual worlds can be very beneficial for the diagnosis and treatment of ASD. Lahiri et al. 2013 presented a virtual social interactive system for children within the ASD (see Figure 2.5). This system encourages the social interaction through two different modules: (1) the task presentation module in which a selected virtual agent talks about different topics, such as sports or films. In this module, the user is only a passive actor. (2) In the bi-directional conversation module, the user interacts with the VA selecting sentences of the dialogue. In addition to the modules of the conversations, there is another module that is responsible for monitoring the user's gaze. The behaviour of the user's gaze is a key element in children with ASD. This module enables the study of how users behave during the dialogue. For example, information about the time spent looking at the face of the VA, or the real-time reactions, i.e pupil diameter. The conversational interaction is implemented by a rule-governed strategy, based on eye-tracking and user responses. This research work presents a usability and efficacy evaluation, concluding that the system contributes to improving social communication skills among the eight participants with ASD.

RC2S

Virtual reality or simulation techniques are recognized methods in the study and treatment of social cognition impairments. This problem assumes difficulties in understanding oneself and others in the social world, including abilities such as emotion recognition, Theory Of Mind (ToM), or social perception. Peyroux and Franck 2014 presented a Cognitive Remediation Program to Improve Social Cognition (RC2S) among people with schizophrenia disorder. In RC2S, patients are represented in a virtual world by a character called Tom, who is trying to improve his social cognition. The patient must control Tom in 10 different scenarios, interacting with other VAs (see Figure 2.6), and train emotion management (anger, fear, sadness, joy, etc.) and other skills in specific social interaction. The behaviour of the VA depends on Tom's responses selection. The cognitive process of the VA is based on a predefined but flexible decision tree that selects adequate facial expressions, gestures, and tone of voice.

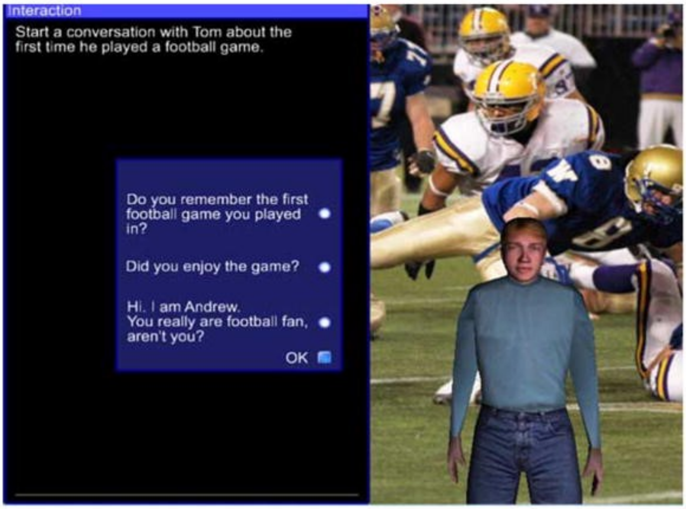


Figure 2.5: Screenshot of the graphical user interface of the Lahiri´s system. The image shows the bi-directional conversation module

SPARX

SPARX (Smart, Positive, Active, Realistic, X-factor thoughts) is an online computerized cognitive behavioural therapy intervention intended to help young adults with mild to moderate depression, stress or anxiety. The main aim of this serious 3D game is teaching users how to resolve their issues on their own through a dialogue based on Cognitive Behavioural Therapy (CBT). There are seven levels that the user must complete. Each level is focused on different problems highlighting the skills and actions necessary to face them, and each one takes about half an hour. At the beginning and at the end of each level, a VA called "The Guide" provides psycho-education, monitors the user progress, and tries to transfer the virtual acquired skills to the real world (see Figure 2.7). During the course of each level, the user interacts with several VAs such as "The Guardian" and "The Mentor".

Merry et al. (Merry et al. 2012) evaluated the SPARX system in order to assess if this system could reduce depressive symptoms better than the usual face-to-face method. In general, the obtained results asserted that E-therapy is effective, practical and low cost. In this clinical trial, 44% of the young people who played SPARX experienced remission (they were no longer depressed) compared to 26% of the young people treated in a traditional psychotherapy group. The final outcomes showed a high adherence levels (62% of the participants finished all the levels of the

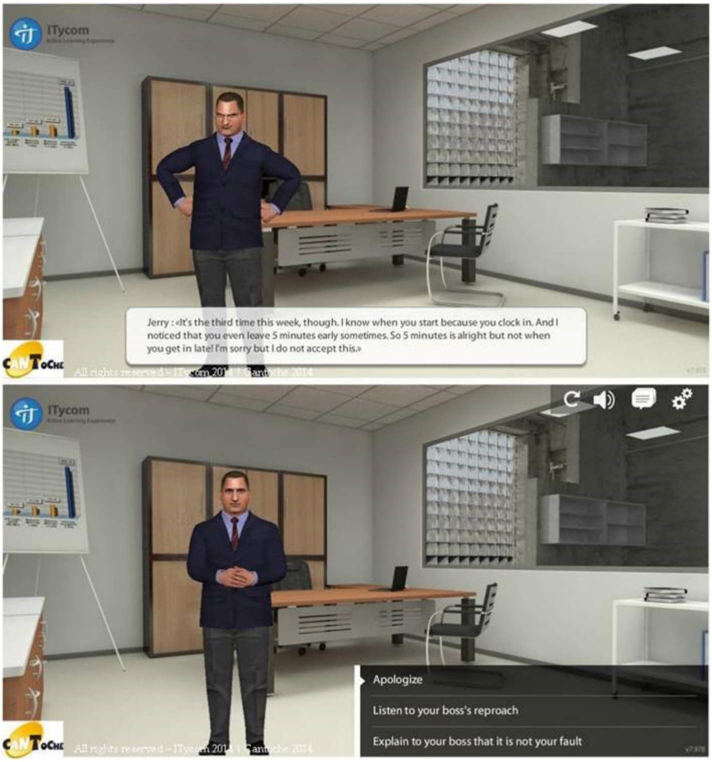


Figure 2.6: Screenshot of one of the virtual scenes in RC2S: Tom is interacting with his boss. In the top image, the boss is reprimanding Tom for arriving late to the work. In the bottom image, Tom is selecting a proper behaviour (Assertive, apologizing for the fault; passive, listening the reproach; Aggressive, not taking the blame).

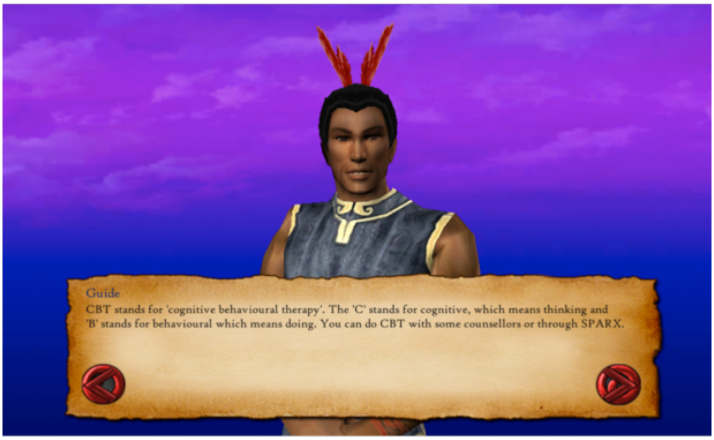


Figure 2.7: This figure shows "The Guide", the VA responsible for guiding the user through SPARX and looking after the user's wellbeing. The Guide also shares his approach and knowledge with the user.

game) and that SPARX is a potential alternative for the treatment of depression in young people.

SimCoach

The SimCoach application (Rizzo et al. 2011) contains one of the most popular online IVAs for supporting military service members (and their families) who need counselling for mental health related problems (see Figure 2.8). Mainly, this system provides support for PSTD but also includes support for depression, brain injury, substance abuse, and prevention of suicide. The behaviour of this IVA is focused on providing users with an accessible and anonymous way of engaging in a dialogue about healthcare concerns. If deemed necessary, the SimCoach will encourage the users to go to a clinical specialist to start a formal clinical treatment. SimCoach provided a 3D graphical representation of a highly realistic virtual coach, who was able to manage emotional reactions and communicate with the user by text typing (in the first versions) or using full, spoken natural language interaction.

The virtual coach interacts with the user in order to gather the appropiate information (concerns, needs, and interests) and provides relevant material such as articles, multimedia content, and video testimonials of people having similar experiences.

Figure 2.8: The SimCoach interface, composed of a 3D virtual coach called Bill and text typing panel for conversational interaction.

JUST-TALK

This system (Frank et al. 2002) is designed to train the conversational and negotiation skills of people employed in law enforcement, in order to improve the results of encounters with people with mental disorders. JUST-TALK provides five one-to-one virtual scenarios in which different VPs are located (see Figure 2.9). These VPs simulate people with different mental disorders such as schizophrenia and depression. The system supports the user with the assessment of the situation and the goal is to stabilise the current situation through interaction with the VA. During the interaction, the VA uses verbal and nonverbal communications, such as body movements and facial expressions in order to convey different emotions (anger, fear, depression and confusion) to the user. The emotional state of the VA is influenced by the user's verbal inputs, which are classified in 8 different classes: commands, queries, requests, informative statements, statements of appreciation, statements of understanding, threats, or insults and/or use of profanity. Based on the current emotional state, the VA will choose the most appropiate response from 5 different defined types (challenging, questioning, denying, getting confused, and responding to the officer's request or query).

The system was evaluated in order to assess reactions such as perceived utility, ease of use, comfort and learning enhancement associated with the virtual trainer. All of these results were extremely encouraging and demonstrated the potential of the JUST-TALK system for training police officers in interactions with people with mental disorders. Some specific recommendations were focused on the improvement of the realism of VA appearance and on the extension of the subject dialogue.

Figure 2.9: A VA in the JUST-TALK system representing a dishevelled white male adult. The user must determine if the VA is hostile or not, and try to obtain his cooperation.

ODVIC

Christine Lisetti and colleagues present the work performed in the ODVIC project in several publications (Lisetti et al. 2013; Amini, Lisetti, and Yasavur 2014; Yasavur, Lisetti, and Rishe 2013). ODVIC is an empathic ECA that delivers computer-based Brief Motivational Interventions (BMIs)(see Figure 2.10). It is focused on substance abuse, specifically in alcohol consumption. The VA in ODVIC adapts its behaviour (verbal and nonverbal actions) in real time based on the course of the interaction with the user. ODVIC implements a user model in order to personalize the content of the interactions. The implemented user model includes demographic information and other variables grouped in 6 categories: motivation, personal attributes, frequency of drinking, risk factors, consequences, and dependence.

The emotional responses in the ODVIC VA are based on different input data (such as the user's facial expressions) to infer –using a decision tree– the most adequate empathic responses during the interaction. Lisetti and colleagues highlighted that the use of empathy is a critical therapeutic condition in order to create an adequate atmosphere of safety and acceptance where users feel free to share their feelings. ODVIC was evaluated in terms of acceptance, perceived enjoyment, and intention to use the system, among other dimensions. Its positive results showed a better user experience using ODVIC than other text-only interface or a non-expressive character.

Figure 2.10: ODVIC embodied conversational agent in an office-based scenario.

2.5 Conclusions

The presented review demonstrates that the research and application of Virtual Agent technology in the mental health domain is increasing due to its several benefits: the provision of therapy-based information and activities at any place such as the patient's home; the safety that virtual environments offer during the treatment through the exposure to simulated stimuli, thus avoiding the risks of harm or embarrassment produced in real scenarios; and a full monitoring of patient behaviours. Nevertheless, there are still some factors that hinder a full adoption of these systems such as the lack of protocol and device standardisation, or the cost required to carry out full clinical trials that demonstrate the clinical efficacy of these solutions.

Despite the growing popularity of this technology, there are not many examples of developed IVAs that effectively adapt their behaviour based on long-term interactions with the user that successfully promote desirable changes in the users. Therefore, we confirmed that although the application examples we have described are now a powerful trend, further efforts are required to develop solutions that fully support psychotherapeutic interventions. Better strategies in the development of appearance and behaviours in IVAs are still key aspects that need to be addressed to effectively facilitate users' adherence and achieve clinical objectives.

During the therapy-based treatment of mental disorders it is necessary to build a good level of trust between the patient and the counsellor in order to achieve the sharing of personal information and thoughts. Several research works are currently studying specific parts of verbal and nonverbal behaviours to be implemented in

IVAs with the aim of facilitating long-term trust relationships with users. For example, Kang et al. 2012 presented a study highlighting the association of intimate self-disclosure and nonverbal behaviour in a VA during counselling interactions. They demonstrated that the appropriate representation of nonverbal behaviour in a VA such as head tilts and pauses resulted in highly intimate self-disclosure increasing the efficacy of the sessions. On the other hand, head nods or eye gazes caused less intimate self-disclosure. Nonverbal behaviours are a powerful means of communication. Sometimes, nonverbal communication is more complex than verbal communication and it could transmit more information, such as specific emotions and empathic responses. In a complementary work, Jason Tsai et al. 2012 provide the first examination of agent-human emotional contagion. Their work concludes that the facial display of an emotion by a virtual character will result in emotional contagion with a human viewer.

Numerous studies focus on the high importance of eye movements in VAs, engaging and helping in the communication process (Vertegaal et al. 2001; Peters et al. 2005; Garau et al. 2001). Lance and Marsella 2007 have published several works about eye movements and general gaze behaviour (coordinated movement of eyes, head, neck and even torso) confirming the importance of VA gaze behaviour in acquiring more natural and intuitive human-agent interaction. An example is the work that identifies the needed of emotional expressivity in a VA and studied the close relationship between emotions and movements of head and torso during gaze shifts. In a further work Lance and colleagues implemented a model called Gaze Warping Transformation (GWT) that maps between emotions (such as joy, sadness, anger, fear, disgust and surprise) and the physical manner of the gaze in order to create more believable and emotionally expressive gaze shifts in an interactive virtual human (Lance and Marsella 2008). Similarly, Li, Mao, and Liu 2009 present a computational framework that provides expressive emotion in a VA through eyes movement. The presented framework models the pupil size, the blink rate and saccade to represent six intermediate emotions: hate, pity, hope, shame, pride and gloating). In a further work, Zheng Li and colleagues (Li and Mao 2012) provide an Emotional Eye Movement Markup Language (EEMML) to describe and generate emotional eye movement in VAs.

Although most of the presented works describe the advantages and benefits of the use of VAs as an additional tool for the treatment of mental disorders, more long-term studies needs to be conducted to assess if some negative effects could emerge. A possible risk in the overuse of this technology was identified by Smhael (Smahel, Blinka, and Ledabyl 2008), which studied the addiction in users that can be generated from the relationship with their online game avatars. Regarding graphic appearance, we highlight that while one benefit of realistic avatars is a greater level of acceptability among users, when the avatar achieves a high level of realism (photorealistic perfection approach) and the behaviour is not as real as its appearance, this can cause the opposite effect (MacDorman et al. 2009) known as the uncanny valley.

From this revision Chapter, we have identified some lacks in which this PhD can contribute in order to improve the HCI in mental health domain. In general, the management processes of the contents offered to the patient were not described in detail. But this process seems not very personalized, adaptive or variable. In some cases it is influenced by user actions, but does not seem to be too reactive systems. Hence, we highlight in the management of contents, the need for providing variability and adaptability in real time according to the detected patient conditions and the clinical requirements. Regarding the nonverbal communication in mental health domain, the management of the emotional link is critical due to many patients have some affective or emotional disorders. Not surprisingly much of the work in IVAs applied to mental health considers the generation and representation of emotional behaviour in the VA as one of the most important features to take into account. The emotional behaviour of the VA was carefully addressed in order to promote and facilitate the acceptability of VAs in users suffering from mental health disorders. Six of the eight selected works uses emotional communication (in major of cases using decision trees), even one of them (ODVIC) uses empathy. Nevertheless, in order to provide an beneficial and effective Therapy, clinicians highlight the use of therapeutic empathy instead "natural" empathy (Martínez-Miranda, Bresó, and García-Gómez 2014b; Martínez-Miranda, Bresó, and García-Gómez 2014a). Hence, this is the second current lack in which we will contribute.

Chapter 3

Management and Planning of Session Contents

Human Computer Interaction (HCI) is a research field aimed to improve the relationship between users and interactive computer systems. A key objective of this research area is to make the user experience more pleasing and efficient, minimizing the barrier between the human's cognition of what they want to accomplish and the computer's understanding of the user's tasks, by means of user-friendly, useful and usable designs. A bad HCI design is one of the main reasons behind user rejection of computer-based applications from users, which in turn produce losses of productivity and economy in industrial environments.

In the eHealth domain, the user rejection towards computer-based systems is a major barrier to exploit the maximum benefit of those applications developed to support the treatment of diseases, and in the worst of the cases a poor design in it systems may cause deterioration in the clinical condition of the patient. Thus, it is highly important a good level of personalisation of the system according to users' needs making them easy to use and contributing to the system's efficacy, which in turn facilitates the empowerment of the target users. Ideally, the content offered through the interactive sessions in these applications should be continuously assessed and adapted to the changing condition of the patient. A good HCI design and development can improve the acceptance of these applications and contribute to promote better adherence levels to the treatment, preventing the patient from further relapses.

In this Chapter, we present one of the two main modules of the Framework described in this Thesis: the **Content Management Module**. It is a novel mechanism to provide **variable and adaptive** daily interactive sessions focused on the support of people with mental health disorders. Additionally, this module is focused in the improvement of the **system usability** and the **treatment adherence**. The personalised sessions generated by the Framework are able to automatically vary and adapt the contents and length of the interactions, willing to get personalised sessions in order to motivate the user with the continuous and long-term use of the system. The tailored adaptation of session contents is supported by decision-making processes based on: (i) clinical requirements; (ii) patient's historical data; and (iii) current responses from the patient.

From the statistical point of view, variability measures how much the patient's scores obtained from standardised questionnaires differ from each other. We related the variability of the Framework with the ability to provide different sessions (which tasks and when they are offered to the user). Regarding adaptability, in computer science field is defined as the ability to fit its behaviour according to changes in its environment or in parts of the system itself. Specifically, the Content Management Module fits the length of the session according on static clinical requirements and current user preferences. The variability and adaptability of the sessions are strongly dependent on the configuration of the system, in which is possible to set the flexibility of these parameters. So, we assume that more flexibility in the configuration (a smaller number of restrictions) and an increase in the number of available tasks, will increase the variability and adaptability of the system.

We have evaluated the Content Management Module through a set of simulations producing different sessions from changing input conditions in order to assess the level of adaptability and variability of the session contents offered by the system. The obtained results indicated a high level of adaptability and variability in the produced sessions according to the input conditions and system configuration.

> *This Chapter is an extended version of the published work as journal paper in (Bresó et al. 2016).*

3.1 Introduction

The ACM Special Interest Group on Computer-Human Interaction (ACM SIGCHI) defines the HCI as a discipline concerned about the design, evolution and implementation of interactive computing systems for human use, and with the study of major phenomena surrounding them (Rusu, Rusu, and Roncagliolo 2008). A good user interface facilitates effective communication between the user and the software, but a bad design of HCI can cause non-acceptance, non-use of the system and user frustration (Bessiere et al. 2006).

Karray et al. (Karray et al. 2008) identified a new HCI generation: (i) **Intelligent HCI**, which are interfaces that incorporates at least some kind of intelligence in the perception process with the user in order to respond accordingly (e.g. the use of natural language understanding and recognition of body movements); and (ii) **Adaptive HCI**, which allows adjustments of its behaviour to every user at any time on the basis of some form of learning, inference, or decision making (Sears and Jacko 2009). Tomlinson et al. (Tomlinson et al. 2007) also defined an adaptive interface as the manner to predict the features a user would find desirable and customizable.

In Adaptive HCI, verbal and nonverbal information (such as facial expressions, posture, point of gaze, and the speed, force with which a mouse is moved or clicked, and bioelectrical signals) can be analysed by the system and infers new knowledge about the user, in order to adapt and enhance the functionalities of the system and in turn achieve higher user acceptance, usability and satisfaction level. This adaptation may refer to the (i) **presentation**, i.e. HOW the interaction is conveyed (such as updating colour screen, sounds, etc. (Börner 1998)), or to the (ii) **content**, i.e. WHAT are the actions to be done during the interaction (such as conversations (Kharat and Dudul 2009)). Additionally, when we are speaking about systems implemented on the Web, there are several authors (Bunt, Carenini, and Conati 2007) (Vasilyeva, Pechenizkiy, and Puuronen 2005) who added a third adaption feature: (iii) the **structure** adaptation or adaptive navigation support which was responsible of changing the appearance of visible links.

One of the applications where a good HCI design is important is in the medical domain due that this kind of applications could provide great benefits to support tasks related with the diagnosis and treatment of patients. Nevertheless, if the design of these applications is faulty or erroneous, it could be harmful and it could have serious consequences for the users such as the treatment abandonment, which could lead to a worsening of the patient's health, or cause a relapse (Novick et al. 2010).

A particular critical field is the use of HCI techniques in the mental health area where the discontinuation of the treatment increases the risk of suicidal and death (Ward et al. 2006). The design of HCI features in applications of computer-based psychotherapy must be performed taking into account the particular characteristics of the targeted users such as their cognitive capabilities and limitations (Patel and Kushniruk 1998). In particular, patients with Major Depression have associated a distorted and negative thinking which makes them prone to suffer anxiety, frustration and stress when interacting with computer systems (Safford and Worthington 1999). Important efforts are needed to develop systems that can be widely accepted and improve the adherence to computer-based psychotherapy.

In this Chapter we describe the architecture and the functionality of the Content Management Module, which is included in the adaptive HCI Framework presented in this PhD Dissertation. Specifically, the work presented in this Chapter is concentrated on the generation of tailored sessions (i.e. WHAT their contents are), based on the analysis of user (objective and subjective) inputs and the planning of the daily interactive sessions. The algorithm developed for the planning of the contents for the daily interactive sessions is based on the knowledge inferred from:

- Objective and subjective collected data from the patient.
- Historical data that forms a dynamic model of the user.
- Set of requirements pre-defined by the clinicians.

The work performed about the HOW to convey the session contents to the patient is presented in the next Chapter and in (Martínez-Miranda, Bresó, and García-Gómez 2014a) (Martínez-Miranda, Bresó, and García-Gómez 2014b) (Martínez-Miranda, Bresó, and García-Gómez 2014).

The hypothesis that conducts the performance of the Content Management Module is that "***the dynamic selection and planning of the activities to be included in daily interactive sessions for the treatment of Major Depression based on a user model would generate better adaptive and varied content***". Hence, the generation of personalised and varied content can in turn contribute to promote the usability and the adherence from users to the system aimed to support the treatment of major depression.

In order to assess how much our proposed Framework is able to generate enough levels of adaptive and varied sessions we evaluated our system running a set of simulations that represent daily interactions between the user and the system. The aim of this evaluation is the functional validation of the Framework through a statistical analysis of adaptability and variability levels of the produced contents. The rest of the Chapter is organised as follows: in Section 3.2 we present the related work. The functionalities implemented to get the adaptive and variability levels are commented in Section 3.3. Section 3.4 describes the design and implementation of the proposed module,which is included in the presented main Framework. The evaluation and obtained results are described in Section 3.5. Finally, section 3.6 presents some conclusions.

3.2 Related Work

Human-Computer Interaction emerged in the early 1980s, but in the last decade there was an increasingly improvement in the field due to more research investment producing the development of new methods and technologies. The recent achievements in this area obtained new approaches such as adaptive HCI, which has been applied in several areas. Regarding Web platforms, we can find adaptive user interface focused on web searching such as the study of Kinley (Kinley et al. 2014), who examined the relationships between users' cognitive styles and their Web searching behaviour. This study may help to provide an adaptive navigation interface that can facilitate efficient retrieval of the relevant search results. In eLearning systems, the adaptive learning interfaces were used to adapt courses, learning material and activities to the learner's individual situation, characteristics and needs (Graf et al. 2014). The development of applications for mobile devices is one of the most popular area in which adaptive HCI is applied. Mobile applications are complex since they need to provide sufficient features to variety of users in a restricted space where a small number of components are available. Some authors had proposed their frameworks for mobile applications to make the user interfaces automatically adapted to the users. Using data mining (K-means clustering algorithm) Nivethika et al. (Nivethika et al. 2013) adapted the application to the experience level of the user based on user historical interactions. Fukazawa et al. (Fukazawa et al. 2009) proposed and evaluated a method that ranks (using Ranking SVM -Support Vector Machine-) the menu functions of a mobile application based on user operation history. Bae et al. (Bae, Oh, and Park 2014) proposed an adaptive transformation framework that automatically adjusts the content and the appearance to different devices (different sizes and capabilities).

The health care domain is a significant area in which adaptive HCI can be of great benefit to eHealth systems where a main challenge is the management and delivery of critical information in an easy way to understand to heterogeneous groups of patients (different individual abilities, interests, and needs) (Vasilyeva, Pechenizkiy, and Puuronen 2005). One of the main goals in this domain is to enhance the acceptability and usability of health care applications, thereby contributing to a better personalisation of the system outputs to a particular user (i.e patient or doctor or both).

Adaptive techniques in HCI have been integrated in several Clinical Decision Support Systems (CDSS) in all stages of medical treatment and in most of the medical areas. Sherimon et al. (Sherimon et al. 2014) presented an adaptive questionnaire for diabetic patients based on ontologies, semantic profiles, guidelines, and risk assessment. This questionnaire adapts itself based on patient's medical history. Bental et al. (Bental et al. 2000) describe an adaptive medical system for the patients with cancer. It uses both content and navigation adaptation. The content of the presented information is adapted to patient's situation and disposition, to the process of illness and treatment. The system decides both what to present and how to present it. The additional hyperlinks to the explanation of the terms used in the texts are generated according to the patient's profile. The system proposed by Francisco-Revilla et al. (Francisco-Revilla and Shipman III 2000) supports adaptive medical information delivery of different medical tasks for users with different level of expertise. This system supports three tasks: description of medical procedures, supporting the diagnosis, and providing information on health concerns. The work described in Giorgino (Giorgino et al. 2005) presents a prototype of a home monitoring system for hypertensive patients through a dialogue on the telephone with an intelligent system. The system implements an automatic speech recognition module in order to collect data about their health status (such as blood pressure, heart rate, or weight) to infer an evaluation using medical guidelines. The strategy of the dialog was able to adapt its behaviour to match the context of the call and to the ability of the human caller. Other related work was presented by Kharat et al. (Kharat and Dudul 2009) in which they presented a system able to generate conversations with humans based on emotion recognition from facial expressions using neural networks.

Several Knowledge-based techniques in Artificial Intelligence are available to represent the knowledge in a DSS. One of the most popular technique used for problem solving in intelligent systems are recommendation systems such as Case-Based Reasoning (CBR) which uses past store cases to solve a new problem by recalling similar cases; and Constraint-Based Recommendation that is based on explicitly defined set of variables and constraints. Another popular technique is Rule-Based System (RBS) which solves problems by facts and rules derived from expert knowledge. We can find RBS applied in different health domain, such as in (Bresó et al. 2015b) in which a RBS was developed and evaluated in the prevention and treatment of diabetes mellitus. In (Serhani, Benharref, and Nujum 2014) an adaptive RBS implemented an iterative technique based on previous experience to increasingly improve clinical-decision making. So a rule-based system can only be implemented if comprehensive knowledge is available. It is possible used hybrid of these systems such Ekong et al. (Ekong, Inyang, and Onibere 2012), where neural networks, fuzzy logic and CBR are combined to model a DSS for the diagnosis of depression disorders. Other hybrid example is providing by Wang et al. (Wang et al. 2007), where he combines CBR and RBS with fuzzy theory for planning treatments in young people with mental disorders. So, a properly acquisition, representation and management of this knowledge is the responsible of the behaviour of the system, so it will determine the efficiency of the HCI.

In the context of adaptive HCI applied in computer-based psychotherapy for the treatment of anxiety or depressive disorders, we found systems that implement Cognitive Behavioural Therapy (CBT) as the key component of the session's content such as *Beating the Blues* (`http://www.beatingtheblues.co.uk/`) (Van Den Berg et al. 2004), Overcoming depression (Colby and Colby 1990), or *MoodGym* (`https://moodgym.anu.edu.au`) (Paddock 2002). The content of the sessions is predefined on sequencing CBT activities where the user continuously follows the path that the CBT therapy sets and patient responses do not influence the planning of the disclosed activities. One of the initiatives that uses a system similar to the one described here is the *SimCoach* project (`http://www.simcoach.org/`) (Ekong, Inyang, and Onibere 2012), which is presented in Chapter 2. SimCoach does perform dynamic planning of session's content before the next activity is disclosed depending on the patient response. The system provides a text analysis mechanism applied to patient input. The system detects keywords associated with different texts/activities and infers the next more suitable activity. A key difference regarding our own architecture is that the content of the session is not only adapted based on the patient's responses but in three main factors: (i) actual patient responses, (ii) historical data, and (iii) clinical requirements. Moreover, the processing and analysis of patient inputs are performed differently according to the type of data received (i.e. questionnaire's scores, signals of physical and sleep activity coming from sensor devices, agreement with suggested activities or the selection of negative thoughts). Finally, Lisetti et al. (Lisetti et al. 2013) presented and evaluated an empathic VA aimed to increase the effectiveness for behaviour change in patient with excessive alcohol consumption, by means of user's engagement and user´s motivation. Main differences between our work and the Lisetti's work is that they analyses only subjective patient input data (such as questionnaires) while in our work we also analyse objective data collected from a set of sensor devices to provide useful and personalised treatment-related activities.

3.3 Functionality requirements

The purpose of an adaptive and variable system is to provide individual personalized sessions and provide new experiences in order to avoid the monotony and user discouragement. To do this, the systems must be sensitive to changes in the environment and must be able to react appropriately. These reactions must be generated at appropriate moments to avoid the creation of inconsistencies. For example, the system should provide adequate information when a user requires it; act quickly and decisively in emergency situation; or congratulate the user after achieving some merit.

The mood of depressive patients is very variable, so it can be negatively influenced when using a computational system if it is hard-to-use, ineffective or shows unclear messages (Lazar, Jones, and Shneiderman 2006). The length of the session is a critical aspect in this field, as it can be frustrating to the user. The user can even drop out the treatment if he perceives that the system does not suit their needs, and does not take into account the information he provides. But the clinical background of the system must not be forgotten. The sessions are based on the clinical requirements defined by the clinicians. Therefore, the system must adapt its length to the user preferences, but meeting the predefined clinical objectives. Sometimes the user will demand a short session but the system, in order to achieve the clinical objectives, shall plan a longer session than the expected by the patient.

The term ***adaptation*** in computer science refers to a process, in which an interactive system adapts its behaviour to individual users based on information acquired about the user(s) and its environment. The concepts Adaptive and Adaptability are similar, but not equal. Adaptivity indicates a system that adapts automatically to the users according to changing conditions, i.e. an adaptive system. Adaptability refers to the situation when users can substantially customise the system through tailoring activities by themselves, i.e. an adaptable system. Benyon and Murray 1993 asserted that an adaptive system should follow the architecture of the three models:

- *User model* or *model of other system*, that describes the characteristics which can be altered.
- *Domain model* or *model of system*, which represents the logical structure or functioning of the system.
- *Interaction model* that is a representation of the current interaction between the user and the system.

The quality of the content offered to the user is critical. The system must select the appropriate content and sort it conveniently. Therefore, it has to meet the specified requirements and evaluate the clinical user interaction. This planning must be performed in each of the interactions at runtime to ensure that the system presents an adequate variability.

Regarding the term ***variability***, there is no common understanding of the nature of variability in the software architecture community (Galster and Avgeriou 2011). Normally, it refers to the changeable customization of the system configuration. In this sense, the proposed Framework provides a high variability. Clinicians can adapt the Framework behaviour easily in order to focus in specific patients, specific stages of the treatment, specific medical approaches, etc. But in this PhD, the term variability refers to the property of being able to provide variable results, that is in the session's contents. The variability reflected in the session's contents highly depends on the clinical configuration and also on the user interaction. A flexible, modular and dynamic approach in the development of the Framework is needed.

Based on these considerations, there are some functionalities that our system must achieve in order to become enough adaptive and variable:

- Management of the user model in order to update the new incoming user data. The data included in this model should represents the current and historical patient condition in order to personalize the interaction.
- Definition of a model of the system in which clinical requirements and general system features are defined.
- A knowledge processes system that implements the interaction model in order to infer new adequate and adapted actions.

- Modular design and development.

3.4 Design of a modular architecture

The Content Management Module is the first module included into the Framework presented in this Dissertation. It is responsible for collecting and analysing the input data, and for producing the content of the daily sessions. The design of the Content Management Module has been performed to be modular in order to facilitate scalability, flexibility, and maintainability. Both modules that form the complete Framework have been designed to be smoothly extended with new contents that can be included in the sessions or easily adapted to other mental health disorders where a continuous monitoring combined with daily sessions could benefit the treatment.

The Figure 3.1 shows the general architecture of the proposed Framework, but modules of the Content Management are highlighted. The Framework allows the interaction with the patient through a Personal Monitor System (PMS) that manages a set of sensors, and a Graphical User Interface (GUI) in which a Virtual Agent guides the patient during the therapeutic session. From this interaction, the Framework gathers objective and subjective patient data respectively. This data is processed and analysed by the Content Management Module in order to infer the most adequate routine work. At the end, the second module of the Framework, the Emotional Module, will add to the routine, the emotion with which the virtual agent must communicate with the patient (this functionality is presented in the next chapter).

The work presented in this Chapter is focused in the data processing generated by the four sub-modules of the Content Management Module; they are the responsible for producing the adaptive outputs of the session according to the detected patient's condition: (1) the **Data Analysis Module (DA)** that receives and analyses the signals from the sensor devices in order to infer clinical findings such as Low Activity or Restless Sleep; (2) the **Knowledge Extraction (KE)**; and the (3) **Knowledge Inference (KI)** modules which infer the recommended tasks to the actual session. This set of tasks is selected and sorted by the (4) **Session Planner module (SP)** according to clinical requirements and patient data in order to determine the next more adequate task to perform during the session. The content of the session is communicated through a Virtual Agent to the patient (Martínez-Miranda, Bresó, and García-Gómez 2014a) (Martínez-Miranda, Bresó, and García-Gómez 2014b). In the next sub-sections we detail the pipeline of the modules in the data processing layer. The summary information from each of these modules is showed in Tables 3.1, 3.2, 3.3, and 3.4.

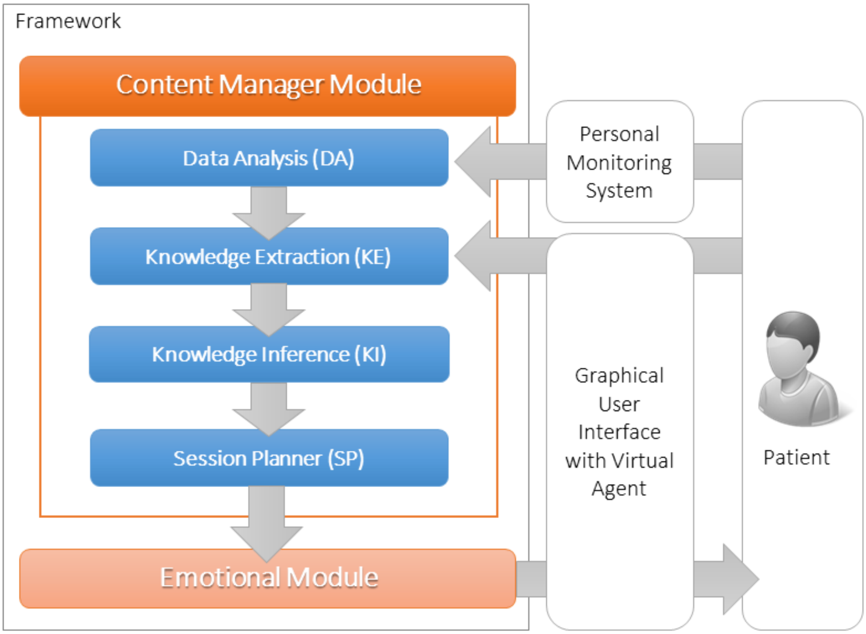


Figure 3.1: This schema shows the general architecture of the developed Framework and the user interaction highlighting the Content Management Module. The patient is able to interact with the Framework by means of an emotional Virtual Agent. The activity sensor devices send the acquired data to the Framework and the content of the daily sessions is generated and continuously adapted through its four sub-modules.

3.4.1 The Data Analysis Module (DA)

This module is responsible for the analysis of the patient's activity data coming from different sensor devices (wrist watch, phone, under-mattress sleep, or a key ring). This analysis allows the monitoring of outpatient activity and the detection of changes in daily physical activity patterns in order to contribute to a better assessment of the progress of the patient's condition. This analysis allows the identification of daily activity models for specific groups of days, such as working days, weekends, or days in which the patient is under specific stages of the treatment in order to detect possible crisis or relevant events in the future. The analysis performed by DA includes the following steps:

- Fusion of the actigraphy signals obtained by multiple sensors: The fusion of the different signals has been done using a robust multi-sensor fusion methodology described in (Fuster-García et al. 2015b). This fusion methodology uses a non-linear regression model based on artificial neural networks to transform all the inputs signals to a common representation space where they can be combined linearly. When the signals are in the same representation space they can be combined linearly to obtain a final fused signal that include the relevant information provided by each of the inputs signals as well as avoiding the influence of missed data periods.

- Detection of missed data, and segmentation of sleep periods: The detection of missed data and the segmentation of sleep periods are based on two steps threshold-based strategy. The first step consists in applying a moving average filter to the actigraphy signal using a 120 min window size. The second step consists in applying a very low threshold to detect periods including missed data, and a slightly higher threshold to detect long resting periods (including sleep).

- Extraction of relevant information from the signals: After the detection of missed data and the segmentation processes, the DA calculates relevant parameters for outpatients monitoring such as: mean daily activity, maximum sustained activity, total hours of sleep, sleep fragmentation, mean activity during sleep and daily percentage of missed data.

- Generation of the daily activity patterns: The main objective of this step is to optimize the daily actigraphy signals to be compared to each other. This step includes: (1) the functional description of actigraphy signals using FDA formalism (Ramsay 2006), (2) the non-linear registration of daily actigraphy signals using a time warping algorithm described in (Ramsay 2006), and the dimensionality reduction of the variables used to described the daily actigraphy signals using principal component analysis (Jolliffe 2002).

- Detection of anomaly activity signals: The detection of anomaly activity patterns could be very useful for the analysis of outpatient's actigraphy patterns by detecting non-usual behaviour in the monitored patients or even creating alerts for the clinicians. To do so the DA module uses an anomaly activity signals detection algorithm based on the K nearest neighbour (Knn) algorithm. The hypothesis of this method is that normal activity signals occur in dense neighbourhoods, while anomalies occur far from their closest neighbours. Detailed introduction to the anomaly detection methods based on Knn can be found in (Chandola, Banerjee, and Kumar 2009).

- Visualization: Once we have obtained relevant information from the actigraphy signals, the DA calculate and display the enriched comparative visualization of daily actigraphy patterns described in (Fuster-García et al. 2013). Moreover, the DA generates a set of simple plots and basic statistical parameters based on the information extracted to be included in the periodic summary report.

All the results of the DA are stored and used by the rest of the components.

Table 3.1: Summary of the main tasks, inputs and outputs of the **Data Analysis (DA)** module which is included in the data processing layer

Main Tasks
• Fusion of the actigraphy signals obtained by multiple sensors (Fuster-García et al. 2015b). • Detection of missed data, and segmentation of sleep periods (Fuster-García et al. 2013). • Generation of the daily activity patterns (Fuster-García et al. 2015a). • Detection of anomaly activity signals (Chandola, Banerjee, and Kumar 2009). • Visualization (Fuster-García et al. 2015a).
Data Input
• Patient's activity data coming from different sensor devices (wrist watch, phone, under-mattress sleep, or a key ring).
Data Output
• Daily activity models (physical activity and sleep patterns) for specific groups of days (such as working days, weekends, or days in which the patient is under specific stages of the treatment). • Detection of possible crisis or relevant events in the future. • Set of graphical plots and statistical calculations to be included in the periodic summary report.

3.4.2 The Knowledge Extraction Module (KE)

The KE module implements a Rule Based System (RBS), composed by a Knowledge Base (KB), an Inference Engine (IE), and a Working Memory (WM). Clinical expert recommendations and clinical rules extracted from medical guides are encapsulated in the KB as clinical expert knowledge using "if-then" rules. For the implementation of the IE, we have selected the JESS Rule Engine because it is fast, stable, and tightly integrated with the Sun's Java platform, the programming language of our Framework. The WM contains the information collected from user responses during the interaction and from the DA results. The input data is analysed using different rules in order to process the results of the DA and the user responses (such as the acceptance or rejection of some task), to infer clinical concepts which are codded using an internal format based on the SNOMED-CT terminology (such as Mild Depression: 310495003, Moderate Depression: 310496002, or Restless Sleep: 12262002) to facilitate the interoperability among the rest of the system's components and with external data repositories (Wolters et al. 2012).

An example of the KE output is based on the Patient Health Questionnaire (PHQ-9) which is a specific self-report questionnaire to assess depression severity during the past 15 days. Question nine on PHQ-9 is related to self-harm and suicidal thoughts. The Algorithm 3.1 shows an example of a KE rule encoding the representation of patient's response to the last PHQ-9 question. The first part of the rule calls a Java function in order to assess if patient suicidal risk exists (using question number 9) or if the overall results of this questionnaire follow a bad tendency in comparison with previous results. In any case, the KE infers the *Deterioration_of_status* clinical concept in order to alert that the patient's condition is bad, which will result in the execution of a crisis plan. The second part of the rule assesses the overall result of the PHQ-9 and classifies the level of depression into one of these SNOMED-CT clinical concepts: Mild, Moderate, or Severe.

Algorithm 3.1: Example of coded JESS rule in the Knowledge Extraction Module. This example is used to assess if exists a suicidal risk or a bad tendency in patient's depression level, inferring the *Deterioration_of_status* concept coded in SNOMED CT as 390772001. Additionally, this rule assesses the depression level and creates a PHQ-9 result concept coded in SNOMED CT (*Mild*: 310495003, *Moderate*: 310496002, and *Severe*: 310497006) based on the current user response

```
;;--------------------------------------------
;; RULE KE_PHQ9_QuestionNumber_9_Received
;;--------------------------------------------
;;'Utils' and 'Data' are Java clases
(defrule KE_PHQ9_QuestionNumber_9
?l <- (Data{name == "Request_PHQ-9_9"}(idSession ?l_IdSession) (value
    ?value)(value2 ?value2))
?ll <- ( variable (name "KE_PHQ9_Summatory") (value ?valueSum))
(test (eq ?l_IdSession(Utils.getIdSession)))
=>
(if (Utils.isEmergencyPlanEnabled (?value ?*
    Threshold_Value_PHQ9_Question9*) then
(bind ?d(new Data))
(?d1 setName "Deterioration_of_status")
(?d1 setCode "390772001")
(Utils.setDate ?d1)
(Utils.setIdSession ?d1)
(?d1 setOntology "SnomedCT")
(add ?d1))
;;Assessment of the questionnaire result
(bind ?d(new Data))
(?d setName "KE_PHQ9_Completed")
(if (and(>= (+ ?valueSum ?value) 0)(<= (+ ?valueSum ?value) 5)) then
        (?d setValue2 "Mild_Depression")
        (?d setCode "310495003"))
```

```
(if (and(> (+ ?valueSum ?value) 5) (<= (+ ?valueSum ?value) 10)) then
        (?d setValue2 "Moderate_Depression")
        (?d setCode "310496002"))
(if (and(> (+ ?valueSum ?value) 10) ) then
        (?d setValue2 "Severe_Depression")
        (?d setCode "310497006"))
(Utils.setDate ?d)
(Utils.setIdSession ?d)
(?d setOntology "Snomed")
(add ?d)
(retract ?ll)
(retract ?l))
```

Similar concepts can be inferred from the analysis of the data collected from the actigraphy sensors to assess the physical activity and sleep patterns of the patient such as Low Activity or Restless Sleep. The inferred clinical concepts are parsed to Java classes using the Java Architecture for XML Binding (JAXB). These java objects are stored in a persistent external file to update the model of the user and to send them to the next Knowledge Inference Module.

Table 3.2: Summary of the main tasks, inputs and outputs of the **Knowledge Extraction (KE)** module which is included in the data processing layer

Main Tasks
• Infer clinical concepts. • Code clinical concepts.
Data Input
• DA findings. • Patient responses. • User Model (demographical + current and historical data). • KE clinical knowledge coded in if-then rules. • KE knowledge base.
Data Output
• Clinical concepts which are codded using an internal format based on the SNOMED-CT terminology (such as Mild Depression: 310495003, or Restless Sleep: 12262002) to facilitate the interoperability among the rest of the system's components and with external data repositories (Wolters et al. 2012).

3.4.3 The Knowledge Inference Module (KI)

As presented in Figure 3.2, the KI implements a similar RBS than the one implemented in the KE but with a different purpose. While the KE infers clinical concepts, the KI infers a set of recommended tasks to be suggested by the system to the patient during the course of the session. These tasks represent specific dialogue acts used by the Virtual Agent during the interaction with the patient and include the suggestion of specific activities, some reminders, the administering of questionnaires to collect more data from the patient or exercises based on Cognitive Behaviour Therapy (CBT) to help the patient in the identification and reflection on thoughts and experiences.

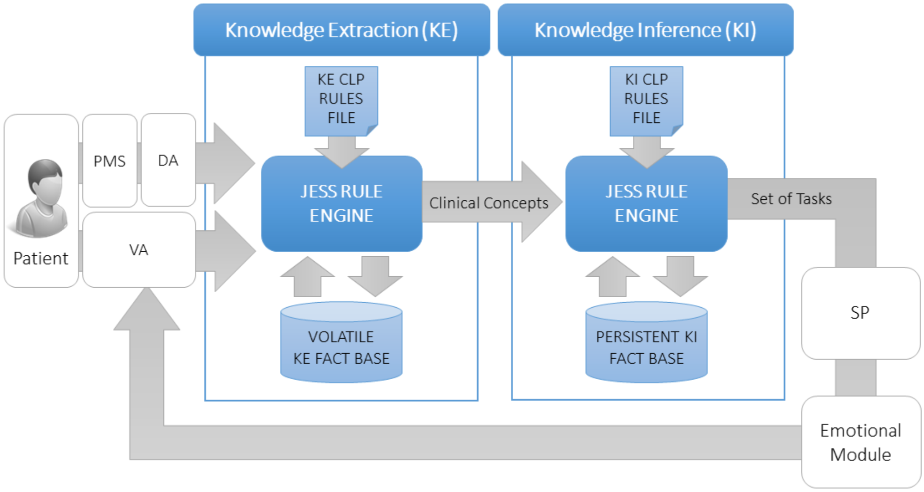


Figure 3.2: Architecture of the Knowledge Extraction and Knowledge Inference Modules. Both implements a RBS but with different purpouse. The KE infers clinical concepts from user data and from analysed data from the DA module. The KI infers a set of tasks from KE inferences.

The inference of the tasks is based on the clinical concepts previously inferred by the KE which are used to build the most adequate set of tasks related to the detected patient's condition. For example, if the KI receives from the KE the "*Restless Sleep*" clinical concept, the KI will infer the task Provide_Sleep_Info used to provide information about some recommendations to be followed that would help the patient to get a better sleep. Other information used by the KI includes some clinical specifications related to the treatment codded in the rule file of the KI. For instance, one of the tasks offered to the patient is the setting of at most three activities to carry out during the current week (e.g. "*go shopping*", "*call a friend*", "*take a walk*", etc.). When the system detects that the patient has configured a weekly activity plan ("*Configure_Activity_Plan*"), the KI will provide the patient with some reminders about the selected activities ("*Ask_For_Planned_Activities*") and will get information about whether the patient has performed the activity plan and how many times during the week those activities were executed. Finally, the historical data retrieved from the user's model is also taken into account to infer new tasks. For example, the system can launch some reminders such as "*Activity_Reminder*" or "*Welcome_Reminder*" when it detects that the last data received from the actigraphy sensor or the last user login into the system was more than 3 days ago, which are used to suggest the user the daily use of the system and execution of activities.

Table 3.3: Summary of the main tasks, inputs and outputs of the **Knowledge Inference (KI)** module which is included in the data processing layer

Main Tasks
• Infer a set of recommended tasks.
Data Input
• KE findings (Clinical concepts). • DA findings. • Patient responses. • User Model (demographical + current and historical data). • KI clinical knowledge coded in if-then rules. • KI knowledge base.
Data Output
• Set of tasks, which include the suggestion of specific activities, some reminders, the administering of questionnaires to collect more data from the patient or exercises based on Cognitive Behaviour Therapy (CBT) to help the patient in the identification and reflection on thoughts and experiences.

3.4.4 The Session Planner Module (SP)

The set of tasks inferred by the KI is managed by the SP module, which is the mechanism responsible for planning the patient's activities during the daily sessions. The flexibility and dynamism of the SP adapt the content of the daily session at each interaction cycle depending on the current responses from the patient. It is able to make a new plan if necessary by adding, removing and/or changing the order of the activities in real time, avoiding the repetition of sessions with exactly the same content preventing a routine work by the patient.

The SP plans the most adequate daily session to the patient based on (1) personalized clinical expert configuration following the most appropriate treatment for each patient (or set of patients) which is established using a XML-based configuration file called *TaskPlanning.xml*, (2) information obtained in previous sessions which is used to manage the periodicity of the executed activities, and (3) the user feedback on the current session which is used to make some decisions such as the choice of the session length (number of tasks to offer).

Algorithm 3.2 shows part of the *TaskPlanning.xml* file, in which each task defined by the clinical expert must contain: a priority; its dependencies (some tasks could be blocked or enabled by other tasks); and periodicity (the minimum and maximum number of executions during a week). These settings can produce different types of sessions according to the characteristics of the addressed users or according to the preferred prevention protocol from the domain experts. Different settings will produce different contents in the sessions and the interaction can be more flexible or more restrictive in terms of variability and adaptability. The second set of settings that influence the specific content of each session is the information stored in the user's model that includes past actions executed in previous sessions. The model of the user stores all these data such as activities blocked by the user, the acceptance or not of the proposed activities, and the number of times that the user has performed the proposed activities.

Algorithm 3.2: Example of the clinical requirements for the task Hopeless Beck Questionnaire established in the xml configuration file. Clinicians may define constrains such as priority, dependence, and periodicity.

```
<?xml version="1.0" encoding="UTF-8"?>
...
<item>
        <description>
                <code>10000140</code>
                <snomed>NO</snomed>
                <name>Negative_Thoughts_Activity_Introduction</name>
        </description>
        <enable>YES</enable>
        <typeOfItem>OPTIONAL</typeOfItem>
        <priority>20</priority>
        <minFrec>1</minFrec>
        <maxFrec>7</maxFrec>
        <codeOfDataInDB>80000136</codeOfDataInDB><!--
            Negative_Thoughts_Complete-->
        <repeatable>NO</repeatable>
        <constrains>
                <constrain>
                        <constrainDescription>
                                <code>10000012</code>
                                <snomed>NO</snomed>
                                <name>Welcome_Reminder</name>
                        </constrainDescription>
                        <constrainType>BEFORE</constrainType>
                </constrain>
```

```
                <constrain>
                        <constrainDescription>
                                <code>10000011</code>
                                <snomed>NO</snomed>
                                <name>Welcome</name>
                        </constrainDescription>
                        <constrainType>BEFORE</constrainType>
                </constrain>
                <constrain>
                        <constrainDescription>
                                <code>10000121</code>
                                <snomed>NO</snomed>
                                <name>Farewell</name>
                        </constrainDescription>
                        <constrainType>AFTER</constrainType>
                </constrain>
        </constrains>
</item>
...
</xml>
```

As shown in the Figure 3.3, this module performs a set of sequential steps described as following:

- **Interruptions detector**: Interruption tasks are special tasks that must be executed immediately, clearing the current plan (e.g. the execution of a Crisis Plan triggered by a requesting of the user in the GUI or triggered by a low score detected in PHQ-9). Normally, this kind of activities finishes the system execution with a farewell message. In this step, the SP checks if some of the incoming tasks are an interruption task. If there is any interruption, the current plan is removed and the interruption task will be selected as the next task to execute, cancelling the next stages of planning module. If no interruption is detected, the next cycle is executed.

- **Task Classifier**: In this step, the SP classifies the tasks as required or optional using the information established in a configuration file called *TaskPlanning.xml*. Additionally, in this file we can set the tasks that the planner will have available, as well as their priorities, constrains, and periodicities. Required tasks are those that must be included in the current session. On the other hand optional tasks can be included or not in the session depending on (1) the number of sessions performed in the current week (*weeklySessionsPassed*), (2) the number of times that the task has been executed (*realWeeklyExecutions*), (3) and the pre-defined thresholds set by the clinicians representing the minimum and maximum number of executions per week of the task (*minExecutions* and *maxExecutions*) defined in the *TaskPlanning.xml* file. According to these thresholds, the optional tasks can be then classified as discarded, mandatory, or available as shown in the Algorithm 3.3.

Algorithm 3.3: Classification of the *Optional tasks* into *discarded*, *mandatory*, or *available* according to the number of executions carried out in the last week regarding the number of executions set in the configuration file

```
For each Task in setOfTasks
{
if (realWeeklyExecutions >= maxExecutions) then
Task.setSate(discarded);
else
        If (realWeeklyExecutions < minExecutions &&
        WeeklySessionsPassed <= minExecutions) then
                Task.setSate(mandatory);
        else
                If (realWeeklyExecutions < maxExecutions) then
                        Task.setSate(available);
}
```

The value of the *weeklySessionsPassed* is set to 1 the very first time the system is started. This value is increased by 1 on daily basis (even if the user does not use the system) to calculate the number of days elapsed since the initial session. At day 7 the value is set again to 1 allowing a new planning of the tasks for the new week. The other *weeklyExecutedActivity* variable controls the number of times that the task has been accomplished in a week. Similarly, this variable is set to 0 every new week.

The discarded tasks are those that reached the maximum number of executions in a week and are not considered for the current session. The mandatory tasks are those needed to be included in the current session in order to reach the minimum number of executions in a week. Finally, the available tasks are those which its minimum number of executions can be still achieved in the remaining days of the week and these tasks may or may not be included depending on the preferred type of session (short, medium or long session).

- **Task Clustering**: In this step, the SP groups the tasks into three sets: Long, Medium, and Short sessions. All required, mandatory, and available tasks are included into the long sessions. The medium sessions are composed of every required and mandatory task plus some of the available tasks. Finally, in short sessions only the required and mandatory tasks are included. The SP algorithm for the clustering of the tasks is showed in Algorithm 3.4.

Algorithm 3.4: Clustering of tasks depending on the classification of each task: The *required* and *mandatory* are always planned. The *discarded* are never planned. And *available* are always included in the long session and randomly selected for the medium sessions

```
For each Task in setOfTasks{
If (Task.isState(taskState.mandatory) || Task.isState(taskState.
    required)){
                sessionMedium.add(Task);
                sessionLong.add(Task);
```

```
                sessionShort.add(Task);
        }
If (Task.isState(taskState. available)){
        sessionLong.add(Task);
        If (alternate) {
                sessionMedium.add(Task);
                alternate=false;
        }
        else{alternate=true;}
        }
}
```

- **Tasks Ordering**: According to the length of the session adapted to each patient, the SP module selects the adequate cluster and sort the included tasks according to the priorities and constraints (after, before, enable-by or block-by) defined by the clinicians in the *TaskPlanning.xml* file. The SP obtains the best plan weighting the different tasks by the priority that satisfies the defined constraints.

- **Tasks Selector**: Finally, this step selects the first activity of the plan and sends it to the Virtual Agent to interact with the patient. The task is then deleted from the active plan. If it is defined as non-repeatable in *TaskPlanning.xml* file, the task will not be planned again in the current session (such as Welcome tasks which cannot be executed more than one time in the same session).

The adapted and sorted plan generated by the SP is consumed at each interaction cycle, sending the next activity to the Virtual Agent until the complete set of activities are consumed, unless the current plan suffers some modifications due to some important information identified in the patient from his/her responses to better adapt and personalize the content of the current session.

3.5 Evaluation

Our research method and functional evaluation of the developed Framework has been motivated to answer the following addressed question: "*Is our developed architecture able to generate enough degree of adaptive and varied sessions that can contribute to increase and maintain the interest of the users?*". For this purpose, we conduct a number of simulations that allow the statistical analyses of the different outputs produced by the data processing layer of the system.

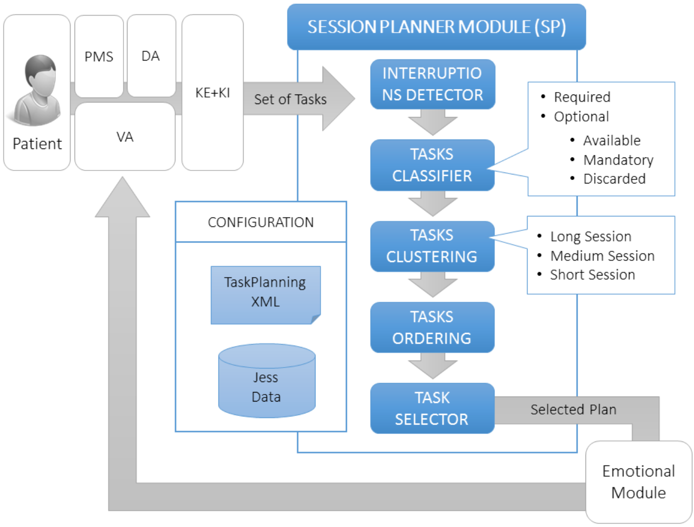


Figure 3.3: Pipeline of the planning session process: (i) Tasks are checked to detect interruptions, (ii) then the tasks are classified, (iii) grouped into short, medium or long sessions. (iv) Each session is ordered, and finally (v) the first task to offer during the session is selected

Table 3.4: Summary of the main tasks, inputs and outputs of the **Session Planner (SP)** module which is included in the data processing layer

Main Tasks
• Interruptions detector. • Task Classifier. • Task Clustering. • Tasks Ordering. • Tasks Selector.
Data Input
• KI findings (Set of inferred tasks). • User Model (demographical + current and historical data). • Clinical/Functional requirements..
Data Output
• The most adequate content of the daily sessions report.

3.5.1 Definition of scenarios

The methodology to assess the levels of adaptability and variability in the content of the sessions produced by our proposed Framework has included the definition of two scenarios based on clinical requirements: restrictive and flexible scenarios. The difference between the two scenarios is based on how some clinical requirements (associated with the support of the treatment) are pre-defined for the generation and planning of the different activities that form a session. Both scenarios are based on the requirements defined by the clinicians of the Help4Mood research project described in Chapter 5. The settings of the flexible scenario are less stringent than the restrictive scenario, i.e. the number of times that an activity needs to be offered to the patient or how these activities should be ordered during a session is more open than in a restrictive scenario (Table 3.5 lists the settings used during the generation and planning of the actions –dialogues and tasks- for both scenarios).

The final planning and selection of the specific content to be included in a session depend on these pre-defined settings and the best way to observe the differences produced from the dynamic input data is the comparison of the sessions produced in the two different scenarios. This comparison will help to assess the level of adaptability in our Framework according the constraints defined by the clinicians. The rationale behind the definition of different scenarios is the generation of different content of the sessions according to the particular preferences of each clinician. For example, while some specialists would prefer the inclusion of a large number of different activities to support the treatment, some others would prefer the execution of a small, more focused, activities based on the specific condition of each patient. Having this in mind, for the functional evaluation of the Framework we have set the restrictive scenario defined by a high number of constraints in the relative order and dependencies between tasks, as well as in the periodicity and priority of the tasks. The flexible scenario was defined with a minor number of constraints. It is expected that the restrictive scenario would provide a low level of variability in the content of the sessions compared to the flexible scenario due to the differences in the pre-defined settings. An extremely restrictive scenario could generate static daily sessions (i.e. producing in every session exactly the same content). On the other hand, an extremely flexible scenario could generate almost fully random sessions based only by the user inputs generated during the interaction.

Table 3.5: Settings used during the generation and planning of the actions –dialogue acts– for both scenarios. This table lists (1) the name of the tasks, (2) the configurations in the two defined scenarios (P=*priority*, m= *minExecutions*, M= *maxExecutions*, C=number of constrains), and (3) the expected planning performed by the session planner module. Tasks that do not contain the *minExecutions* and *maxExecutions* values are only planned if they are inferred by the KI (based on the detected patient condition).

ID	Main tasks	Restrictive scenario	Flexible scenario	Expected Planning
01	Welcome	P:100/m:-/M:-/C:1	P:100/m:-/M:-/C:1	Always 1st task
02	Welcome Reminder	P:100/m:-/M:-/C:1	P:100/m:-/M:-C:1	Always 1st task
03	Daily Mood Check 1	P:100/m:-/M:-/C:3	P:100/m:-/M:-/C:3	Always 2nd task
04	Daily Mood Check 2	P:100/m:-/M:-/C:1	P:100/m:-/M:-/C:1	Randomly planned between 3 and 7 position
05	Daily Mood Check 3	P:100/m:-/M:-/C:1	P:100/m:-/M:-/C:1	
06	Daily Mood Check 4	P:100/m:-/M:-/C:1	P:100/m:-/M:-/C:1	
07	Daily Mood Check 5	P:100/m:-/M:-/C:1	P:100/m:-/M:-/C:1	
08	Select Session Type	P:80/m:-/M:-/C:2	P:80/m:-/M:-/C:1	Always 8th task
09	Sleep Questionnaire	P:100/m:5/M:7/C:1	P:20/m:0/M:7/C:1	Position determined by the restrictions in the scenario
10	Configure Activity Plan	P:50/m:-/M:-/C:4	P:20/m:-/M:-/C:3	
11	Generate Report	P:2/m:-/M:-/C:3	P:20/m:-/M:-/C:3	
12	Introduce Relaxation Task	P:10/m:1/M:3/C:3	P:20/m:1/M:7/C:3	
13	Negative Thoughts Activity Introduction	P:60/m:3/M:7/C:2	P:20/m:1/M:7/C:2	
14	Ask For Planned Activities	P:10/m:2/M:3/C:10	P:20/m:1/M:7/C:10	
15	Speech Activity	P:20/m:3/M:5/C:3	P:20/m:1/M:7/C:3	
16	Activity Monitoring	P:5/m:-/M:-/C:3	P:20/m:-/M:-/C:3	
17	Introduce PHQ-9	P:10/m:-/M:-/C:3	P:20/m:-/M:-/C:3	
18	Crisis Plan	P:-/m:-/M:-/C:-	P:-/m:-/M:-/C:-	Executed immediately
19	Farewell	P:1/m:-/M:-/C:1	P:1/m:-/M:-/C:1	Always last task

3.5.2 Variables and evaluation space for simulations

One of the goals in the evaluation process was to demonstrate that our Framework is able to produce different levels of adaptive and varied content according to the settings in the different scenarios. A set of simulations were executed representing the interaction between the system and the user through the generation of random values in the simulated responses from a patient. The random values used as patient responses were based in the range of values that a patient could give in a real interaction with the system. For example, if the virtual agent of the system asks "How is your mood today?" -which correspond to the Daily Mood Check 1 activity-, the simulated response generates a random value between 0 and 100, the same scale that a patient need to choose during a real interaction. In other cases, we used categorical responses, such as when the virtual agent asks: "Which session length do you prefer?", corresponding to the activity Select Type Session. In this case a random value is generated representing the available "Long", "Medium", or "Short" responses. In this way we have generated a set of simulations containing values that a patient could select during a real interaction. The evaluation space corresponds to the multivariate combination of answers to all questions that might have sense given the context of a patient.

During the execution of the simulations we used 19 tasks (see Table 3.5) and 31 subtasks. A task could be formed by one or more sub-tasks –i.e. different dialog acts used to provide the patient with all the information to execute the task. E.g. the Introduce Relaxation Exercise is formed by three subtasks: Select Voice (the patient selects a pre-recorded voice which provides the instructions of the relaxation exercise), Preparing Relaxation Exercise (the patient receives the information required to start the exercise), and Perform Relaxation Exercise (the dialogues that represent the execution of the exercise). In order to obtain smoothed distributions of our results, we have executed a total of 20.000 simulations of interactive sessions (10.000 of them with the restrictive scenario and 10.000 with the flexible scenario). After simulations execution, we conducted the assessment of the adaptability and variability levels of the produced contents of the session. For our evaluation purposes, we define the adaptability as how much the content of a session (activities/suggestions/questionnaires offered to the patient) can change dynamically during the interaction according to the current and past information received and inferred about the patient's condition. The variability was defined as how the order of the content is offered depending on user's actions during the interaction and the set of restrictions defined by the clinicians.

3.5.3 Evaluation of the adaptability

Taking into account that a key characteristic of people with depression is the loss of interest in doing things, and even simple daily life activities would represent a major effort, the most relevant parameter to assess if the level of adaptability of the system is adequate or not according to the patient condition is the length of the sessions. This may allow knowing if the length of the sessions needs to be adapted according to the patient's stamina, which is the energy and strength for continuing to do something over a long period of time. Hence, we evaluate the adaptability level as the number of planned tasks during a session.

In the Content Management Module, the estimation of the patient's stamina level is obtained through a direct question about what type of session's length the patient would prefer (Select Session Type task - ID08). According to the patient preference our Framework adapts the content, hence the length of the session, according to the scenario and to the model of the user. In the flexible scenario it is expected that the length of the session will be more conditioned by the user answer, because only functional restrictions and minimum clinical restrictions have been set in the system. However in the restrictive scenario it is expected that the length of the session will not be conditioned only by the user answer but also by the restrictions set in the system based on therapeutic and clinical indications. It is expected that long sessions will be longer in the flexible than in the restrictive scenario, and that short sessions will be shorter in the flexible than in the restrictive scenario mainly due to the different settings related to the values associated with the minimum and maximum (*minExecutions* and *maxExecutions*) number of executions of the activities per week in the two scenarios.

The analysis of the adaptability level is based on the differences between the probability distributions of the short, medium and long sessions obtained from the simulations in both scenarios. These distributions have been obtained using Kernel smoothing function estimate (Bowman and Azzalini 1997) based on normal kernel smoother. From the obtained distribution of the total amount of planned activities we can identify in the graphs of Figure 3.4 the three different types of sessions.

As we observe in the plots, there is a difference in the length of the session depending on the defined scenario. These differences are originated from the settings associated with the periodicity of the activities defined in the *maxExecutions* and *minExecutions* parameters set with different values in each scenario. In the short and medium length sessions, the number of activities planned in the restrictive scenario produce a bit longer sessions than in the flexible scenario (see the slope of the probability distribution functions in the first two plots of Figure 3.4). The reason of this difference is that in the restrictive scenario the values of the parameter *minExecutions* are greater than in the flexible scenario (representing a strong requirement that specific activities must be performed a minimum number of times

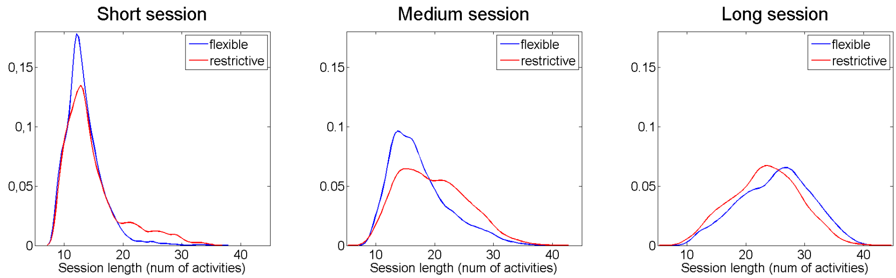


Figure 3.4: Probability distributions of the duration of short, medium and long sessions obtained from the simulations in the two scenarios (flexible scenario in blue line and restrictive scenario in red line

during a week). Therefore, at some point the session length is extended to meet the requirement to execute the minimum number of times the specified activities. On the other hand, long sessions tend to be shorter in the restrictive scenario than in the flexible scenario. The reason is that the Session Planner module -regardless of the scenario- always includes all the tasks inferred by the KI, excepting those tasks that have been executed the number of times defined in the *maxExecutions* parameter or that fail to fulfil with any other criteria. In the restrictive scenario the values of the *maxExecutions* parameter are smaller than in the flexible scenario (representing a strong condition that some activities should be executed only a few times during a week). Therefore, for long sessions the number of activities planned in restrictive scenarios is smaller than in flexible scenarios.

The differences in session length between the two scenarios are also reflected in terms of the variation in the mean values of the distributions as presented in the following Table 3.6.

Table 3.6: Mean values of the distributions of the simulated sessions at each type of session and scenarios

	Mean duration of the session (number of planned tasks)	
	Flexible scenario	Restrictive scenario
Short session	13.4	14.8
Medium session	17.4	19.7
Long session	24.9	23.3
AVG	18.6	19.3

To assess the differences between the two scenarios for each of session types we have used the nonparametric Mann-Whitney U test. For the three session types (long, medium and short), the differences in session duration between flexible and restrictive scenarios have been found significantly different, obtaining p-values under 0.01.

The obtained results support the expected results: in restrictive scenarios the content of the session is highly influenced by the clinical and therapeutic restrictions or preferences. On the contrary, in flexible scenarios the length of the session is more influenced by the actions and inputs received from the user than by the pre-defined settings.

3.5.4 Evaluation of the variability

One of the key aspects in the provision of daily sessions to patients is the capability of the system to offer different content that minimises the risk of discontinuation of the system due to the repetitive and routine execution of exactly the same sequences of activities. One strategy to provide varied content during the sessions, even when the offered tasks could be the same in order to meet the pre-defined clinical constraints, is to offer the activities in different order during the interaction with the user. This way, the patient will address the offered tasks at different moments during the session and the feedback obtained from the Virtual Agent will also change depending on the results of the activities received from the patient. In the simulations, we have also analysed the level of variability produced by our proposed framework.

Similarly as in the evaluation of the adaptability, we expected that the level of variability highly depend on the configuration that the clinician had defined. Since the framework has been designed to be configured with a high level of flexibility or moderately static, we have used again the same two scenarios to assess the level of variability that the framework can produce. Comparing the different positions in which a same task is planned for each of the scenarios, we can see some differences. In general, there is more variability in the task position in a flexible scenario than in a restrictive scenario. In a flexible scenario the probability of transition from one activity to another are quite similar for all the activities excepting those transitions that are subjected to functional restrictions. The inclusion of clinical and therapeutic preferences in the settings of the system reduces the number of choices or degrees of freedom in the system, potentiating some transitions above others. This behaviour means that the level of variability in a flexible scenario will decrease with the inclusion of the clinical preferences or restrictions.

Figure 3.5 shows two heat maps, one for each scenario, where the numbers of transitions from one activity to other during the simulations are represented. We can see that in both scenarios the transition from tasks 1 and 2 to task 3 occurs with high frequency. The task 1 and task 2 represent the dialogue acts to welcome the user at the beginning of each session while task 3 is the first question of the

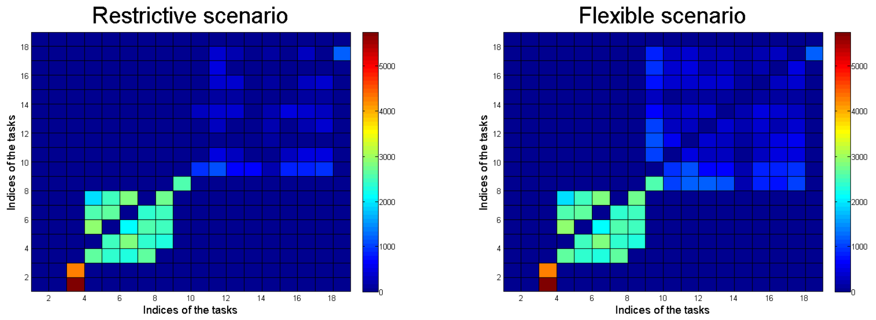


Figure 3.5: Heat maps with the number of transitions from one activity to other produced during the simulations. The heat map of the left is obtained from the flexible scenario while the heat map of the right is obtained from the restrictive scenario. The indices of the axis are labelled in Table 3.5

daily mood check questionnaire. Due that the clinicians defined that the daily mood check questionnaire must be the very first task (just after the welcome) in each session, we can see in the Figure 3.5 almost the similar tasks transitions in the two scenarios (indices from 1 to 9). In the two scenarios there is a low variability in the order of the tasks corresponding to the four questions belonging to the daily mood check questionnaire activity.

Beyond these initial activities, we can start to see the differences between the flexible and the restrictive scenarios on the top right area of the graph. In the flexible scenario, the transitions are more homogeneous and there are not many defined patterns and we can argue that in a flexible scenario there is more variability between sessions than in restrictive scenarios. For the analysis, we have focused in the transitions between indices from 9 to 18 which corresponds to the variable transitions, excluding the transitions that are forced by functional requirements (Fig. 3.6).

As can be seen in Figure 3.6, in the flexible scenario most of transitions have a similar probability while in the restrictive scenario there is a clear occurrence of banned and recurrent transitions. When analysing the differences in number of low probability transitions (i.e. transitions with a probability to occur less than 2%), we can see that in the flexible scenario only the 30% of the transitions where low probability transitions, while in the restrictive scenario the number of low probability transitions increases to the 64%. These experiments show how the variability of the session significantly decreases when adding an important number of restrictions in the settings of the system. We have also analysed the number of repeated sessions obtained during the simulations for the two scenarios. Repeated sessions are those that contain exactly the same number and in the same order the activities produced in the session planner. From this analysis, we can see that

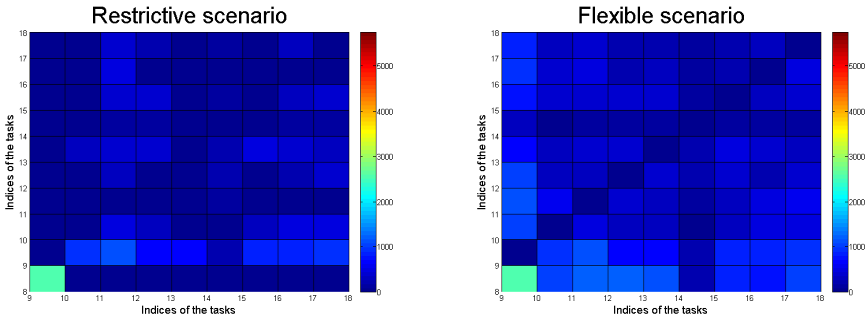


Figure 3.6: Detailed view of the region in the heat maps that shows the variable transitions between activities. On the left graph the detailed heat map obtained in the restrictive scenario and, on the right the detailed heat map obtained in the flexible scenario. The indices of the axis are labelled in Table 3.5

in the flexible scenario the level of variability is greater than in the restrictive scenario (see Tables 3.7 and 3.8). The results obtained in the restrictive scenario show an 11.87% of repeated sessions. We can also see that in short sessions, the variability level is lower than in medium and long sessions, which is justified for the smaller number of planned activities.

Table 3.7: Repeated sessions in the simulations using flexible scenario for each type of session

	Flexible scenario		
	Simulations	Repeated	Repeated (%)
Short	3.306	782	23,65%
Medium	3.374	179	5,31%
Long	3.320	36	1,08%
General	10.000	997	9,97%

3.6 Discussion and Conclusions

In this Chapter, an adaptive and flexible Content Management Module to produce the content of interactive daily sessions applied for supporting patients with Major Depression has been presented and evaluated. This module has been designed with the aim to improve the usability of the Framework in the targeted users, which in turn would help to increase the adherence to the treatment.

Table 3.8: Repeated sessions in the simulations using restrictive scenario for each type of session

	Restrictive scenario		
	Simulations	Repeated	Repeated (%)
Short	3.263	873	26,75%
Medium	3.347	207	6,18%
Long	3.390	107	3,16%
General	10.000	1.187	11,87%

In the design and implementation of HCI addressed to support the self-treatment of patients there are several recommendations to follow in order to avoid frustration and loss of interest. These recommendations include the promotion of the variability and the adaptability of the system outputs to the patient condition. The proposed Framework provides a mechanism that produces a personalised adaptation and offers a good variability in the content of the sessions based on a continuous and dynamic planning of the activities to offer to the patient. The planning adapts the content of each session according to the patient condition and input actions at each interaction cycle. The session can vary the content, the length and the order of the tasks to produce different sessions every day. The management of the produced sessions is based on the patient direct answers, the historical data, and the preferences of the clinicians promoting a better adherence of the patient to the treatment.

The functionality of the Framework has been evaluated to observe the produced levels of variability and adaptability in the daily sessions. The evaluation has been performed using simulations to represent patients' inputs and the corresponding system responses. After analysing the results, and considering that a session is composed of an average of 18 tasks (13 for short session, 17.5 for medium sessions, and 24 for long sessions), we can conclude that there is a 30% of overall adaptability between planned sessions in our Framework. Regarding variability, we obtained only a 10.92% of repeated sessions. We can argue that the presented Framework provides good levels of variability and adaptability according to the inputs received from the patient.

Due to the high dependency between the planning process and the configuration of the system set by the clinicians, we performed simulations using two different configurations (which we called scenarios): a restrictive scenario in which we set a high number or restrictions; and a flexible scenario in which we set a more open configuration (see Table 3.5). We have shown that when the system is configured in a more restrictive way, the level of variability and adaptability is reduced.

In contrast, when more flexible configuration is set in the system, the level of variability and adaptability is improved.

The adoption of different configuration scenarios allows the system a better adaptation to the needs of the clinicians and their patients. We can ensure that our Framework provides an efficient degree of adaptive and varied sessions, allowing the personalisation of the interactive sessions in order to improve the user experience. The proposed Framework can be used to support computer-based psychotherapeutic interventions in patients that require high restrictions in the generation of different session contents guided by clinical settings, or in patients who need a more flexible treatment. The clinician is the responsible for setting up the tasks and conditions to generate the more adequate content for the treatment including the frequency and restrictions of the different activities based on the patient condition or the protocols of the clinical institution.

For future work we are considering different actions to improve the current Framework. Mainly, from the analysed feedback obtained in the evaluation pilots, we plan to implement a method to estimate the patient's stamina from the findings in the collected data, instead to ask it directly through the VA. This will allow the automatic adjustment of the length of the sessions instead of asking to the patient what kind of session (long, medium or short) he/she prefers.

Chapter 4

Modeling Therapeutic Empathy

The management of the emotions is a very important aspect in human communication. These communication skill is emphasized in medical environment in doctor-patient relationship. Specifically, in mental health the use of empathy is critical, which is defined as the ability to identify another person's feelings and to view the world from their perspective. Increased empathy also results in higher patient satisfaction with their physician and promotes an honest interaction that leads to better medical outcomes (Bresó, Martínez-Miranda, and García-Gómez 2016). There are several studies which confirm that the use of empathy improve the interpersonal communication and promote the therapeutic alliance (Bresó, Martínez-Miranda, and García-Gómez 2016).

Affective Computing (AC) is the study and development of systems and devices that can recognize, interpret, process, and simulate human affects. It is an interdisciplinary field spanning computer science, psychology, and cognitive science (Bresó, Martínez-Miranda, and García-Gómez 2016). The combination of AC and VA offers new ways to address mental disorders providing a realistic social interaction. An emotional virtual agent relies on the possibility to reproduce interactive social situations without the threatening or distressing consequences of such situations in the real world.

Computational models of affective processes have allowed the construction of synthetic characters able to produce empathic behaviours. The use of empathy, as a strategy to enhance engagement and cooperation with human pairs has proved good results in different application domains. Mental care is a particular area where the use of empathic virtual characters would offer several advantages facilitating the self-treatment management. Empathic responses in counselling and psychotherapy differ from natural or normal empathy produced in everyday situations. When someone is talking with us, he is expressing emotions. So we copy and return these emotions in order to establish an emotional connection. If we use therapeutic empathy, we do not copy the emotion, we modify it before returning it, in order to help the other person. Hence we need to identify and transform the emotion into an adequate emotion for the purpose of the clinical treatment. Therapeutic empathy requires an emotional involvement of the therapist with the patient and an emotional detachment for a more objective appraisal of the situation.

This Chapter introduces a model of emotion regulation as the first step to get therapeutic empathy responses in a VA constructed to support patients of major depression. The modelling of two specific strategies of emotion regulation (cognitive change and response modulation) based on Gross theory (Gross 2001) is described. This contribution is included into the developed Framework, and it is focused to reach the four objectives specified in the Table 1.1: Usability, Acceptability, Engagement, and Adherence.

> *The novel approach described in this chapter, was included and published in the book titled "Emotion Modeling: Towards Pragmatic Computational Models of Affective Processes" (Martínez-Miranda, Bresó, and García-Gómez 2012b).*

4.1 Introduction

The interest in the development of Embodied Conversational Agents (ECAs) as advanced human-computer interaction interfaces has generated a good number of initiatives aimed to construct the underlying mechanisms able to produce more human-like behaviours in those agents. The modelling of the emotional phenomenon, as a basic component of human behaviour, has produced different computational models of emotion that are used to analyse and simulate different aspects of this complex process. Most of these computational architectures of emotion are based on different cognitive and psychological theories influenced by the particular components and phases of the emotional phenomenon that the model tries to represent. Examples of these architectures include FLAME (El-Nasr, Yen, and Ioerger 2000) and EMA (Marsella and Gratch 2009) based on appraisal theories of emotion; WASABI (Becker-Asano 2008) based on dimensional theories of emotion; or the model proposed in (Armony et al. 1997) which is based on the anatomic approach of emotions (for a deeper discussion refer to (Marsella, Gratch, and Petta 2010)). A common expected benefit from these tools is the construction of more believable ECAs that better engage their human pairs during interaction.

One emotion-related element well studied and commonly used to create better interactive scenarios with ECAs is empathy. Empathic agents have been constructed to achieve a better cooperation and complete longer interaction sessions in different domains, including learning (Burleson and Picard 2004), training (Prendinger and Ishizuka 2005) and clinical applications (Bickmore et al. 2010). Within the clinical domain, a particular area where the use of empathic VAs can be particularly beneficial is in the treatment of mental health disorders (Hudlicka et al. 2008). Empathy is considered a fundamental aspect in promoting therapeutic change when providing counseling and psychotherapeutic interventions (Rogers 2012) and some studies concluded that empathy accounts for between 7-10% of the variance in therapy outcome (Bohart et al. 2002).

The modelling of empathic responses in ECAs as virtual assistants to support the treatment of mental health disorders faces some challenges that need to be carefully addressed. For example, in the treatment of major depression, an interactive VA must not display a “pure emotional” empathic behaviours by adopting the same –typically negative– mood of the patient. The disadvantage is that these behaviours can be interpreted as sympathetic expressions of condolence that may imply a sense of unintended agreement with the patient’s (negative) views (Clark 2014). What is most beneficial from a clinical perspective is not to produce “only” natural empathic reactions as response to the patient’s input, but to generate *therapeutic-empathy* responses in the agent.

As mentioned in (Thwaites and Bennett-Levy 2007), it is important to distinguish *natural empathy* (experienced by people in everyday situations) from *therapeutic empathy* in order to provide the patients with useful feedback for their particular condition. One of the key differences between natural and therapeutic empathy is the “addition of the cognitive perspective-taking component to the emotional one; the cognitive component helps the therapist to conceptualize the client’s distress in cognitive terms” (Thwaites and Bennett-Levy 2007)). In other words, a therapist should ”assume both the role of an emotional involvement in an interview with a patient and an emotional detachment that allows for a more objective appraisal” (Clark 2014); a wrong empathic attitude is generated when the therapist does not to some degree maintain an emotional distance from the patient (Vanaerschot 1990).

In this Chapter, we describe the modelling of this *perspective-taking component* aimed to produce in a VA the required emotional detachment or emotional distance at specific stages of the interaction with patients with major depression. The theoretical basis of the proposed model lies in J. J. Gross’ process model of emotion regulation (Gross 2001). In particular, we are modelling two strategies of emotion regulation: *i) cognitive change* and *ii) response modulation*. The **cognitive change strategy** is triggered when the patient is reporting a *bad situation* (e.g. low mood level) which in a first step would also produce (empathically) a negative emotion in the VA. Once triggered, the cognitive change strategy seeks for additional information that can change (positively) the significance of the detected situation (e.g. finding a positive tendency in the mood level regarding the reported values in past days) allowing *a more objective appraisal*. Complementarily, the **response modulation strategy** is used to regulate those negative emotion-expressive behaviours in the agent produced when the cognitive change strategy has not succeed (i.e. there is no information that changes the -*negative*- situation meaning). The suppression of negative expressive behaviour helps the VA in not to convey a sense of condolence that would be counterproductive due to the patient's condition. The implementation of the model have been developed as an extension of the FAtiMA (appraisal-based) computational architecture of emotions (Dias and Paiva 2005).

The rest of the Chapter is organised as follows: in Section 4.2 we put in context our research by introducing the Emotional Module, which aims to support the management of the emotions in the VA. Then, in Section 4.3 we present in more detail the relevant parts of Gross' emotion regulation theory used in our model, complemented by some related work in the ECAs community. Section 4.4 presents in detail our model of emotion regulation as the core component able to produce better therapeutic empathy reactions in a VA. Finally, Section 4.5 presents the conclusions and further directions of the presented work.

4.2 An Emotional Virtual Agent to Support Patients with Major Depression

The emotional behaviour of the VA is managed in the Emotional Module of the Framework presented in this Dissertation. As is showed in Figure 4.1, this module is the responsible for eliciting the adequate emotional response for the created session planned. Hence, the both modules of the presented Framework have been designed to provide the adequate behavior to the VA. The emotional response will be rendered by the VA, which acts as the main interface with the patient.

The VA behavior facilitates the collection of relevant data including subjective measures (by applying standardised questionnaires and guided interviews), and neuropsychomotor measures (by offering tasks for speech input and/or selected games) which are designed to complement the objective measures obtained from the PMS. The collection of the patient data is carried out through daily sessions between the patient and the system; the content of each session varies, with some tasks being carried out every day (such as the Daily Mood Check consisting of a single item measuring overall mood plus four items of the CES-D VAS-VA questionnaire (Moullec et al. 2011)), and some others executed weekly (e.g. the standardised PHQ-9 questionnaire (Kroenke, Spitzer, and Williams 2001), for example). Moreover, the virtual agent also helps users to identify negative thinking (a key characteristic of depressive disorder) and challenge it by adapting a protocol in concordance with the principles of Cognitive Behaviour Therapy (CBT), the main non-pharmacological treatment method for major depressive disorder.

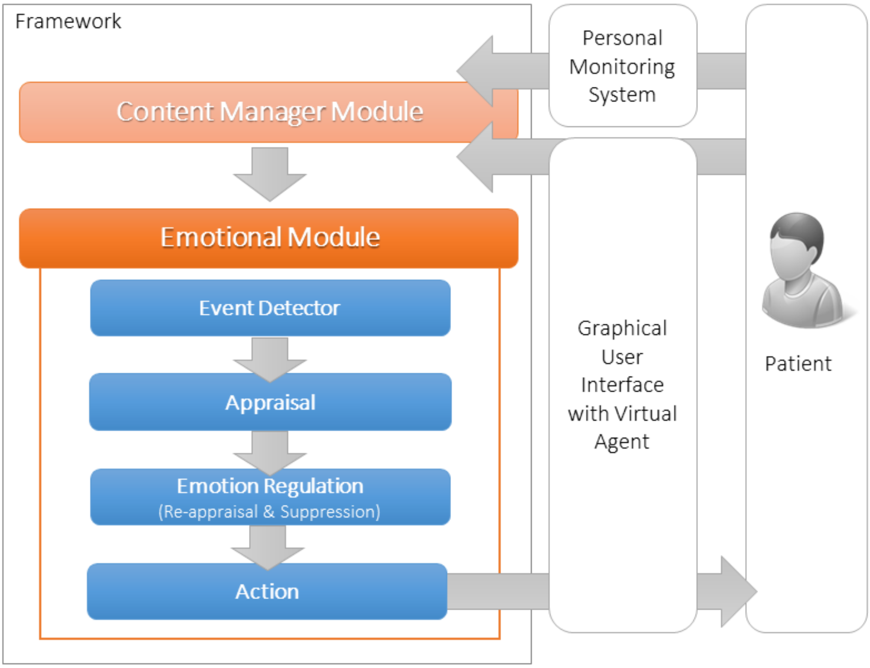


Figure 4.1: This schema shows the general architecture of the developed Framework and the user interaction supported highlighting the Emotional Module. The patient is able to interact with the Framework by means of an emotional Virtual Agent. From the plan inferring by the Content Management Module, the Emotional Module is the responsible to infer the appropriate emotion that the VA will uses in the content communication.

The Emotional Module, which is the focus of this Chapter, has been developed as a Java-based application and extends the FAtiMA computational model architecture (Dias and Paiva 2005) following these four steps:

- **Detection of the event**/s generated as a consequence of the next task that the Content Management Module has selected for the next iteration with the patient. This event/s must be classified as desirable or not, based on specific goals.

- **Emotional appraisal**, that generates one of these defined emotions from the OCC model (Ortony, Clore, and Collins 1990):

  1. **Joy** [Positive]: activated when an event is appraised as *desirable* for the VA (e.g. when the user accepts the activities offered by the VA during a session).

2. **Happy-For** [Positive]: elicited when an event is appraised as *desirable for the patient* (e.g. good self-reported moods, thoughts or scores in the proposed activities).

3. **Admiration** [Positive]: activated when an event is appraised as a *desirable consequence of a patient's action* (e.g. the correct completion of the proposed activities during the session or the completion of the whole session).

4. **Pity** [Negative]: activated as a result of appraising some events as *not desirable for the patient* (e.g. when reporting a low mood, negative thoughts or decreased physical activity).

5. **Distress** [Negative]: triggered when an event is appraised as *not desirable for the agent itself* (e.g. when a not daily use of the system is detected).

- **Emotion regulation**, which is required depending on the previous emotion elicited and its intensity. This is the main contribution of this Chapter and it is deeply described in the following sections.

- The corresponding **action generation** to provide in the interaction. We authored all the goals, actions and action tendencies to cope and react towards the events produced during the interaction with the patient. All these events are directly related with the user's responses and are the basis to produce the next more adequate action and emotion in the VA. As all the actions in the VA are directed to provide the different standardised questionnaires or CBT-based activities defined by the clinicians, the range of user's responses is delimited to provide the input and follow up of the offered activities. When new questionnaires and/or exercises are necessary to be added -which in turn extend the content of the daily sessions- new goals, actions and action tendencies are authored in the VA to correctly cope with the user's inputs to the new events.

In terms of the emotional module, the production of richer emotional responses became necessary to better engage the users. The inclusion of negative emotions which produce affective reactions to adverse situations would contribute to perceive a more realistic and empathic agent. The challenge here is to generate an optimal intensity in these negative emotions that allows an adequate response (in terms of action-selection and feedback provided) during the interaction with the user. To face this challenge, we have incorporated a model of emotion regulation aimed to modulate the negative emotions elicited in the VA. The emotional regulation is achieved following two strategies: changing the perspective of the current situation (producing an emotional detachment), and suppressing the expressive (negative emotion-based) behaviour to convey the appropriate reactions.

4.3 Emotion Regulation

4.3.1 Theoretical Foundations

The study and understanding of the emotion regulation process has attracted the interest of an important number of researchers in the last three decades (Campos, Campos, and Barrett 1989), (Gross 2013). Although some works consider the emotion regulation process as part of the emotion generation process (Campos, Frankel, and Camras 2004), (Frijda 1986), some others show the neural differences between them (Davidson, Fox, and Kalin 2007) and the benefits of studying emotion and emotion regulation separately (Gross and Thompson 2007), (John and Gross 2007). In line with the second view, J. J. Gross (Gross 2001), (Gross and Thompson 2007) proposed a theoretical model of emotion regulation which refers to *the heterogeneous set of processes by which emotions are themselves regulated*. In detail, the process model of emotion regulation covers the conscious and unconscious strategies used to increase, maintain, or decrease one or more components of an emotional response. The main characteristic of this model is the identification and definition of five families of emotion regulation processes: *situation selection*, *situation modification*, *attentional deployment*, *cognitive change* and *response modulation*.

Situation selection is described as when an individual takes the necessary actions to be in a situation the individual expects will raise a certain desirable emotion. *Situation modification* refers to the efforts employed by the individual to directly modify the actual situation to alter its emotional impact. The third family, *attentional deployment*, refers to how individuals direct their attention within the current situation in order to influence their emotions. *Cognitive change* is described as when the individual changes how the actual situation is appraised to alter its emotional significance, either by changing how the individual thinks about the situation or the capacity to manage it. Finally, the *response modulation* family refers when the individual influences the physiological, experiential, or behavioural responses to the situation.

Each family of emotion regulation processes occurs at different points in the emotion generation process and there are substantial differences between them (see details in Gross and Thompson 2007). An important aspect to consider is that the first four emotion regulation families occur before any appraisal produces the full emotional response (antecedent-focused), while the last family (response modulation) occurs after response tendencies have been initiated (response-focused). Two particular strategies of emotion regulation have been studied in (Gross 2001): one is *reappraisal* as a type of cognitive change (antecedent-focused) and the other is *suppression* as a type of response modulation (response-focused). According to the authors, reappraisal occurs early in the emotion generation process and it involves cognitively neutralizing a potentially emotion-eliciting situation. In consequence, reappraisal should decrease experiential, behavioural, and physiological responses. On the other hand, suppression occurs later in the emotion generation process and requires an active inhibition of the emotion-expressive behaviour that is generated when the emotion is triggered.

4.3.2 Computational Models of Emotion Regulation

The Gross process model of emotion regulation has inspired the development of some computational models of emotion regulation. The group of Bosse and colleagues have formally modelled the four antecedent-focused emotion regulation strategies and incorporate it in synthetic characters as participants in a virtual storytelling (Bosse et al. 2007). In a subsequent work, Bosse and colleagues constructed virtual agents not only with the capacity of regulate their emotions, but also with the ability of *reasoning* about the emotion regulation processes of other agents (Bosse and De Lange 2008). This model has been called CoMERG (the Cognitive Model for Emotion Regulation based on Gross) and it formalizes Gross model through a set of difference equations and rules to simulate the dynamics of Gross' emotion-regulation strategies (Bosse, Pontier, and Treur 2010).

CoMERG identifies a set of variables and their dependencies to represent both quantitative aspects (such as levels of emotional response) and qualitative aspects (such as decisions to regulate one's emotion) of the model. These variables include e.g. the level of -the actual- emotion, the optimal -desired- level of emotion, the personal tendency to adjust the emotional value, or the costs of adjusting the emotional value, among others which are used to simulate and evaluate the results in the use of the four antecedent-focus strategies of emotion regulation. The modelling and simulation of the different emotion regulation strategies is the main aim of CoMERG, but the underlying appraisal and affect derivation mechanisms required to generate specific emotions according to the observed world-state are not explicitly addressed. In a more recent work (Hoorn, Pontier, and Siddiqui 2012) the integration of CoMERG with other two computational models of emotions EMA (Marsella and Gratch 2009) and I-PEFIC^{ADM} (Hoorn, Pontier, and Siddiqui 2008) is proposed to cover the complete process of emotion generation, regulation and action responses in virtual agents.

Similarly, the work presented in (Soleimani and Kobti 2012) proposes an extension of CoMERG by adding an emotion-dependent regulation process based on the mood and personality of individuals. Moreover, the occurrence of new (positive and negative) events during the simulation time was included to analyse the influence of these events on the emotion regulation process. However, as an extension of CoMERG, this approach does not have an appraisal and affect derivation mechanism for monitoring events in the world nor have been reported its integration in virtual characters.

It is important to mention that FAtiMA also applies its own strategy (which is based on (Marsella and Gratch 2003)) for changing world interpretation and lowering strong negative emotions. This mechanism is part of the FAtiMA deliberative layer which implements two types of coping to deal with changes in the environment. The problem-focused coping acts on the agent's world to deal with the situation and consists of a set of actions to be executed to achieve the desired state of the world. The emotional focused coping is used to change the agent's interpretation of circumstances. When a specific plan or action fails in the intention to achieve or maintain a desired goal, a mental disengagement is applied. Mental disengagement works by reducing the importance of the goal, which in turn reduces the intensity of the negative emotions triggered when a goal fails (Dias and Paiva 2005).

For the Help4Mood scenario, what is still needed is the mechanism to re-interpret (i.e. reappraise) a situation that is detected as adverse to the patient's condition and that could lead to the triggering of a negative emotion. While the current emotion-focused coping of FAtiMA is concentrated in the achievement/maintenance, or not, of the agent's internal goals and the reduction of the intensity of the negative OCC prospect based emotions (i.e. *disappointment* and *fears_confirmed*), we need an emotional regulation module that down-regulates the intensity of the negative affective state produced by a situation derived from those negative events in the patient's status. Thus, the verbal and nonverbal feedback provided to the patient based on the VA's affective state would contribute to a better therapeutic empathy communication during the session. The design and implementation of this module is detailed in the following section.

4.4 Adapting a Model of Two Emotion Regulation Strategies

The initial version of the emotional module in the Help4Mood's virtual agent has been extended by allowing the elicitation of two OCC-based negative emotions. *Pity* and *Distress*. The challenge is how to communicate these emotions not as a sense of condolence due to the adverse events, but as a sense of understanding and provide useful feedback that motivates the patient towards the daily use of Help4Mood. As with the positive emotions, the negative emotions are reflected through a particular facial expressions and some dialogues constructed in the Dialogue Manager. The main objective is to produce the optimal intensity in the negative emotion to display an adequate facial expression, and at the same time, take the necessary actions to cope with the situation.

The proposed solution is to implement a mechanism of emotion regulation that can be used to modulate the negative emotions and produce an emotional detachment from the situation which helps to provide useful responses during the interaction. Based on Gross theory of emotion regulation, we have implemented two of the strategies defined in Gross's model of emotion regulation: cognitive change (through the reappraisal of events) and response modulation (through suppression of the emotion-expressive behaviour). At the moment, we are not considering the inclusion of the other three antecedent-focused emotion regulation strategies.

The main reason behind this decision is the particular context of the VA's environment in the Help4Mood scenario: the main events received and appraised by the VA are all closely related with the actual detected or reported condition of the patient. During the interaction cycle, there are no other alternative situations to select, i.e. there are no other possible values in the patient's condition (situation selection) that the VA can concentrate on. Also, the VA cannot modify by itself the detected or reported patient condition (situation modification) and it is desirable that the VA should appear focused on what the patient is actually reporting (attentional deployment). Nevertheless, it is still possible to positively *reappraise* the current situation by analysing how the patient's condition has evolved during past sessions. If after the reappraisal process the current situation cannot be assessed in positive terms, some *suppression* in the intensity of the activated negative emotion is still possible to modulate the displayed facial expression and/or head movements related to the current negative affective state of the VA.

We have incorporated an initial model of these two emotion regulation strategies as an extension of the FAtiMA architecture. A key advantage of FAtiMA is its modular implementation which is composed of a core functionality plus a set of components that add or remove particular functionalities (in terms of appraisal or behaviour) making it more flexible and easier to extend (Dias, Mascarenhas, and Paiva 2014). Thus, the proposed model of emotion regulation has been added as an extended component of the FAtiMA core functionality as presented in Fig. 4.2 (the new component is displayed using dotted red lines).

4.4.1 Modelling Cognitive Change - Reappraisal

Based on Gross theory of emotion regulation, we have implemented a mechanism to reappraise those events susceptible to triggering a negative emotion in the VA. Following the concepts of Gross theory, we represent a situation composed of the event or events produced in the VA's environment. The actual situation meaning can be changed using a pre-defined set of situation meanings which in turn are formed by the different events that are used during the reappraisal process. The reappraisal process is triggered only when the target (negative) emotion exceeds a configured threshold which represents the maximum intensity allowed in the target emotion. The reappraisal process can produce a different -positive- emotion or the same negative emotion with a decreased *-down-regulated-* intensity. In the case where the resultant emotion is still negative with an intensity greater than the desired maximum threshold, the suppression emotion strategy is applied (see next

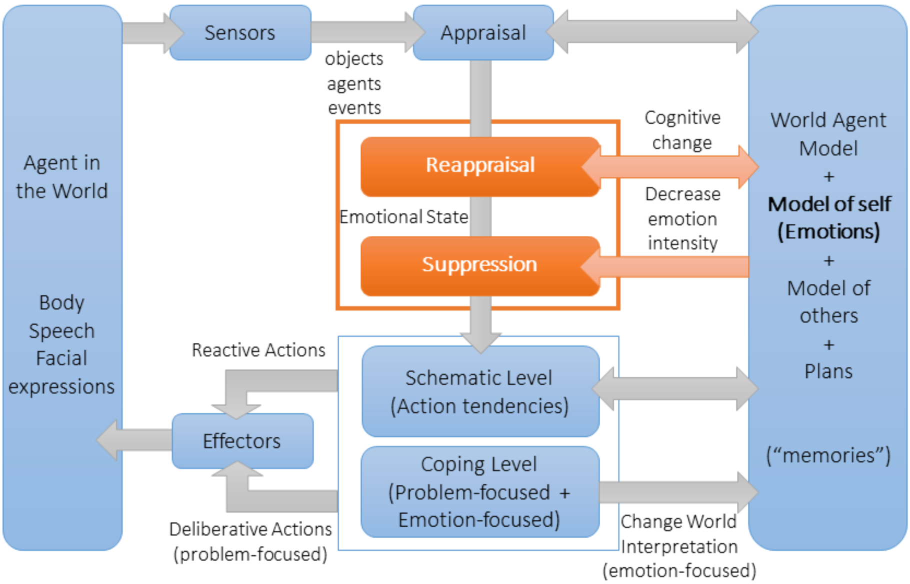


Figure 4.2: The FAtiMA architecture (Dias and Paiva 2005) with an added emotion regulation component (Reappraisal and Suppression)

section). The diagram in Fig. 4.3 graphically represents the different concepts and the flow of the cognitive change process.

According to Gross's theory, the cognitive change is an antecedent-focused strategy of emotion regulation, which means that it occurs before appraisals give rise to full-blown emotional response tendencies (Gross and Thompson 2007). Thus, our model of cognitive change is activated when a new event is received from the environment. A prospective appraisal is executed to assess if the event derives from a desirable or undesirable (in terms of the agent's goals) situation related to the patient's condition. The result of this prospective appraisal is the projection of the potential emotional state produced by the event. In other words, our model "simulates" the appraisal and affect derivation processes to analyse the emotional consequences of the current situation, but without producing the full-blown emotional responses.

If the projected emotional state involves the activation of a positive emotion - no emotion regulation is required- then the same event is used to execute the *real* appraisal and generates the corresponding responses in the VA. On the other hand, if the projected emotional state includes the activation of a negative emotion with intensity greater than the pre-defined maximum threshold, the corresponding

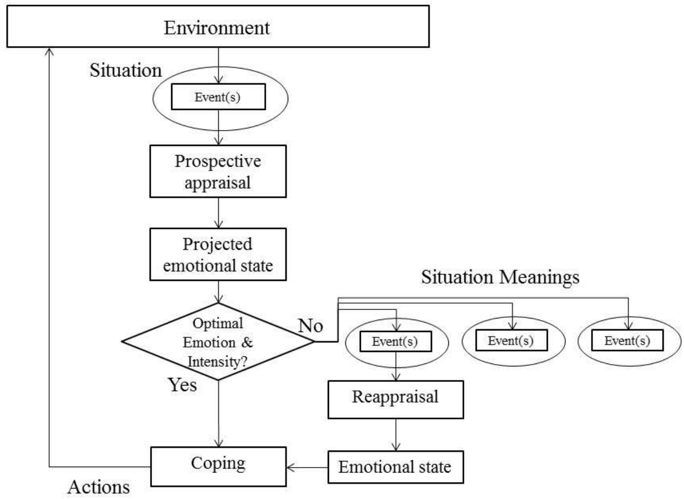


Figure 4.3: Cognitive change model diagram

pre-defined alternative event(s) is selected for reappraisal which would construct a more positive meaning of the original situation. If the emotional state produced by the reappraisal is better (i.e. produces a positive emotion or the same negative emotion with a reduced intensity) than the simulated situation, all the (reactive and deliberative) responses are executed continuing with the next interaction cycle.

To exemplify this process consider the following: during a patient's current sessions one of the activities to perform is the assessment of the patient's depression level in the last 7 days through the PHQ-9 questionnaire. If the score obtained indicates that the depression level is quite high, the VA can appraise this result as highly undesirable for the patient's condition, generating a strong *pity* emotion. Using the cognitive change strategy of emotion regulation, the VA can change the meaning of this situation using an alternative view. In the example, the VA can consult the results obtained in the PHQ-9 questionnaire during previous sessions (stored in the model of the patient maintained in the DSS module) and check whether the current result shows a positive tendency in the patient's condition taking into account the previous results. If this positive tendency is found, the original event would be reappraised as "not much undesirable" to the patient (thought the current PHQ-9 score is still not the optimal). This reappraisal can change the emotional state or the emotion's intensity in the VA which is reflected in the feedback provided to the patient, something like Ok, it seems that your current condition is not very good, but in general terms you are making good progresses in the last days". This is different from the feedback that the VA would provide if the response is based only on the negative meaning of the current situation (e.g. Ok, it seems that you have had some difficult days, but please continue with the treatment"). In both cases, the verbal feedback is accompanied by the appropriate facial expression according to the the activated emotion and its intensity.

Similar events to change the meaning of the current situation can be pre-defined to cope with the result of other session activities (e.g. the Daily Mood Check questionnaire, the negative thoughts challenge, or the behaviour activation modules). All the targeted emotions to be regulated, the maximum intensity threshold and the different situation meanings with the events used during the reappraisal can be authored in an XML file in a similar fashion as the emotional thresholds and decay rates; the emotional reaction rules; the set of action tendencies; and the goals and actions that form the whole VA's behaviour are currently authored in FAtiMA. A simple example of this XML-based file is as follows:

Algorithm 4.1: Emotion regulation configuration example.

```
<EmotionRegulation>
 <!--Targeted emotions for regulation-->
 <EmotionalDesiredIntensities>
   <EmotionalDesiredIntensity emotion="Distress" desiredIntensity="3"
          suppressionRate="3">
   <EmotionalDesiredIntensity emotion="Pity" desiredIntensity="3"
        suppressionRate="4">
          ...
 </EmotionalDesiredIntensities>
 <!--Situation meanings used for reappraisal-->
 <SituationMeanings>
 <Situation name="High_Depression_Score">
   <ElicitingEmotion type="Distress" minIntensity="6">
     <CauseEvent subject="User" action="High_Score_PHQ-9">
   </ElicitingEmotion>
   </EventForReappraisal subject="[SELF]" action="
        getPreviousDepressionScore"  target="User" parameters="2">
 </Situation>
 <Situation name="Low_Mood">
   <ElicitingEmotion type="Distress" minIntensity="6">
     <CauseEvent subject="User" action="Low_Score_DailyMoodCheck">
   </ElicitingEmotion>
   </EventForReappraisal subject="[SELF]" action="getPreviousMood"
        target="User" parameters"5">
 </Situation>
  ...
 </SituationMeanings>
</EmotionRegulation>
```

The content of the file is divided into two main parts: the first part under the `<EmotionalDesiredIntensities>` tag defines the targeted emotions that will be regulated (in our case, we concentrate only on negative emotions). It contains the values for the maximum desired intensity of the emotion and the suppression rate value used in the response modulation strategy (see next section). The second part of the content under the `<SituationMeanings>` tag defines the set of situations that are candidates to be reappraised with a more *positive* perspective. Each situation contains the event (`<CauseEvent>`) that would elicit the *negative* emotion (`<ElicitingEmotion>`) and the definition of the event used for the reappraisal (`<EventForReappraisal>`). The event that is used during the reappraisal process is composed by four fields following the same definition of an event used in FAtiMA (Dias and Paiva 2005):

- The *subject* who performs the action
- The *action* to perform
- The *target* of the action
- A list of parameters that specify additional information about the action

The mechanism to select the specific situation in the emotion regulation component is based on the activation of action tendencies process provided in FAtiMA. When executing the prospective appraisal using the event defined in the `<CauseEvent>` tag, if the projected emotional state activates the emotion type with an intensity equal or greater than the *minIntensity* value, then the event defined in `<EventForReappraisal>` is selected for the reappraisal. This event contains the action that will be executed to get an alternative meaning of the current situation (e.g. in the *Low_Mood* situation of the XML example, the virtual agent gets the scores of the mood reported by the patient in the past 5 days to detect if the mean of the previous values is high or if there is a positive tendency in the mood of the patient).

The result of the reappraisal does not necessarily change a negative situation. Continuing with our example, the result of the previous depression scores could indicate a negative tendency in the evolution of the patient. In these cases, the resultant emotional state could even increase the intensity of the negative emotion. As a requirement of the VA in the Help4Mood scenario is not to convey strong negative emotional responses during the interaction, the response modulation strategy is activated in these cases.

4.4.2 Modelling Response Modulation - Suppression

Response modulation is an emotional regulation strategy that occurs late in the emotion-generative process, once the response tendencies have been initiated (Gross and Thompson 2007). According to (Gross, Richards, and John 2006), a common form of response modulation involves regulating emotion-expressive behaviour. In this sense, suppression as a form of response modulation can be used to model the regulation of the activated on-going expressive behaviour in the VA during the interaction with the patient. The activation of negative emotions in the VA could be useful in selecting the appropriate action to cope with specific situations.

An example that can occur during the daily sessions is when the VA detects cues that indicate thoughts of self-harming (i.e. a high score in question number 9 of the PHQ-9 questionnaire). In this case, an action tendency triggered by the activated -negative- emotional state is the execution of the Help4Mood crisis plan: display contact information for crisis services and trusted family/friends plus discontinuing the use of Help4Mood. The expressive behaviour (i.e. the displayed facial expression and the verbalised utterances) during the execution of the crisis plan should avoid an unnecessary sense of alarmism, but promote calming and understanding of the situation.

The way to regulate the expressive behaviour in the VA produced by the on-going emotional state is through decrementing the intensity of the emotion. As the intensity is used to generate the corresponding facial expression (stronger intensity means more marked expressivity in the face of the VA), what we need is a mechanism to down-regulate the intensity of the activated negative emotion. In FAtiMA, the intensity of an emotion is a variable which depends on the elapsed time and it is influenced by a pre-defined decay rate parameter. The decay function for each emotion is implemented in FAtiMA using the following formula, as proposed in (Picard 1997):

$$I(m,t) = I(m,t_0) \cdot e^{-bt}, \tag{4.1}$$

Where the *Intensity* (I) of an emotion (m) at any time (t) depends on the intensity of the emotion when it was generated $I(m,t_0)$, and the value of the decay rate (b) determines how quickly the intensity of the emotion decays over time. A slight modification of this formula by introducing an additional value called suppression rate (S_R) is used to introduce a high decrement in the emotion intensity aiming to reach the optimal intensity value in the regulated emotion:

$$I(m,t) = I(m,t_0) \cdot e^{-bt} \cdot \frac{1}{S_R} \quad \text{, where } S_R >= 1 \tag{4.2}$$

The two values, the optimal intensity and the suppression rate, are pre-configured for each emotion in the emotion regulation XML-based file presented in the previous section. Different values for these parameters will generate different behaviour in the VA: higher values in the *desiredIntensity* parameter will allow stronger intensities in the negative emotions triggering the corresponding coping behaviour. In contrast, low values for this parameter will force the application of the implemented emotion regulation strategies to achieve the desired intensity in the negative emotions. On the other hand, higher values in the S_R parameter will produce a faster decrement of the emotion intensity and the suppression of the emotion expressive behaviour.

4.5 Discussion and Conclusions

The combination of the two -reappraisal and suppression- emotion regulation strategies produces more varied emotional responses in the VA. In particular, the emotional reactions of the VA in front of *adverse situations* have been improved which facilitates the provision of a more empathic feedback according to the detected events. Initial tests have been performed to analyse the different reactions and feedback produced during the reappraisal of some negative events. These new emotional reactions has facilitated the inclusion of more specific dialogues during the session which in turn would facilitate a better level of **acceptability** in the users. Using the adequate emotion, the user will be more informed and aware about the intention and purpose of the VA. Therefore, use of the system will be easier to him, which results in improved **usability**. Additionally, the management of the emotional response provides a personalized feedback to the users that convert them to active engage users. The **engagement** of the users is also leveraged thanks to the realism of the VA behavior at each interaction (Bickmore et al. 2010). The engagement of the users is strongly related with the improvement of the treatment **adherence**.

The development of the emotional module described in this chapter was focused on the achievement of the objectives detailed in the Table 1.1. The evaluations of the described emotional module are performed in the following two chapters. These evaluations will support the believability and acceptability of the virtual agent has increased.

In terms of further work, the current presented model can be extended in at least one interesting direction: the inclusion of a mechanism to select the specific emotion regulation strategy depending on the personality modelled in the virtual agent. During the user and system requirements stage of the Help4Mood project, some of the people in the group of potential users identified the importance to get two different styles of interaction in the virtual agent. While a group of users prefer a closer and friendly virtual agent, some others suggest that the virtual agent should adopt a more formal or professional stance.

At the moment, these two different *personalities* have been modeled by authoring different thresholds and decay rates in the modeled emotions. The thresholds for the the activation of the positive emotions in the *friendly* virtual agent are smaller than in the *formal* version of the agent. Moreover, the decay rates for these positive emotions in the friendly agent are also lower than in the formal agent which produce more positive emotional reactions in the first one and a more neutral attitude in the second one. What it is interesting to model in terms of emotion regulation, is the selection of the specific emotion regulation strategy and its frequency of use based on the different personalities. There is an evidence that the emotion regulation strategies habitually adopted by people are related to some individual differences characterised by different personalities (John and Gross 2007). The behaviours produced in the agent through the selection and frequency of the particular emotion regulation strategy would help to clearly differentiate the two personalities and provide the users with their preferred style of interaction.

Chapter 5

Evaluation: Case of Study I (Treatment)

The framework described in previous chapters (Chapters 3 and 4) has been evaluated in two real scenarios described in this and the next chapter. Current evaluation has been possible thanks to the participation during more than three years in the European project Help4Mood, which was aimed primarily at improving the monitoring of patients with major depression to support their treatments. Hence, the system has been applied during the treatments of real depressed patients. In order to carry out this evaluation, the generic framework has been integrated and adapted to clinical and technological specifications.

The professional clinical staff involved in Help4Mood (H4M) was responsible for customizing and selecting the best support material for the treatment of the patients in the three pilots of the evaluation. This material was mainly based on Cognitive Behavioural Therapy (CBT). Some of the material was performed ad-hoc by the clinicians given their expert knowledge.

The evaluation presented in this Chapter was focused to assess the achievement of some of the objectives presented in the first chapter (Table 1.1). Specifically, on the user acceptance, user engagement, and treatment adherence. Additionally, the system usage, subjective evaluations from the users about key features of the framework, and some clinical outputs were included.

In this Chapter, we summarize the depression disorder and the Help4Mood project as a technological proposal to treat it. Next, the framework adaptation, the definition of the evaluation environment, and the final outcomes are described.

5.1 Introduction

Depression is a persistent and intense alteration of mood, associated with cognitive, behavioural and physiological changes resulting in functional impairment (Freeman and Power 2007). Depression has been proved to be one of the most common causes of short and long term disability, accounting for substantial costs to health services, causing lost productivity and increasing the burden of caring. Most patients with major depression recover with treatment such as antidepressants, psychological therapy or, in severe cases, hospitalisation.

eHealth technologies have been used in many different ways to help people with depression and their clinicians. A prominent line of work focuses on computer-based and internet-based Cognitive Behaviour Therapy (Kaltenthaler et al. 2008; Williams and Martinez 2008), which provides access to therapy for remote rural areas and other situations where access to trained CBT therapists is difficult. Computerised Cognitive Behaviour Therapy (CCBT) is a useful self-help intervention in addition to traditional bibliotherapy, i.e., asking patients to work through selected self-help materials (Anderson et al. 2005). A related strand of research focuses on telepsychiatry (Monnier, Knapp, and Frueh 2003; García-Lizana and Muñoz-Mayorga 2010), where clinician and patient are connected over a video link, and cybertherapy (Galimberti and Belloni 2003; Wiederhold and Wiederhold 2004), which can take place in virtual worlds such as Second Life where both therapist and patient are represented by avatars, virtual persons whose appearance may not resemble their actual self. New technologies can solve the most important cause of treatment failure: the premature discontinuation of treatment. CCBT, in collaboration with face-to-face or telephone support, allows to increase the patient motivation to continue the treatment (Johansson and Andersson 2012).

Help4Mood is an European research project that aims to develop a research prototype of a system based on a CCBT for supporting the treatment of people with major depression at home. Thus, the project focused on (1) facilitating ongoing assessment/monitoring of mood, integrating monitoring of activity, neuropsychomotor symptoms, self-reported mood, cognitions, and behaviours; (2) facilitating simple activities that can be given as homework between therapy sessions, such as behaviour activation or relaxation training; (3) allowing clinicians and patients to identify relapse or stagnation more easily through a report designed to facilitate communication between patient and clinician; and (4) increasing compliance with activities through an engaging virtual agent, who talks to the users and takes them through exercises and activities and offers tailored responses with appropriate emotion. The aim is to create a sense of therapeutic alliance between the user and the agent, which encourages the user to keep using the system regularly.

In the following sections of this Chapter, the clinical evaluation in the Help4Mood environment is presented after a brief description of some related works. Next, the singularities and adaptations of the Framework are described, as well as the evaluation methodology and the obtained results. Finally, the conclusions are presented.

5.2 Related Works

Clinical decision support systems (CDSS or CDS) are interactive systems that assist physicians and other health professionals when making clinical decisions based on a given set of health information, such as determining a patient's diagnosis.

In the context of Help4Mood, we will extend the definition of DSS to cover intelligent, adaptive, and interactive monitoring: Existing health information is used to determine and to decide other pieces of self-reported health information that need to be collected in order to arrive at a comprehensive view of a patient's mental and emotional state. This functionality will be the cornerstone of the patient-side DSS, one of the key features of Help4Mood. In eHealth, the decision support can be provided either by a specialist team that makes recommendations based on a patient's Electronic Health Record (e.g., Pyne et al. 2010), or by a fully computerised system that implements well-validated guidelines (e.g., Kurian et al. 2009). Trials where a specialist team recommended medication records based on information from the Electronic Health Record tend to have equivocal outcomes. While Pyne et al. 2010 report that the intervention improved quality-adjusted life years (QALY), albeit at a cost of over $85K per QALY, Rollman et al. 2002 found no significant difference in outcomes for patients whose treatment was adjusted based on expert recommendations than for patients who received usual care. Fully computerised CDSS consist of three parts, knowledge base, inference engine, and user interface. The knowledge base contains rules and associations which most often take the form of IF-THEN rules. The inference engine combines the rules from the knowledge base with the patients data. The resulting analyses are displayed through the user interface, which also takes input from the user that can result in new queries and exploration of alternative scenarios. A comprehensive search of PubMed and Google Scholar identified three early stage DSS projects to improve diagnosis, one implementing a standardised interview (Bergman and Fors 2008), and two based on machine learning, one from EEG (Khodayari-Rostamabad et al. 2010) and one from clinical input (Tortajada et al. 2009). The main algorithms for adjusting patients' medications that have been reported in the literature are the TMAP algorithm and its successor, the STAR*D algorithm (Fava et al. 2003; Mark Sinyor, Schaffer, and Levitt 2010). The Texas Medication Algorithm Project (TMAP) guidelines are based on serial mood monitoring at 2-4 weekly intervals and was drawn up by consensus in 1999 (Rush et al. 1999). The main TMAP algorithm has been successfully implemented in a CDSS (Trivedi et al. 2004). The CDSS supports scheduling and summarises simple information such as questionnaire scores. However, the time intervals for trying medication regimes and definitions for improvement were not made very explicit-the target was a 50% reduction in the baseline questionnaire score. In a trial of the CDSS version of TMAP, issues regarding computer literacy and hardware/software requirements were identified as initial barriers. Clinicians also reported concerns about negative impact on workflow and the potential need for duplication during the transition from paper to electronic systems of medical record keeping (Kurian et al. 2009; Trivedi et al. 2009). While TMAP is relatively general, STAR*D focuses on patients where treatment with a particular antidepressant, citalopram, does not result in improvement. Although it takes into account whether a patient is receiving therapy, treatment plans focus on adjusting medications. According to Trivedi and Daly's review of CDSS for the TMAP and STAR*D guidelines (Trivedi and Daly 2007), the main role for a CDSS in this context is to ensure health care practitioners can easily access the algorithm and obtain correct information about suggested next steps at the point of care. The main problem with designing a traditional CDSS for Help4Mood is that none of the existing CDSS for depression have gone beyond a simple directed algorithm for adjusting medications. CBT and other forms of talking therapy, which are a mainstay of specialist practice, are not integrated. None of the existing systems use detailed daily monitoring and self-reports of the type that can be collected through Help4Mood. Instead, they rely on fortnightly or monthly monitoring. Furthermore, the existing CDSS extend specialist practice (in particular management of depression through medications) to non-specialists; they are not suitable for advising specialists, who are one of the key target clinician user groups for Help4Mood.

Help4Mood provides an innovation beyond the state-of-the-art in computerised support for people who are recovering from major depressive disorder in the community. This approach is based on the monitoring of patient self-reported mood, thoughts, physical activity, and sleep patterns. The system was attempt to improve adherence to computerised cognitive behavioural therapy, partly through the use of monitoring both physical signs and partly through interactions with a VA.

5.3 Framework

The Help4Mood project implements a distributed online platform to support the treatment of major depression, which is composed of three main layers as was described in Chapter 3. From these layers we highlight these three components respectively:

- A **Personal Monitoring System (PMS)**, installed at the home of the patient, which collects behavioural, neuropsychomotor, and subjective data. The PMS was designed by *Universitat Politècnica de Catalunya (UPC)* to be as non-obtrusive as possible. Objective monitoring is focused on two main aspects: activity patterns, and sleep. More information is available in (Cerio et al. 2012).

- A **Decision Support System (DSS)** with clinician and patient side components. The patient-side DSS controls what kind of information Help4Mood gathers from the patient and performs initial analyses for providing summaries to the patient. The clinician-side DSS analyses the patient data, determines trends that are important for making therapy-related decisions, and provides high-level summaries for patient and clinician. The main role of the patient-side Decision Support System will be to facilitate intelligent, adaptive collection of self-reported data. This will be crucial for the successful long-term deployment of Help4Mood. The clinician-side Decision Support System will distill both self-reported and objective data into a short textual and graphical overview that will help busy clinicians assess the patient's current mental and emotional state and guide further treatment decisions.

- A **Virtual Agent-based user interface (VA)** which serves as the main interface between Help4Mood and the patient. During interactions with the VA, subjective data is collected. The VA was designed by the Italian company *FVA* to be an animated, realistic talking head highly customisable, with several distinct personalities and appearances to choose from. VA component aims to increase user engagement and help users form an alliance with the system. More info is available in (Ferrini and Albertini 2012).

The overall architecture of Help4Mood was designed to be flexible enough and configurable. It was not linked to a specific treatment package, so it can be adapted to fit many different clinical settings and pathways across Europe. All layers were developed easy-to-use configuration interfaces for site-specific, treatment-specific, and user-specific adaptation. The documentation will also include clinical guidelines on incorporating Help4Mood into existing approaches to treatment.

The DSS for treatment management is one of the three main components of the Help4Mood system that needs to be carefully designed according to the clinical needs. The DSS component has been conceived as the main mechanism that will support the treatment of major depression at both sites where the Help4Mood system is deployed: at patient and clinical sites. At patient site the DSS aims to provide the support for the self-treatment of the patient, while at clinical site the DSS will support caregivers with specific information and recommendations for a better management of the treatment.

The PMS and the graphical development of the VA are out of the scope of this Thesis and they are only mentioned as part of the whole system. The main contribution of this dissertation is focused in the DSS component of Help4Mood, which is an adaptation of the presented Framework in the previous chapters (Chapters 3 and 4). This Framework is composed by two main modules:

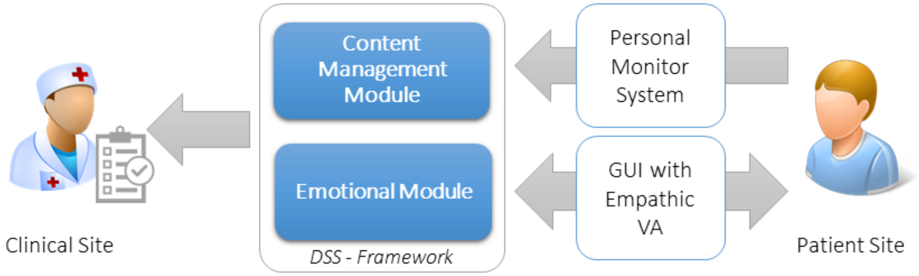


Figure 5.1: Overall architecture of the Help4Mood Project. The system is divided in two locations connected by the Internet: the patient and clinical sites. Both are managed by the DSS, which manages, analyses and summarises the user's daily sessions. The patient site includes the sensors of the Personal Monitoring System (PMS) which are used to collect objective measures from the user, including physical activity and sleep patterns; and the Virtual Agent (VA), which acts as the main interface with the user. In the Clinical site, a summary report is sent in order to keep the clinicians informed about the patient status. The DSS structure is the adaption of the Framework described in this Thesis, which is composed by two modules: the Content Management Module, and the Emotional Module.

- **Content Management Module**, whose functionalities are focused on a **cognitive process**, in which all the input data (from the PMS and VA) are processed; and the **session planner process** that is responsible for planning the most adequate therapeutic session;
- **Emotional Module**, which manages the inference of most adequate emotion conveyed through the VA to communicate the content session.

In the following section, the particular adaptations to Help4Mood and the configurations of the modules described in Chapters 3 and 4 are detailed.

5.3.1 Content Management Module

Cognitive Process

This layer is the responsible for analysing al the input and store data in order to infer clinical knowledge. The technical details of this layer are extended in Chapter 4. So this section is not focused on the functionality of this layer, but on the clinical content defined. The clinical staff defined the following tasks to provide the necessary support to the patient during the treatment:

- **Welcome** (ID01): Normal Welcome. It is inferred by DSS if the last login occurs within the 3 days (the value of the days can be included as parameter in the task structure).
- **Welcome_Reminder** (ID02): Welcome and reminder to the user that it is recommended to use the system regularly. It is inferred by DSS if the last login occurred more than 3 days ago.
- **DailyMoodCheck** (ID03-07): This questionnaire composed by four items of the CES-D VAS-VA questionnaire (Moullec et al. 2011) plus one item about the mood of the patient (DailyMoodCheck_1). The user will select a numeric answer based on 5 likert-scale (0-Strongly disagree; 1-Disagree; 2-Neither disagree nor agree; 3-Agree; and 4-Strongly agree).
  - **DailyMoodCheck_1** (ID03): VA ask "How is your mood today?".
  - **DailyMoodCheck_2** (ID04): VA say "I feel happy".
  - **DailyMoodCheck_3** (ID05): VA say "I feel like talking".
  - **DailyMoodCheck_4** (ID06): VA say "I feel other like me".
  - **DailyMoodCheck_5** (ID07): VA say "I feel like crying".
- **Select_Type_Session** (ID08): This task allows the user to choose the session length (long, medium, short). This selection will be taken into account for the Session Planner module in the performance of the session creation.
- **Sleep_Questionnaire** (ID09): This ad-hoc questionnaire is composed of nine questions about the time to go to bed, the number of times that the user gets up in the night, or the subjective quality of the sleep.
- **Configure_Activity _Plan (or Behaviour Activation)** (ID10): In this task the system provides a list of categorized activities such as '*read a book*', '*walking with friends*', '*phone some familiar*', etc. The user must select some of these activities in order to set an activity plan for the next days. These activities must be executed offline of the therapeutic sessions, without the virtual agent supervision.
- **Generate/Send Report** (ID11): This task is inferred if the last report occurred more than 7 days ago. This task will show a few options to the patient: print report, view report, send report to the clinician.
- **Introduce_Relaxation_Task** (ID12): A set of relaxation voices and themes are provided to the user.

- **Negative_Thoughts_Activity_Introduction** (ID13): Ask if the patient wants to start the activity of the negative thoughts. This task tries to identify the negative thoughts and transform them into positive ones. This is one of the most complex and long tasks.
- **Ask_For_Plannig_Activities** (ID14): This task is the responsible for checking if the activities selected by the user were executed. In case that some of them have not been executed, the virtual agent asks the reason (difficulty, time, engagement, etc.) and it will try to offer a new set of more appropriate activities.
- **Speech_Activity** (ID15): This task record the speech of the user in order to analize some variables (tone, speed, intonation, etc.) which are connected with the mood.
- **Activity_Monitoring** (ID16): Activity monitoring dialog is inferred if the DSS detects that the PMS is not reporting sensor data in the last 3 days. The system asks why the patient is not using the sensor devices.
- **Introduce_PHQ9** (ID17): This standarized questionnaire is one of the most used with depressed patients. It shows the nine questions to assess the level of depression.
- **Crisis_Plan** (ID18): This is a very important task. When the system detects that the user is in a suicide risk, or he has deteriorate their clinical status, it launches an emergency plan called crisis plan. The system tries to relax the user and provides some emergency centers or relatives/friends contact information. Additionally, for future sessions, the system restricts the activities disclosing only the Daily Mood Check (DMC) questionnaire.
- **Farewell** (ID19): Regular goodbye session. It is inferred when all the previous tasks are done.
- **Shutdown** (ID20): When DSS receives Farewell feedback from the user, DSS sends a shutdown signal.

Session Planner Process

As introduced in Chapter 4, the Session Planner module is the responsible for sorting and selecting the most adequate tasks attending some established restrictions. In Figure 5.2 there is a simple flow diagram of the Session Planner execution.

The configuration reported by the clinicians in this Case of Study is described in (Bresó et al. 2016) and Chapter 4 as '*restrictive scenario*'. This conservative configuration was performed by the expert clinical staff of the Help4Mood project.

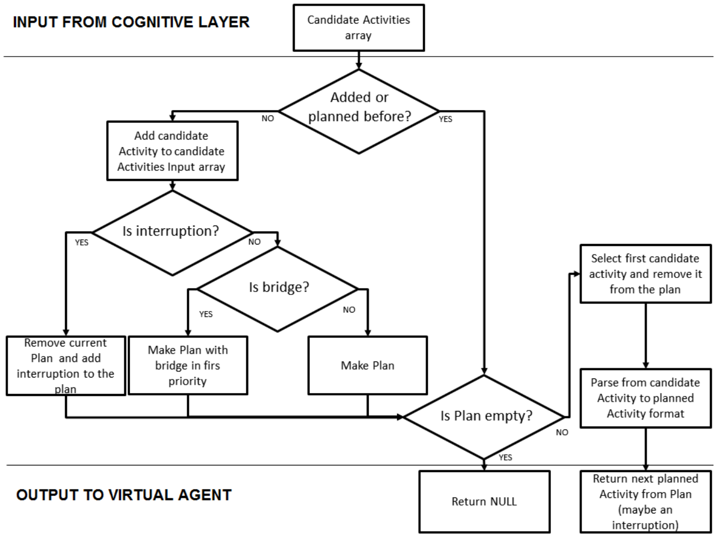


Figure 5.2: Flow diagram of Session Planner execution

This configuration provides a guided sessions, so the expected levels of variability and adaptability are low.

5.3.2 Emotional Module

As specified in Chapter 4, the Emotional Module is based on the cognitive appraisal theory of emotions (Lazarus 1991; Scherer, Schorr, and Johnstone 2001). For this Case of Study I, the emotional layer was presented with two different implementations in order to compare it. The first one, simulates the natural empathy using the cognitive appraisal theory of emotions. This theory of emotions postulates that the events occurred in a person's environment are evaluated constantly (not necessarily conscious or controlled) by the individual. This cognitive evaluation (appraisal) leads the individual to an emotional response (according to the event's relevance for the person), which in turn generates a specific behaviour to cope with the appraised events. In this sense, the cognitive-emotional component of the VA is the responsible for appraising the specific events that occur during the interaction with the patient. From each event's appraisal process, the Cognitive-Emotional Module will select the concrete emotion in order to communicate the task selected by the session planner.

The second one tries to simulate etherapeutic-empathy responses in the agent and not only natural empathic reactions. They are based on Gross's theory of emotion regulation, which refers to the heterogeneous set of processes by which emotions are themselves regulated. More detail are published in (Martínez-Miranda, Bresó, and García-Gómez 2014).

In the specific implementation in Help4Mood, the VA is composed of different but inter-related components, which process and generate different aspects in the agent's behaviour. The components include the Emotional Module which receives the events inferred in the DSS (using the PMS and GUI user inputs) during a session with the patient. These events are used by the Emotional Module to produce the specific task and the corresponding -if any- emotion to be disclosed during the interaction with the patient. A second component is the Dialogue Manager System (DM), which transforms the task received from the cognitive-emotion module as dialogue acts. The dialogue acts are passed to the Natural Language Generator (NLG), which produces the content of the agent's verbal response in an appropriate style. The generated text string is sent to the Text-To-Speech (TTS) engine which realises the audio with the appropriate tone of voice. The audio and time-aligned phonemes used for lip-syncing are passed to the graphical representation of the virtual agent which takes the form of a talking head immersed in the GUI of the application (see Fig. 5.3). The current active emotion is also passed to the GUI for the rendering of the corresponding non-verbal communication (i.e. head movements and a set of facial expressions to convey the triggered emotion).

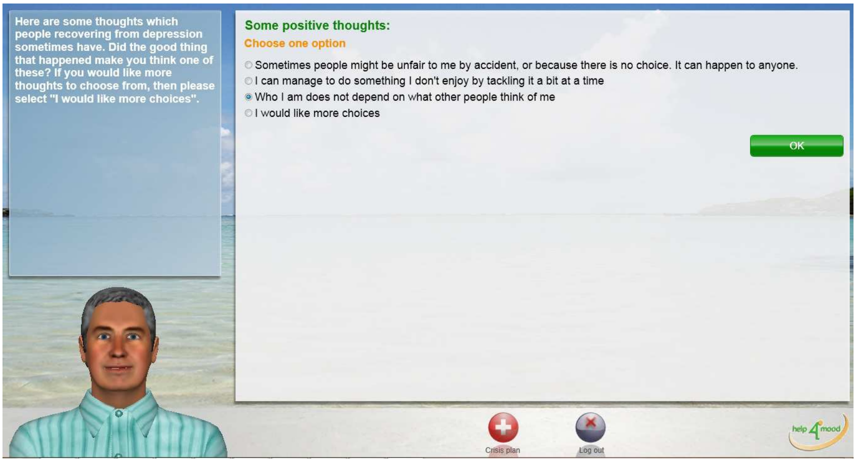


Figure 5.3: The Help4Mood GUI in which the VA is embebed

When something *goes wrong* in the clinical condition of the patient (inferred in the DSS from the PMS data or from patient's self-reports), a neutral attitude (i.e. no emotion) is adopted by the VA. The three positive emotions, when elicited, are conveyed to the patient through the combination of open and close mouth smiles plus some head movements such as nodding (identified as a key element to reinforce the sense of attention and understanding during clinician-patient communication (Rogers 2002)). As stated in (Ekman 2003), most of the positive (*enjoyable*) emotions share the smiling expression and it is not straightforward to differentiate them just through the face but other signals, such as the voice, are required. The strategy followed in our scenario was to use the intensity of the triggered emotion to display a mouth open (greater intensity) or mouth closed (lesser intensity) smile. Moreover, the positive emotions are also used by the Dialogue Manager to select and add specific utterances to the verbal feedback provided by the VA (e.g. "*That's great!*" or "*Well done!*").

5.4 Case of Study

Thanks to Help4Mood, the development described in this Thesis. has been evaluated in three clinical pilots (see Table 5.1). The evaluation has been planned by the clinical staff of the project in different clinical centers. Thus, the Framework has had to be adjusted (see Chapter 5.3) to provide the contents recommended by the clinicians to support treatment for patients with major depression.

Ethical approval for the studies was obtained from the Babes-Bolyai Research Ethics Committee (Romania), the Ethics Committee of the University of Edinburgh College of Medicine and Veterinary Medicine, and the Ethics Committee of the St. Joan de Deu (Barcelona) hospital.

The evaluation process was composed of **three incremental pilots**. These pilots were sequential and they increase the number of participants, the length of the period, and the number of functionalities of the system (see Tables 5.1 and 5.2). Each of these pilots was focused on different participants and different aims, so they are described in the following subsections. Although each pilot specify their own criteria, they share common and basic criteria. These overall inclusion and exclusion criteria for participant selection in all pilots are summarized as follow:

- **Inclusion criteria**
  - Between the ages of 18 years and 64 (inclusive).
  - Recruitment on a voluntary basis.
  - Currently living at home, in the community.
- **Exclusion criteria**
  - A recent major adverse life event such as bereavement; a history at any time, of bipolar disorder, psychotic depression, other psychotic disorder, organic brain disorder, learning disability or substance misuse.

- An organic brain syndrome, mental learning difficulty, difficulties in comprehension, communication or dexterity which would restrict the ability to use Help4Mood.

- Currently receiving psychological therapy that goes beyond general psychological supportive treatment, such as structured Cognitive Behaviour Therapy.

- Any change to antidepressant medication within the three months prior to enrolment.

- Requiring personal assistance for activities of daily living or mobility.

Table 5.1: Summary of the defined features for the three evaluation Pilots. Selected participants column shows the number of participants selected before applying inclusion and exclusion criteria. Enrolled Participants column shows the participants who confirmed their participation and started in the pilot. The first Pilot was conducted by 5 scottish participants during one week. In 2013, the second Pilot was conducted in Cluj-Napoca (Romania) and Catalunya (Spain) by 7 participants. The last Pilot was conducted during four weeks in June 2014 by 28 participants from the three countries (14 in the intervention group + 14 in the control group).

Pilot	Start Date	Country	Selected Participants	Enrolled Participants	Duration (days)
1	February 2013	Scotland	5	5	7
2	August 2013	Romania	4	4	14
		Spain	3	3	14
3	June 2014	Romania	28	18 (9+9)	28
		Spain	3	3 (2+1)	28
		Scotland	13	7 (3+4)	28

Based on common criteria, for each Pilot they were clarified and specified as described in the following sections. Pilot 1 was the most basic and was applied to recovered patients. The other two pilots were performed with patients under treatment. The first Pilot included a minimum set of activities, and the VA only showed neutral and positive emotions. The number of activities were incremented in the second Pilot. The clinical staff allowed the inclusion of regulated negative emotions, using the suppression strategy in order to satisfy the request from participants in the first Pilot. Finally in the third Pilot, all the activities were included. Regarding the emotional model used in Pilot 3, clinicians scheduled the use of the full implementation emotion model (cognitive change), but it could be only applied in two users from the Spanish center (see Table 5.3).

Table 5.2: Summary of the functionalities (tasks, actions and modules) included at each evaluation Pilot

Functionality	Pilot I	Pilot II	Pilot III
Welcome/Welcome Reminder (ID01/02)	X	X	X
Farewell (ID19)	X	X	X
Shutdown (ID20)	X	X	X
Daily Mood Check (ID03-07)	X	X	X
Activity Monitoring (ID16)	X	X	X
Select Type Session (ID08)	—	X	X
PHQ-9 (ID17)	—	X	X
Negative Thought Questionnaire (ID13)	—	X	X
Speech (ID15)	—	X	X
Crisis Plan (ID18)	—	X	X
Summary Report (ID11)	—	X	X
Sleep Questionnaire (ID09)	—	X	X
Behaviour Activation (ID10 & 14)	—	—	X
Relaxation (ID12)	—	—	X

Table 5.3: Summary of the strategy implemented in the Cognitive-Emotional Module for each evaluation Pilot

Emotional implementation	Pilot I	Pilot II	Pilot III
Natural Empathy (neutral and positive emotions only)	X	—	—
Therapeutic Empathy with response modulation (neutral, positive and negative emotions)	—	X	X
Therapeutic Empathy with cognitive change (neutral, positive and negative emotions)	—	—	X

Additionally, the clinicians were established the minimum and maximum number of executions for each task as is showed in Table 5.4. These information will be used in order to calculate the adherence to the treatment in the Pilots 1 and 2.

Table 5.4: Setting of the minimum and maximum number of executions per week of each optional tasks involved in the three pilots. The required tasks are not included in this table because if they are inferred by the KI they will be planned. This configuration was set by the clinicians.

Task	Min. executions	Max. executions
Daily Mood Check Questionnaire	7	7
Speech Activity	3	5
PHQ-9 Questionnaire	1	1
Sleep Questionnaire	5	7
Negative Thought Questionnaire	3	7
Relaxation	1	3

5.4.1 Pilot 1: Evaluation of the first prototype with recovered users

Objective

The main aim of this study was to investigate the usability of a limited first integrated version of the Help4Mood integrated system in participants who are recovered from a major depressive episode. Since recovered participants have the experience of being depressed, they have key advantage when using the system. A secondary aim was to obtain qualitative and quantitative data regarding monitoring and basic participant system interaction.

Participants

In Pilot 1, based on the common criteria and the following specific inclusions criteria, five participants were recruited from Scotland (see Table 5.5):

- They had a previous episode of Major Depression Disorder (MDD) diagnosed by a general practitioner, psychiatrist or clinical psychologist between 6 and 18 months previously, but were either fully recovered or had only residual mild depressive symptoms.

- Their score on the Patient Health Questionnaire 9 (PHQ-9) was less than 10 out of 27.

- Their score on the Beck Depression Inventory II was 13 or less.

Table 5.5: Features of the patients involved in the evaluation of Pilot 1.

Participant	Gender	Country
P1.1	Female	Scotland
P1.2	Female	Scotland
P1.3	Female	Scotland
P1.4	Male	Scotland
P1.5	Male	Scotland

Evaluation

Pilot 1 conducted five case studies that covered a one-week period of activity and mood monitoring and patient-agent dialogue. The clinical staff of the project limited emotional responses of the VA to neutral and positive: the VA must never generate a negative emotion (see Table 5.3). This first pilot provided a limited functionality regarding available tasks (see Table 5.2) and emotions, but every components were integrated (PMS+DSS+VA). So a full version of the system was assessed in this evaluation, following a pre- and post-interview methodology in 3 different steps in order to identify any usability problems:

- **First step**: Clinicians conducted a short semi-structured interview about participants previous experience with technology, in particular any experience of using it to manage their depression or record their symptoms. No standardized questionnaire was applied.

- **Second step**: The participants used the Help4Mood system in their homes during 7 days. In this period the system stored all the information of the interactions. As describe in Bresó, Martínez-Miranda, and García-Gómez 2014, two factors were studied from the gathered data: (1) system usage, which is obtained directly from the daily use, and it refers to the percentage of days on which the system has been used during the duration of the pilot; and (2) adherence to the treatment, which is the ratio between the maximum number of tasks recommended by clinicians (see Table 5.4) with the number of tasks actually completed by the user using the system (Process-oriented). In this first Pilot, only one required task was configured (*Daily Mood Check*) and it was configured to be executed in every session, so it should be performed once per day during the seven days of the system's use.

- **Third step**: At the end, the participant returned the system and clinicians conducted another semi-structured interview to assess their experience on the use of the system. The interview covered (1) activity monitoring; (2) the mood monitoring component of the system; (3) the agent interface; (4) the dialogue component of the agent; (5) the patient-agent interaction.

Results

The results obtained in this first Pilot were very promising. Specifically we focused on the (1) system usage, on (2) treatment adherence, and on (3) subjective personal interviews in order to assess the overall usability of the Framework. We processed the system logs to conclude that the **system usage and the treatment adherence obtained high rates**, both were 94% as showed in Table 5.6. Both results are equal in this Pilot because the configured tasks were set as mandatory. Users could not refuse to do the tasks, the system directly planned them without the opportunity to decline them. So if the system was used, the four tasks were necessarily planned and executed.

Table 5.6: First Pilot results regarding system usage (%) and treatment adherence (%).

ID	System Usage(%)	Treatment Adherence(%)
P1.1	100	100
P1.2	75	75
P1.3	100	100
P1.4	100	100
P1.5	100	100
AVG	94	94

From the final interviews of the first Pilot, we highlight a very common and important advice from the participants: "*The behaviour of the virtual agent has been very neutral, it didn't showed emotional variation*". As expected, this feedback confirmed the need to implement a set of negative (but regulated) emotions in the VA as response to the negative events reported by the user, and not to maintain a neutral attitude in front of those events. The Cognitive-Emotional model was extended for the next pilot by incorporating the emotion regulation model described in Chapter 4. Additionally, the participants also reported that the question number four of the DMC was confusing and it must be rewritten.

Regarding other technical components, out of the scope of this Thesis, the participants highlighted that the biggest problem in this Pilot was the sensors synchronisation. In some cases, although the system startup was slow, that was not perceived as a problem. However, for two participants, the system failed to start, which led to intense frustration. In general, the system was accepted by the participants although they demanded a system with more feedback.

The gathered feedback obtained in this first Pilot was very valuable and it was taken into account to perform updates for the framework to improve it.

5.4.2 Pilot 2: Evaluation of the second prototype with depressed patients.

Objective

For this second Pilot, the main aim was obtaining from real patients with depression, the acceptability of the system regarding the management of the sessions and emotional reactions of the VA.

In Pilot 2, the system was updated with more functionalities (see Table 5.2). The most important update was focused on the Cognitive-Emotional model of the VA: regulated negative emotions were added using response modulation strategy, which was described in Chapter 4. This emotion management allowed to simulate more empathic reactions.

Participants

Seven participants were recruited (see Table 5.7) after refining the common inclusion criteria as follows:

- Currently fulfilling criteria for a Major Depressive Episode as diagnosed by the Structured Clinical Interview (SCID) for DSM disorders.
- Their score on the Beck Depression Inventory II (Beck, Steer, and Brown 1996) was between 14 and 28, indicative of at least mild depression.

Table 5.7: Features of the patients involved in the evaluation of Pilot 2.

Participant	Gender	Age	Country
P2.1	Female	30	Romania
P2.2	Female	26	Romania
P2.3	Female	23	Romania
P2.4	Female	27	Romania
P2.5	Female	45	Spain
P2.6	Female	59	Spain
P2.7	Female	38	Spain

Evaluation

Pilot 2 followed a similar methodology than Pilot 1. During two weeks, 7 patients were exposed daily to the Help4Mood system. In this Pilot, the system was provided with a wider range of emotions (see Table 5.3) and more functionalities than Pilot 1 (see Table 5.2). These are the steps of Pilot 2:

- **First step**: For both countries, clinicians intaked data collection consisted of several parts:

  - A standard demographics questionnaire covering information such as age, sex, employment status and a standardized questionnaire probing attitudes to computers, aversion to computers, and familiarity with computers (Schulenberg and Melton 2008).

  - A semi-structured interview that probed participants attitudes to technology, their familiarity with and use of technology, their experience with and history of monitoring symptoms of their depression; their experience with treatment of depression; their support network; and preferred coping strategies.

  Additionally, in Romania a set of four questionnaires covering mood and quality of life were used: Beck Depression Inventory – II, Dysfunctional Attitude Scale – Short Form 2 (Beevers et al. 2007), Brief Quality of Life Assessment (Brooks, Rabin, and De Charro 2013), and Quick Inventory of Depressive Symptoms - Self-Report (Rush et al. 2003).

- **Second step**: The participants used the Help4Mood at their homes during 14 days. In this period the system stored all the information of the interactions. As described in Bresó, Martínez-Miranda, and García-Gómez 2014, three factors were studied from the data gathering: (1) system usage; (2) adherence to the treatment; and (3) System engagement, that is measured based on the length (Long, Medium, Short) of the daily session selected by the patient. Specifically, for the measurement of the engagement we reviewed published works such as Bickmore et al. 2010, in which the author showed different measurement proposals. He related the engagement with the desire to continue using the system. So we based our engagement metric in this statement. Our patients could select the length of the session that allows us to analyse the patient engagement to the system (see Table 5.9). The choice of long sessions suggests greater involvement and motivation. On the other hand, the selection of short sessions suggested little engagement and commitment.

- **Third step**: After two weeks, the system was returned, and a researcher administered the four main questionnaires of the first stage in Romanian center.

  Additionally, all participants were asked about their experience with the Help4Mood system in a semi-structured interview. Specifically, we highlighted questions related with the acceptability of the developments described in the Chapters 4 and 5. Therefore, we based the acceptance on three variables: (1) length, (2) variability, and (2) content of the session. The personalized and adaptive daily interactive HCI-based Framework described in Chapters 3 and 4 is the responsible of managing these variables. Length and variability are related with the Session Planner module, and the content with the other three modules (Data Analyses, Knowledge Extraction, and Knowledge Inference System).

  In order to evaluate the acceptability by the participants of the updated emotional reactions of the VA (called *response modulation*), a Likert-based scale questionnaire was performed (Table 5.8) for the Spanish participants. The questionnaire was designed to assess whether the inclusion of the regulated negative emotions is appreciated by the users.

Table 5.8: Likert-based scale questionnaire used for evaluating the emotional behaviour of the agent. This short questionnaire allowed obtaining the perception of users about the empathy generated by the VA.

Question	Text
Q1	The virtual agent behaves cold and aloof
Q2	The virtual agent is trustworthy
Q3	The virtual agent looks emotionally stable
Q4	The virtual agent motivates me to use the Help4Mood system on daily basis
Q5	Please comment anything that you found disliking in the appearance or behaviour of the VA

Results

This second Pilot was more complete and complex than Pilot 1, hence we obtained more information for assessing the acceptability from the patients about the framework. All of the data collected and analysed in Pilot 2 was also used to refine the analytical algorithms for the objective monitoring of activity and sleep, and to develop the summary reports.

As expected, the treatment adherence and system usage rates (Table 5.9) were lower than in Pilot 1 (Table 5.6) due to the increment in the number of tasks.

Tables 5.4 and 5.2 show that patients in Pilot 2 were requested to perform a minimum of 38 activities in 15 days and a maximum of 60 (optimal result that we take as a reference to calculate the treatment adherence). It is worth to mention that the calculated adherence to the treatment depends on the number of completed activities, not on the days that the users use the system. So **the adaptive session planner management facilitates that the users with low use of the system can achieve high adherence**.

In general, the user engagement in this pilot was good: the 48% of the session selections were 'long session', while 'medium session' 13% and 'short session 39%. Patient P2.2 had a low system usage (60%), so adherence was also low (51%). The patients P2.1 and P2.3 got a 100% use of the system. Regarding adherence, they presented different results. This is due to the selection of each patient in the length of the conducted sessions. P2.1 selected mainly short sessions, while P2.3 selected long sessions. Similarly, P2.4 has less system usage than P2.1 but has almost the same treatment adherence. That is because P2.4 has made many more long sessions than P2.1, so P2.4 was able to complete more tasks.

Table 5.9: Values of the patient engagement (%) based on type session selection (long, medium, or short), patient system usage (%), and adherence to the treatment (%) in Pilot 2. Only results from Romanian participants (P2.1-P2.4) were available. Data from Spanish participants (P2.5-P2.7) were inaccessible.

ID	Session Selection(%)			System	Treatment
	Short	Medium	Long	Usage(%)	Adherence(%)
P2.1	66	20	13	100	77
P2.2	25	12.5	62.5	60	51
P2.3	10	20	70	100	88
P2.4	54	0	45	87	72
AVG	39	13	48	87	72

From the final interviews conducted with participants of both countries, subjective data about the function and acceptability of the system was obtained. Regarding the length of the session, four patients asserted that the sessions were very short and the remaining patients claimed that the duration was adequate. Hence, the feedback indicates that more tasks may improve the user experience with the system, and in consequence, we may expect the increment of the adherence. The final Pilot was performed with more tasks.

> Participant P2.3: *"I would have liked the sessions to be about ten minutes longer"*.

> Participant P2.4: *"The long session is about half of what a long session should be".*

> Participant P2.6: *"The long session is the same as the middle session... short session is too short".*

> Participant P2.7: *"The short session is too short".*

Regarding the variability of the session, three patients asserted that the sessions were predictable and repetitive. Three patients did not comment about this parameter in the interview. One patient reports that the system provided the variability necessary:

> Participant P2.1: *"I would vary a bit the content of the longer session so you do not get the exact same items every day...".*

> Participants P2.5 and P2.7: *"Sessions are repetitive".*

> Participant P2.2: *"The sessions, in terms of length, content and format, were very good".*

Finally, three patients did not comment about this the content of the session in the interview, but four patients were satisfied with respect to content.

From these interviews, we focused on the perception of the patient on the interaction with the system. Specifically, we were interested in the perception that they have about the management of the session: variability, length, and content. So we tried to make a correlation between the subjective opinions of the patients in the interviews regarding the variables that we want to study, using categorical results (*adequate*: +1, *neither*: 0, or *non-adequate*: -1) as is showed in Table 5.10. These results show that the participants agreed with the contents, neutral about the variability of the sessions, but they considered that sessions length was non-adequate. In order to improve these aspects, we decided to include new more available tasks.

Regarding the perception of the emotional behaviour of the virtual agent, a questionnaire (Table 5.8) was administered to Spanish participants. These results are summarized in the Table 5.11. We can highlight that 2 of the 3 participants strongly agreed with the sentences that the VA is warm, close, emotionally stable and motivates them to use the system on daily basis. Regarding question Q5 (which is text free) we can highlight that last participant (P2.7) was the most critical, for her the VA did not seem credible neither convincing. In contrast, for

Table 5.10: Summarized results of the evaluation of the acceptability of the management of the session. Each variable was evaluated as *adequate* (+1) if the patient agreed with the functionality, *neither* (0) if the patient had no opinion about this feature in the interview, and *non-adequate* (-1) if they did not agree.

ID	Session Evaluation		
	Length	Variability	Content
P2.1	+1	-1	0
P2.2	+1	+1	+1
P2.3	-1	0	0
P2.4	-1	0	0
P2.5	+1	0	+1
P2.6	-1	-1	+1
P2.7	-1	-1	+1
Mode	-1	0	+1

Table 5.11: Responses to the performed questionnaire which was performed to assess the acceptability of the emotional reactions of the virtual agent by the patients. Only the participants from Spain filled this subjective questionnaire. The available responses were based in 5 likert-scale: 0-Strongly disagree; 1-Disagree; 2-Neither disagree nor agree; 3-Agree; and 4-Strongly agree. *Question Q1 was formulated as inverse approach (see Table 5.8), so the lower the value, the better results.

ID	Questions			
	Q1*	Q2	Q3	Q4
P2.5	0	4	4	4
P2.6	0	3	4	4
P2.7	4	2	2	1
AVG	1.3	3	3.3	3

the other two participants the VA experience was real, but one of them noted that the VA was a little predictable.

Regarding the standardised clinical questionnaires, only the Romanian participants answered those questionnaires. They filled the four questionnaires in the first and last stage of the evaluation. This information is shown in Table 5.12, and suggest a marked improvement in BDI II scores for three of the four participants. All participants scored below 14, the cut-off for mild depression, on the BDI II after they had used Help4Mood for two weeks. Scores on the DAS SF-2 dysfunctional attitude scale and on the QIDS SR 16 measure of depressive symptoms also dropped. DAS SF-2 scores range from 36 (highest dysfunctional attitudes) to 9; scores on the QIDS-SR 16 range from 27 (worst) to 0 (lowest incidence of depressive symptoms). Clinical outcomes are not the focus of this evaluation but these obtained results are very interesting, as are discussed in Wolters et al. 2014.

Table 5.12: Pre- and post-test results on questionnaires measuring symptoms of depression and quality of life were improved during the second Pilot. Only the data from Romanian participants were available. Results from BDI-II are classified as minimal depression (0-13), mild depression (14-19), moderate depression (20-28), and severe depression (29-63). The range of DAS-SF2 final scores are from 12 (best score) to 33 (worst score). QIDS-SR results are classified as: no depression likely (0-5), possibly mildly depression (6-10), moderate depression (11-15), severe depression (16-20), and very severe depression (21 or Over). EQ-5D is range from 0 (best score) to 100 (worst score).

ID	BDI-II			DAS-SF2			QIDS-SR			EQ-5D		
	Pre	Post	Dif.	Pre	Post	Dif.	Pre	Post	Dif.	Pre	Post	Dif.
P2.1	21	12	-9	27	22	-5	15	8	-7	85	85	0
P2.2	15	6	-9	24	22	-2	11	4	-7	95	95	0
P2.3	14	12	-2	20	14	-6	10	8	-2	85	92	7
P2.4	21	13	-8	22	19	-3	15	4	-9	80	78	-2

5.4.3 Pilot 3: Evaluation of the full system in Randomized Controlled Trial (RCT)

Objective

The main aim of this evaluation was to test the feasibility of deploying H4M in different clinical contexts (Romania, Scotland, Spain) and obtaining study design parameters for testing H4M in future trials. Additionally, the acceptability of the Help4Mood system when it is used over the intended period of at least 1 month is evaluated. Additionally, two different implementation of the emotional components included in the framework were performed in order to compare the user acceptance for each strategy: *response modulation* for simulating natural empathy (strategy applied in Pilot 2) Vs. *change behaviour* using reappraisal in order to simulate therapeutic empathy (see Table 5.3).

Participants

In this last Pilot, the recruitment of participants was more complex than in the previous pilots due to the addition of the control group for the evaluation purposes. Based on the below imperative criteria and following specification inclusion criteria, a total of 28 participants were recruited for the evaluation but finally, only data from 21 participants was available (see the consort flow diagram in Figure 5.4).

In this case, the specific inclusion criteria were the following:

- Major Depressive Disorder (MDD) as primary diagnosis.
- Their score on the Beck Depression Inventory II (BDI-II) score must be above 9 and below 31.
- They must be under the supervision of a clinician.
- If they are under treatment with antidepressant medication, neither dose nor agent should have been changed in the four weeks prior to recruitment. Patients prescribed additional hypnotics or anxiolytics for symptom relief were also eligible.

Table 5.13 sumarizes the demographical data of the participants from the intervention group.

Table 5.13: Features of the patients added in the intervention group of the Pilot 3.

Participant	Gender	Age	Country
P3.1	Female	57	Scotland
P3.2	Female	31	Scotland
P3.3	Female	32	Romania
P3.4	Female	54	Romania
P3.5	Male	28	Romania
P3.6	Male	29	Romania
P3.7	Female	27	Romania
P3.8	Female	30	Romania
P3.9	Female	20	Romania
P3.10	Female	33	Romania
P3.11	Female	49	Spain
P3.12	Female	60	Spain

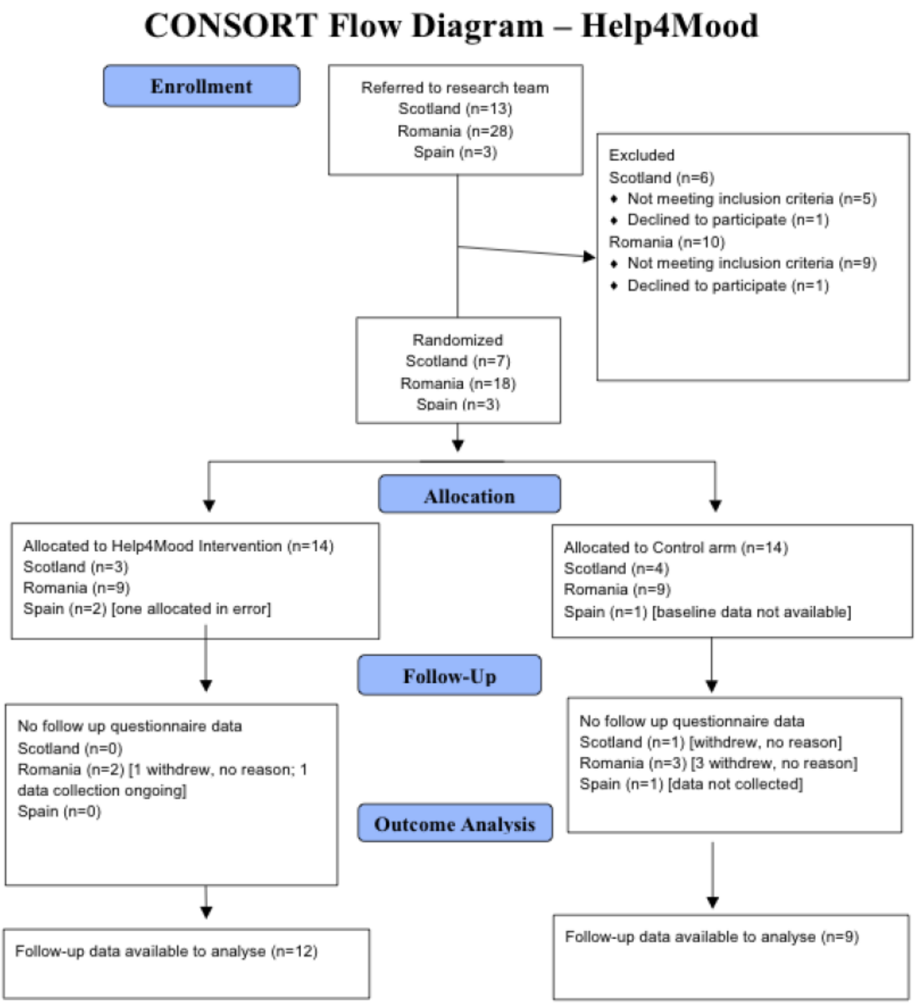


Figure 5.4: CONSORT Diagram for Help4Mood Pilot 3. Left branch corresponds to intervention group, and right one to control group (Source: Burton et al. 2015).

Evaluation

The RCT was performed using the following two groups of 14 participants:

1. **Control group**: Treatment as usual (TAU) or usual care with antidepressants; wait list for psychotherapy, and followed up by clinician.
2. **Intervention group**: This participants follow up during four weeks the treatment with the Help4Mood system (TAU + H4M).

So each group completed these defined steps:

- **First step**: As in Pilot 2, clinicians intaked data collection consisted of questionnaires and interview:

  - A standard demographics questionnaire covering information such as age, sex, employment status and a standardized questionnaire probing attitudes to computers, aversion to computers, and familiarity with computers (Schulenberg and Melton 2008).
  - A semi-structured interview that probed participants attitudes to technology, their familiarity with and use of technology, their experience with and history of monitoring symptoms of their depression; their experience with treatment of depression; their support network; and preferred coping strategies.
  - Five questionnaires covering mood and quality of life: Beck Depression Inventory – II (Beck, Steer, and Brown 1996), Dysfunctional Attitude Scale – Short Form 2 (Beevers et al. 2007), Brief Quality of Life Assessment (Brooks, Rabin, and De Charro 2013) (Utility and VAS version), and Quick Inventory of Depressive Symptoms - Self-Report (Rush et al. 2003).

- **Second step**: The intervention group used the Help4Mood system at homes during 2 weeks. After this period, the clinicians phoned them to follow-up. Then, they continued using the system 2 weeks more. Instead, the control group received usual treatment during four weeks.

  For Spanish participants (P3.11 and P3.12), a different system version was used. This version implemented the cognitive change model in the Virtual Agent. So, when the emotional component infers a negative emotion from a received event, the system will take into account other variables in order to reappraise the situation and change the interpretation of the event, which may infer a positive emotion (or a negative emotion with a lower intensity).

For Scotland and Romanian participants (P3.1-P3.10) (as in Pilot 2), the elicitation of negative emotions are suppressed using response modulation.

- **Third step**: Four weeks after the second step, the intervention group returned the system. For both groups, a researcher administered the four main questionnaires of the first stage. Follow-up semi-structured interviews were also administered.

  Specifically, a Technology Acceptance Model (TAM) questionnaire was prepared for two Spanish participants of the intervention group in order to obtain their perception about the functionalities of the system. The first 5 questions (from Q1 to Q5) were related to the content of the adaptive daily sessions, and the other questions (from Q6 to Q11) were related to the way in which the Virtual Agent communicates with the patient (see Table 5.14).

Table 5.14: Likert-based scale questionnaire used for evaluating the behaviour of the agent in Pilot 3, which is performed by the two modules included in the Framework: Session Planer Module and Emotional Module.

Question	Text
Q1	The length of the sessions were adequate, allowing me to achieve the goal
Q2	The variability of the sessions was adequate, allowing me to achieve the goal
Q3	The content of the session was adequate, allowing me to achieve the goal
Q4	I am satisfied with the planned sessions, it helps me to achieve the goal
Q5	I would like to continue working with this planned sessions
Q6	The virtual agent behaves cold and aloof
Q7	The virtual agent is trustworthy
Q8	The virtual agent looks emotionally stable
Q9	The virtual agent motivates me to use the Help4Mood system on daily basis
Q10	I am satisfied with the emotional responses of the VA, it helps me to achieve the goal
Q11	I would like to continue working with this VA

Results

The control group (or usual care) and intervention group (Help4Mood) presented similar values regarding gender, education, age, and medication status. The mean age (and standard deviation) from all Romanian participants was 37.3 years (11); for Scotland was 38.9 (12.4); and for Spanish participants were older with 54.5 (7.8). The mean age for the participants in the control group were 41.9 (10.9), while in intervention group was 37.5 (12.9).

At the end of the Pilot 3, the generated data in the Help4Mood daily sessions from 12 participants were analyzed. These data are overall summarized in Table 5.15, and in Table 5.16 the assessment of engagement and the system usage are detailed. In this Pilot, it was not possible to analyse the treatment adherence as in the past Pilots, due to technical incompatibilities (such as Java installed versions) or technical mistakes (such as the wrong initialization of the system logs or losing data).

Table 5.15: Overall summary of the collected data in the intervention group: selections by the user of the type of the session and the days and minutes elapsed.

ID	Session Type Selected			Sessions	Days with H4M	Sessions Time (min)	Mean Time (min)
	Short	Medium	Long				
P3.1	4	0	8	12	19	189	16
P3.2	2	4	1	7	9	92	13
P3.3	6	8	9	23	30	369	16
P3.4	0	1	1	2	2	26	13
P3.5	9	6	4	19	29	150	8
P3.6	2	3	1	6	27	43	7
P3.7	6	2	3	11	41	195	18
P3.8	5	6	4	15	36	225	15
P3.9	4	2	4	10	15	118	12
P3.10	7	4	2	13	18	176	14
P3.11	2	0	0	2	28	34	17
P3.12	2	1	4	7	17	106	15
Total	49	37	41	127	270	1723	14

Table 5.15 shows the different patterns of use by the participants in the intervention group. We did not specify in advance a target for sufficient use, but at least half of the participants spent more than 2 hours spread over at least 10 sessions.

The variation in the average of the session duration (from 7 to 18 minutes) confirms the variability provided by the session planner. As explained in Chapter 3, normally the length of the session is related to the choice of the type session by the user but not always the long sessions are longer than the short sessions, and vice versa. There are a number of constraints that the planner must meet. Therefore, the length of the session is not only restricted by the selection of the session type by the user. For example, in Table 5.15 we can see how user *P3.11* has only executed 2 times the system during 28 days. On both occasions the user selected the short session. With this low system usage (that is showed in 5.16 also), clinical objectives established minimum parameters that were not meet, and the planner attempted to meet them. To do this, the Session Planner includes in the sessions all the required tasks to achieve the clinical pre-defined requirements which greatly increases the average session time: 17 minutes.

Regarding the patient engagement, the scores have been divided: the short session was selected by the participants with 39%, medium with 29%, and long with 32% (as is showed in Table 5.16). Hence, the engagement of the user seems discrete but positive.

Table 5.16: This Table shows the assessment of the patient system usage (%) in Pilot 3, and the assessment of the patient engagement (%), based on type session selection (long, medium, or short). The system usage is based in the number of sessions regarding the days with H4M (both are showed in Table 5.15

ID	Session Selection(%)			System
	Short	Medium	Long	Usage(%)
P3.1	33	0	67	63
P3.2	29	57	14	78
P3.3	26	35	39	77
P3.4	0	50	50	100
P3.5	47	32	21	66
P3.6	33	50	17	22
P3.7	55	18	27	27
P3.8	33	40	27	42
P3.9	40	20	40	67
P3.10	54	31	15	72
P3.11	100	0	0	07
P3.12	29	14	57	41
AVG	39	29	32	47

Regarding the additional evaluation performed with Spanish participants, a very promissing results were obtained (Table 5.17). Both patients were satisfied with the session plan management, and they agreed and strongly agreed with the adequate length, variability and content of the sessions. Regarding the provided trust and management of emotions both users were very satisfied. One of the users reported doubts regarding the motivation that the agent causes, and he was not convinced of wanting to continue working with the same VA.

Table 5.17: Responses for the TAM in Pilot 3. Available responses: 0-Strongly disagree; 1-Disagree; 2-Neither disagree nor agree; 3-Agree; and 4-Strongly agree. *Question Q6 was formulated as negative approach (see Table 5.14), so the lower the value, the more positive it is.

ID	Questions										
	Q1	Q2	Q3	Q4	Q5	Q6*	Q7	Q8	Q9	Q10	Q11
P3.11	4	3	4	3	3	0	4	4	2	4	1
P3.12	4	4	4	4	4	0	4	4	4	4	4
AVG	4	3.5	4	3.5	3.5	0	4	4	3	4	2.5

The subjective opinions of the participants, gathered in the final interviews, were generally very positive. We highlight some of the obtained responses related with the modules and functionalities in which this Dissertation is focused:

> Participant P3.9: *"I could choose the type of session I wanted... if one day I needed a long session, I could choose a long one. Sometimes, when I was not in a good mood I could choose a shorter version and I liked that".*

> Participant P3.8: *"I think it is a useful system. For me at least, it was very helpful in some moments when I felt low and I did those exercises. It gave me some energy. I hope you will improve it so that it can be more useful".*

> Participant P3.3: *"What was interesting was the fact that at some point the program was divided in several parts: when you answered the questions regarding your positive or negative thoughts. Then it became a little bit more interesting. And based on this answer you got one version or another, and there you had some examples of thoughts of people who recovered from depression or who suffer from depression. I don't know why but I found this part very useful, knowing that there are other people who recovered from depression or who have the same problem as me".*

The responses related to the appearance of the agent are also divided. Some users think the VA was too realistic and would prefer a cartoonish version (participant P3.2), while others think it is unrealistic (participant P3.1). But everyone appreciated the possibility to change the gender and appearance of the virtual agent. In general, the VA was found empathic by the participants. Even one participant (P3.7) used female VA and stated at the final interview "*I will miss her*". Despite, patients requested more variation in the reactions of the Virtual Agent, both its facial expressions and its utterances

Table 5.18 shows the clinical scores obtained in both groups, at the beginning and at the end of the evaluation. Negative values indicate improvement in measures of depression (BDI-2, QIDS-SR16) and dysfunctional cognitions (DAS-SF2) but worsening of reported quality of life (EQ5D Utility and VAS). Whereas the difference between Help4Mood and Usual Care in EQ5D-VAS looks striking, this is due to spontaneous improvement in one participant in the Usual Care group and is likely to be an artefact of the small sample size. In general, the users enrolled in the H4M intervention, seem to have improved more than the control group. Specifically in BDI-2 as is highlighted in Burton et al. 2015.

Table 5.18: This table shows the depression and general health measures post-evaluation in both groups (control and intervention), with change from baseline obtained in the pre-evaluation. For BDI-2, QIDS-SR16 and DAS-SF2, lower values indicate better health. Instead, for EQ-5D, higher values indicate better health. Last column (Diff.) indicates the variation between both changes.

Questionnaire	Control Group			Intervention Group			Diff.
	Mean	SD	Change	Mean	SD	Change	
BDI-2	17.6	6.8	-4.2	13.9	8.1	-5.7	-1.5
QIDS-SR16	14.7	6.2	-3	14.2	7.2	-2.7	0.3
DAS-SF2	23.5	4.2	-1	18.1	5.4	-2	-1
EQ5D (utility)	0.89	0.19	0.13	0.76	0.21	0.04	-0.09
EQ5D (VAS)	79.9	17	17.3	75.2	19.2	2	-15.3

5.5 Discussion and Conclusions

The results obtained from the three incremental pilots were very valuable and promising. In general, the system was well accepted by the users. This incremental evaluation allowed us to evaluate different features and functionalities in some stages. The main goals of this Chapter have been met: the evaluation of the acceptability (Obj4), the user engagement (Obj5), and treatment adherence (Obj6) as were showed in Table 1.1.

The system usage and treatment adherence was assessed in all the pilots. As expected, the results were lower because the number of tasks and the complexity of the session were higher. Additionally, the participants in P2 and P3 were patients under treatment (instead recovered patients as in P1), who in general are less motivated and participative. Unfortunately, we did not get the final data of the treatment adherence of the Pilot 3 due to technical issues, but from available data collected we estimated that the treatment adherence was about 45.5%. This value was estimated from the average of the daily executed tasks of some patients. This estimation was normalized to the seven sessions of the week and to the average of the system usage showed in Table 5.16. This value is only an estimation, but is very positive because indicates that although the use of the system was not high, the system tries to fulfill the treatment. In general, the average results shows very positive results.

Table 5.19: This Table summarizes the average results at each Pilot regarding the system usage (%) and treatment adherence (%). *This value was estimated because a lot of information was lost due technical problems.

Pilot	System Usage(%)	Treatment Adherence(%)
P1	94	94
P2	87	72
P3	47	45.5*
AVG	76	70.5

Regarding the engagement of the user, we find similar results than in the system usage and treatment adherence: the scores were decreasing in the pilots but the average score remains very good. In general, the participants selected the medium and long session in 61%. This demonstrates a high commitment and motivation in using the system.

Table 5.20: This Table shows the average results regarding the user engamente throught the session selection.

Pilot	Session Selection(%)		
	Short	Medium	Long
P1	—	—	—
P2	39	13	48
P3	39	29	32
AVG	39	21	40

From the obtained results, we can assert at the end of the three performed Pilots, that the framework is ready to be applied in more real clinical environments. Overall acceptance of both modules of the framework has been validated by the users as positive. There was no unanimity on the preferred contents. There were participants who liked the relaxation activities, other the other negative thoughts questionnaire and so on. But all of them liked the ability to influence in the length of the sessions by selecting the desired option. In general, the users appreciated the management of the different sessions and the variability of the contents. Hence, good levels of the adaptability and the variability produced by the framework have been achieved.

Regarding the technical approach, the framework was stable and correct. No incidents were reported neither in the integration with the other modules of the Help4Mood system, nor during the execution of the system in the different pilots.

Regarding emotional responses of the VA, despite the low number of participants that used the *emotion regulation model* (which includes both the *cognitive change* and the *response modulation*), we can conclude that the users can recognize both implementations and that they scored better the use of therapeutic empathy (cognitive change strategy) rather natural empathy (response modulation) (see Table 5.3). The best results regarding the acceptance of the emotional behaviour of the VA were obtained in the Spanish participants of Pilot 3 (see questions from Q6 to Q11 in Table 5.17) who used the framework version which implements the cognitive change strategy.

Although it is not one of the goals of this Dissertation, from the clinical perspective we can see that users who used the framework as part of the Help4Mood system presented better clinical outcomes (see Table 5.12). They presented more improvements than the users in the control group, which used traditional treatments (see Table 5.18).

Chapter 6

Evaluation: Case of Study II (Prevention)

The adaptation of the content and the way of how this content is communicated to the users in interactive sessions is a critical issue to promote the acceptability and usability of any computational system. This adaptation should be personalized to the particular characteristics and needs of each user. Ideally, the continuous customization of an interactive system must be based on dynamic user models.

In this Chapter, we present the evaluation of the acceptability and usability of the Framework presented in chapters 3 and 4 (as summarized the Table 1.1) in a different scenario that the one presented in Chapter 5. Our Framework was integrated into an interactive computational system able to adapt the content and the style of interaction according to the detected user's specific needs. An empathic Virtual Agent (VA) is the main interface with the user and it has been designed to generate the appropriate dialogues and emotions during the interaction with the user. The adaptation of the dialogue contents is based on a dynamic user model nurtured with clinical, demographical and behavioral information. Direct responses from the user during the sessions are used to detect user's well-being and update the user's model, which in turn influences the course of future interactions.

This evaluation was performed in a case of study aimed to the prevention of suicide and depression in the student community. We evaluated our system with 60 users through the assessment of the system's usability, the acceptability of the user-adapted content and the emotional responses of the VA. The obtained results are positive getting good levels of usability (75.7 %) and acceptability (70.9 %) allowing the execution of a further clinical trial.

The content of current chapter has been accepted for publishing as journal paper in (Bresó et al. 2015a).

6.1 Introduction

Human-Computer Interaction (HCI) is becoming ever more important in interactive systems for human-centered computing. This cross-discipline (including e.g. engineering, psychology, ergonomics, and design) investigates and tackles all issues related to the design and implementation of better systems for the interaction between humans and computers. Good design of HCI systems enhances the quality of the interaction between people and computers. It is responsible for achieving a good usability level (Dix 2009), ease of use, acceptable productivity and safety of the system (Preece et al. 1994). A key issue in the good design and implementation of interactive systems is the assessment of the user conditions in order to adapt the contents and style of interaction to the individual characteristics, skills and behaviors detected in each person (e.g. age, gender, personality, etc.) (Wirtz, Jakobs, and Ziefle 2009; Darves, Oviatt, and Coulston 2002; Rajamanickam 2011; Capuano et al. 2015; Arning and Ziefle 2007).

A good interactive system, should not only adjust its contents to the user's characteristics, but also dynamically update these contents at each cycle of the interaction depending on the user responses. These capabilities are known as adaptive HCI. Hence, unlike passive interfaces, an adaptive HCI can adapt its appearance, its content or its structure. Adaptive HCI can be considered a complex system, that need to correctly react to the different inputs data, such as visual (e.g. face recognition, gesture recognition, body movement tracking, or eye movement tracking), audio (e.g. speech recognition, voice-based, emotion analysis, or noise detection), traditional (e.g. keyboard, mouse, or touch screen), or physiological (e.g. position, humidity, respiration, pressure, temperature, or galvanic response) inputs. All these different types of inputs need to be processed and correctly interpreted to get a suitable profile of the user's characteristics, capabilities and limitations, in order to "*say the 'right' thing at the 'right' time in the 'right' way*" (Fischer 2001). So the design of an internal user representation, i.e. a user model, is required in personalized interactive systems. Attending to the data gathering method and the design process, two classifications of a user model are considered. Basically, a user model can be dynamic or static, depending on whether it contains a continuous adaptation or not based on the information provided by the user. A second capability is based on asking or learning processes depending on whether it acquires the information through direct questions to the user or observing and interpreting the behavior and actions of the user (Johnson and Taatgen 2005).

Adaptive systems are particularly required in clinical contexts, specifically when the target users may be people suffering from a mental disorder such as depression or suicidal tendencies. Both, depression and suicide are two major problems in the global society and are close related. A study shows that 90% of adolescents who die by committing suicide had a mental health problem, usually depression, substance abuse or both (Williams and Morgan 1994). The World Health Organization (WHO) estimated that 804.000 suicide deaths occurred worldwide in 2012 (WHO et al. 2014) becoming a leading cause of death among college and university students in the United States (Schwartz 2006). Specifically, suicide rates are the second leading cause of death among people between 15–29-year-olds globally. Other relevant data is that for each adult who committed suicide there might be more than 20 others attempting it. Unfortunately, many people experience the first symptoms of depression during their college or university years. If these symptoms are not opportunely detected and the individual does not receive an appropriate support, in some cases the person commits suicide. Early diagnosis and treatment of depression can relieve depression symptoms, prevent depression from returning, and help students succeed in college and university.

The interactive system described in this paper has been developed attending a user-adapted HCI approach in order to ensure personalized and adaptive interaction with users for the early detection of symptoms related with depression and/or suicidal behaviour. This system is based on an empathic virtual agent that continuously interacts with the user. Depending on the detected condition of the user, the virtual agent provides: (1) a set of personalized activities and (2) a set appropriate facial expressions and dialogues representing an emotional state in the VA to convey empathic responses while interacting. The system has been evaluated in three academic environments in order to assess its level of acceptability and usability among the users' community.

The rest of the paper is structured as follows: section 6.2 presents an overview of existing adaptive HCI systems. Section 6.3 presents our Framework while section 6.4 describes the adaptation of our Framework in the prevention of suicide and depression in the community of University student's scenario. Finally, we discuss about findings and the further work in section 6.5.

6.2 Related Work

The identification and prevention of problems related to mental disorders are a clinical research hot topic. There are a lot of literature and many initiatives aimed to prevent cases of suicide, specifically in universities (Corrieri et al. 2014; Kirsch et al. 2014; Joffe 2008; Haas, Hendin, and Mann 2003). In the last years there is an increasing number of universities implementing evidence-based programs designed to identify and prevent distress-related problems and suicide behaviours in young adults. Several universities, such as the University of Cambridge, provide special services related to support and guide to people with suicidal intentions. The

Universidad Autónoma de Madrid published a protocol (Torre 2013) for suicide prevention and for supporting users in the initial steps. The Ohio State University founded a suicidal prevention training for teaching faculty, staff and students including issues about how to (1) recognize warning signals, (2) engage with empathy, (3) ask directly about suicide, (4) communicate hope, and (5) help suicidal individuals to access formal care and treatment.

The continuous and wide use of Information and Communication Technologies (ICT) in the universities has promoted the emergence of technological-based solutions adapted to the problems of these communities. There are a large number of software systems addressed to the prevention of depression and suicide in the university community. Griffiths et al. (Griffiths and Christensen 2007) present an evaluation of the effectiveness and efficacy of two unguided internet-based self-help systems (commonly used by University students): MoodGYM (`http://moodgym.anu.edu.au`) and BluePages (`http://bluepages.anu.edu.au`). MoodGYM is a web-based system that provides five interactive training modules in order to increase the knowledge about the symptoms of depression, negative automatic thoughts, dysfunctional attitudes, emotions and coping strategies to face stress and interpersonal relationships. BluePages provides evidence-based information about depression including information about symptoms; general and specific sources of help; information about the effectiveness of medical, psychological and alternative treatments; and information about how to prevent depression. Grittiths concluded asserting that both programs are associated with improvements in mental health, knowledge and the promotion of positive attitudes in the users. MEMO is another technological-based solution presented by Whittaker et al. (Whittaker et al. 2012) as a cognitive behavioral therapy (CBT) based intervention to prevent depression in adolescents via mobile phone texts and video messages. They evaluated the acceptability and utility of the intervention through a randomized controlled trial (RCT) enrolling a total of 1.348 volunteered students. In general, the obtained results were positive and the majority of the participants (82.4%) perceived the system as helpful and useful. The system succeeded in improving positive thoughts, promoting the solution of problems, having fun, and dealing with particular issues in the school. More than 1.200 American universities and colleges have teamed up with the Jed Foundation (`www.jedfoundation.org`) for the development of the ULifeline project (`www.ulifeline.org`), an online resource center for college students that provides a self-assessment questionnaire and information on suicide prevention and mental health issues such as depression. Jed Foundation provides other similar online resource center called Half of us (`www.halfofus.com`) that aims to help students and their friends by fighting the stigma around mental health and speaking up when support is required. This web-based application provides information about depression, bipolar disorder, suicide, eating disorders, anxiety disorders, stress and alcohol/drugs consumption. Horgan et al. (Horgan, McCarthy, and Sweeney 2013) developed and tested a web site designed to support university students with depressive symptoms. The web site provides a forum to allow participants to offer peer support to each other. It also provides information on depression and links to other support material. The pilot study (with 117 students of the Ireland University with self-reported depressive symptoms) has demonstrated that online peer support has the potential to be of benefit to young people, specifically students experiencing depressive symptoms. Unfortunately, the small sample in the pre and post evaluation did not to obtain significant clinical evidence.

There are several systems that implement more adapted interfaces in order to improve the interaction with the users. Manning and colleagues (Manning, Manolya, and Tarashankar 2012; Rudra, Li, and Kavakli 2012) used a virtual agent to manage the stress of the students during the exams period. High levels of stress have been reported during exams period that can lead to depression or suicide (among other mental health implications for students)(Lee, Hong, and Espelage 2010). Offering adequate support during these periods helps to prevent depression and suicide. In the Manning and colleagues' work, the students verbally interact with a highly personalized and animated virtual character called eCounsellor. The eCounsellor takes the roll of a virtual psychologist, which is implemented through an Embodied Conversational Agent (ECA) with the modelling of behavioural traits, a set of facial expressions and gestures that make the interaction more immersive. The eCounsellor aims to enhance the student coping strategy and converting his stress into work efficiency. Based on a user model, the eCounsellor tries to maximize personalization and anthropomorphism. Personalization refers to providing tailored exam management advice to accommodate individual differences. Anthropomorphism (Zanbaka, Goolkasian, and Hodges 2006) refers to the extent a virtual agent resembles the appearance or behavioural attributes of a human psychologist. A similar approach is used in the Miami University containing two avatar-based programs developed by Kognito Interactive (`www.kognito.com`): "*At-Risk for College Students*" (Bartgis 2014) and "*At-Risk for Faculty & Staff*" (Albright 2013). Both are online role-play training simulations that help to identify emotionally distressed students and faculty members and prevent suicide. The users enter into a virtual environment and engage in a series of interactive exercises including a simulated conversation with a virtual student that exhibits signs of psychological distress, anxiety, depression, and/or suicidal ideation. A sample of 270 students from 10 different American states was included in the evaluation. A Significant increment of acquired skills to manage the symptoms was reported after a 3-month duration study.

In general, the reported findings from the online counselling applications have positively evaluated in the promotion of working alliance, helpfulness and impact and most of them have reported client improvement and satisfaction (Richards 2009). Regarding the use of virtual agents, there are supporting studies suggesting that people usually feel more comfortable when interviewed by media-mediated electronic doctors and are more likely to release their flinched mind during the consultation process in contrast to human doctors (Yoshida et al. 1993). Nevertheless, in order to optimize the effectiveness of these tools, a high level of personalization is required during the course of a session and through every session. The next section presents the components of a modular Framework as the core component of an interactive system aimed to dynamically adapt both, the contents and the style of interaction offered through a virtual agent to prevent symptoms of depression and suicide ideation in students.

6.3 Framework

The PrevenDep project presented a more basic architecture than Help4Mood (see Figure 6.1). There are not personal monitor sensor management neither clinician communication. The system only interacts with the users by means of the empathic virtual agent. The core of PrevenDep system is an adaptation of the presented Framework, which is used as DSS; and the graphical user interface corresponds to a new adhoc development carried out by the author of this PhD also.

The functionality is very similar than the presented in the Case of Study I: In the Content Management Module the contents of the session are personalized through a cognitive process, which is responsible for the processing of user's incoming information, knowledge extraction and updating of the user's model; and planning process that selects and plan the contents to be offered to the user during a session according to the information inferred in the cognitive layer. The other module of the Framework, Emotional Module, is the responsible for the interaction style personalization, i.e. the most adequate way to communicate the contents to the user. Finally, a new visualization component was developed as graphical representation of the virtual agent and used to convey the produced emotions through a set of facial expressions and dialogues.

All modules of the Framework have been designed to be independently from each other and the input/output information of each layer is XML-based formatted facilitating a highly configurable system for different case of studies (e.g. the provision of support for other mental health related problems such as anxiety or phobias). The functionality of each layer has been conceived to produce the output information according to the user's model updated from the user's inputs and based on some clinical pre-defined guidelines assuring a high level of adaptation to the personal characteristics of each user.

The cognitive and session planner layers of the Content Management Module were presented in Chapter 3, and Emotional Module in Chapter 4. Hence, from these layers we only highlight their adaptation in this evaluation Chapter. Instead, the visualization layer was developed ad-hoc for this case of study, so it will be presented in the following sections.

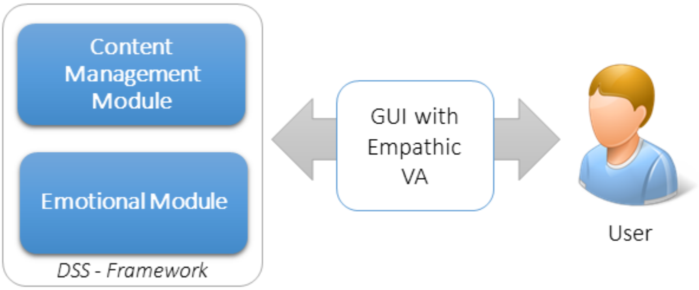


Figure 6.1: Overall architecture of PrevenDep Project. This system is composed by a DSS which manages the content and the communication provided to the user. The user interacts with the system through a virtual agent.

6.3.1 Content Management Module

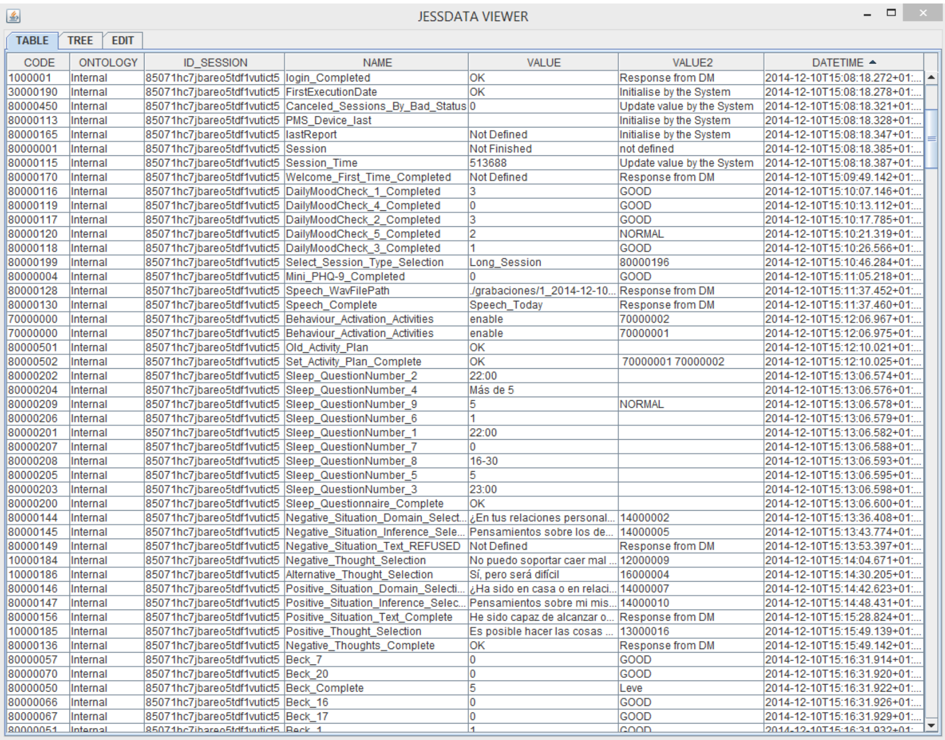
Cognitive Process

The core of this layer is a Rule Based System (RBS) configured with multiple "*if-then*" rules used to codify some clinical-based expert knowledge. The rules allow to infer (1) the condition of the user based on the responses to direct questions, (2) the updating of the user's model through the addition or change in values of clinical-related concepts (which are codded using an internal format based on the SNOMED-CT terminology), (3) the selection of a set of activities and questionnaires based on Cognitive Behaviour Therapy (CBT) that can be offered to the user, and (4) the generation of alerts if the system detects a high risk situation in the user, such as suicide ideation.

Some rules from Case of Study I (Chapter 5) have been reused but new set of rules have been added. These new rules were related with the prevention approach and suicidal attempts. For example, we added some standardized questionnaires and multimedia contents:

- **Beck Depression Inventory** (ID21): It is composed by 21 questions multiple-choice self-report inventory in order to measuring the severity of depression (Beck, Ward, Mendelson, et al. 1961).
- **Beck Hopelessness Scale - BHS** (ID22): This questionnaire was selected because it may be used as an indicator of suicidal risk in depressed people who have made suicide attempts (Beck and Steer 1988).

- **Happy/Relaxing moment** (ID23): Three relaxing and positive videos were added in order to provide positive stimulus at certain times.



CODE	ONTOLOGY	ID_SESSION	NAME	VALUE	VALUE2	DATETIME
1000001	Internal	85071hc7jbareo5tdf1vutict5	login_Completed	OK	Response from DM	2014-12-10T15:08:18.272+01:...
30000190	Internal	85071hc7jbareo5tdf1vutict5	FirstExecutionDate	OK	Initialise by the System	2014-12-10T15:08:18.278+01:...
80000450	Internal	85071hc7jbareo5tdf1vutict5	Canceled_Sessions_By_Bad_Status	0	Update value by the System	2014-12-10T15:08:18.321+01:...
80000113	Internal	85071hc7jbareo5tdf1vutict5	PMS_Device_last		Initialise by the System	2014-12-10T15:08:18.328+01:...
80000165	Internal	85071hc7jbareo5tdf1vutict5	lastReport	Not Defined	Initialise by the System	2014-12-10T15:08:18.347+01:...
80000001	Internal	85071hc7jbareo5tdf1vutict5	Session	Not Finished	not defined	2014-12-10T15:08:18.385+01:...
80000115	Internal	85071hc7jbareo5tdf1vutict5	Session_Time	513688	Update value by the System	2014-12-10T15:08:18.387+01:...
80000170	Internal	85071hc7jbareo5tdf1vutict5	Welcome_First_Time_Completed	Not Defined	Response from DM	2014-12-10T15:09:49.142+01:...
80000116	Internal	85071hc7jbareo5tdf1vutict5	DailyMoodCheck_1_Completed	3	GOOD	2014-12-10T15:10:07.146+01:...
80000119	Internal	85071hc7jbareo5tdf1vutict5	DailyMoodCheck_4_Completed	0	GOOD	2014-12-10T15:10:13.112+01:...
80000117	Internal	85071hc7jbareo5tdf1vutict5	DailyMoodCheck_2_Completed	3	GOOD	2014-12-10T15:10:17.785+01:...
80000120	Internal	85071hc7jbareo5tdf1vutict5	DailyMoodCheck_5_Completed	2	NORMAL	2014-12-10T15:10:21.319+01:...
80000118	Internal	85071hc7jbareo5tdf1vutict5	DailyMoodCheck_3_Completed	1	GOOD	2014-12-10T15:10:26.566+01:...
80000199	Internal	85071hc7jbareo5tdf1vutict5	Select_Session_Type_Selection	Long_Session	80000196	2014-12-10T15:10:46.284+01:...
80000004	Internal	85071hc7jbareo5tdf1vutict5	Mini_PHQ-9_Completed	0	GOOD	2014-12-10T15:11:05.218+01:...
80000128	Internal	85071hc7jbareo5tdf1vutict5	Speech_WavFilePath	./grabaciones/1_2014-12-10...	Response from DM	2014-12-10T15:11:37.452+01:...
80000130	Internal	85071hc7jbareo5tdf1vutict5	Speech_Complete	Speech_Today	Response from DM	2014-12-10T15:11:37.460+01:...
70000000	Internal	85071hc7jbareo5tdf1vutict5	Behaviour_Activation_Activities	enable	70000002	2014-12-10T15:12:06.967+01:...
70000000	Internal	85071hc7jbareo5tdf1vutict5	Behaviour_Activation_Activities	enable	70000001	2014-12-10T15:12:06.975+01:...
80000501	Internal	85071hc7jbareo5tdf1vutict5	Old_Activity_Plan	OK		2014-12-10T15:12:10.021+01:...
80000502	Internal	85071hc7jbareo5tdf1vutict5	Set_Activity_Plan_Complete	OK	70000001 70000002	2014-12-10T15:12:10.025+01:...
80000202	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_2	22:00		2014-12-10T15:13:06.574+01:...
80000204	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_4	Más de 5		2014-12-10T15:13:06.576+01:...
80000209	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_9	5	NORMAL	2014-12-10T15:13:06.578+01:...
80000206	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_6	1		2014-12-10T15:13:06.579+01:...
80000201	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_1	22:00		2014-12-10T15:13:06.582+01:...
80000207	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_7	0		2014-12-10T15:13:06.588+01:...
80000208	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_8	16-30		2014-12-10T15:13:06.593+01:...
80000205	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_5	5		2014-12-10T15:13:06.595+01:...
80000203	Internal	85071hc7jbareo5tdf1vutict5	Sleep_QuestionNumber_3	23:00		2014-12-10T15:13:06.598+01:...
80000200	Internal	85071hc7jbareo5tdf1vutict5	Sleep_Questionnaire_Complete	OK		2014-12-10T15:13:06.600+01:...
80000144	Internal	85071hc7jbareo5tdf1vutict5	Negative_Situation_Domain_Select...	¿En tus relaciones personal...	14000002	2014-12-10T15:13:36.408+01:...
80000145	Internal	85071hc7jbareo5tdf1vutict5	Negative_Situation_Inference_Sele...	Pensamientos sobre los de...	14000005	2014-12-10T15:13:43.774+01:...
80000149	Internal	85071hc7jbareo5tdf1vutict5	Negative_Situation_Text_REFUSED	Not Defined	Response from DM	2014-12-10T15:13:53.397+01:...
10000184	Internal	85071hc7jbareo5tdf1vutict5	Negative_Thought_Selection	No puedo soportar caer mal ...	12000009	2014-12-10T15:14:04.671+01:...
10000186	Internal	85071hc7jbareo5tdf1vutict5	Alternative_Thought_Selection	Sí, pero será difícil	16000004	2014-12-10T15:14:30.205+01:...
80000146	Internal	85071hc7jbareo5tdf1vutict5	Positive_Situation_Domain_Selecti...	¿Ha sido en casa o en relaci...	14000007	2014-12-10T15:14:42.623+01:...
80000147	Internal	85071hc7jbareo5tdf1vutict5	Positive_Situation_Inference_Selec...	Pensamientos sobre mi mis...	14000010	2014-12-10T15:14:48.431+01:...
80000156	Internal	85071hc7jbareo5tdf1vutict5	Positive_Situation_Text_Complete	He sido capaz de alcanzar o...	Response from DM	2014-12-10T15:15:28.824+01:...
10000185	Internal	85071hc7jbareo5tdf1vutict5	Positive_Thought_Selection	Es posible hacer las cosas ...	13000016	2014-12-10T15:15:49.139+01:...
80000136	Internal	85071hc7jbareo5tdf1vutict5	Negative_Thoughts_Complete	OK	Response from DM	2014-12-10T15:15:49.142+01:...
80000057	Internal	85071hc7jbareo5tdf1vutict5	Beck_7	0	GOOD	2014-12-10T15:16:31.914+01:...
80000070	Internal	85071hc7jbareo5tdf1vutict5	Beck_20	0	GOOD	2014-12-10T15:16:31.920+01:...
80000050	Internal	85071hc7jbareo5tdf1vutict5	Beck_Complete	5	Leve	2014-12-10T15:16:31.922+01:...
80000066	Internal	85071hc7jbareo5tdf1vutict5	Beck_16	0	GOOD	2014-12-10T15:16:31.926+01:...
80000067	Internal	85071hc7jbareo5tdf1vutict5	Beck_17	0	GOOD	2014-12-10T15:16:31.929+01:...
80000051	Internal	85071hc7jbareo5tdf1vutict5	Beck_1	1	GOOD	2014-12-10T15:16:31.932+01:...

Figure 6.2: Data stored in the model of the user. The data is updated by the cognitive layer, which collects objective information such as questionnaire's scores, and the inference of subjective evaluations

The cognitive layer is the component that maintains a continuous updating of the user's model according to the inferences made over the new input information. The data that form the model of the user is presented in Figure 6.2, including objective (e.g. obtained questionnaires scores, user selections, rejected and completed tasks, user logins, elapsed time, or number of critical situations) and subjective information (assessment of each user response). Depending on the user's inputs at each interaction cycle, the selection of the action(s) (e.g. recommend some activities or ask other questions to gather more information) that the virtual agent will implement in the next interaction cycle is executed. For example, according to the user response to the Patient Health Questionnaire 9 (PHQ-9), a standardized questionnaire to assess the level of depression, the RBS would infer based on the SNOMED-CT terminology, a new condition in the user. If the user condition was assessed as severe depression, the system will select a mandatory action called Crisis Plan. When implemented, this action produces a dialogue in the virtual agent to inform the patient about the (pre-configured) supporting contacts and tries to calm him. Additionally, the system can send an email to alert a specialist to establish a direct contact. Complementarily, if the user condition was assessed as not severe depression, but the obtained score in the PHQ9 still correspond to a mild/moderate depression, the RBS will launch some special activities in order to support the patient (such as Show a Happy/relaxing Video).

Session Planner Process

In this layer, all the inferred tasks in the cognitive layer must be managed and selected for inclusion in the interactive session. All the activities inferred in the cognitive layer are based on clinical expert knowledge, but the session planner filter these activities and arrange them on a specific order based on (1) a set of predefined clinical requirements; and on (2) the historical user data (included in the user model). The set of clinical requirements are predefined according to clinicians' preferences or protocol to offer different activities used to detect and prevent depression or suicidal ideation.

For this Case of Study II, we have maintained the functionality presented in Chapter 3. We have only updated the configuration file *TaskPlanning.xml* with the configuration of the new tasks added. Part of this new configuration is showed in Algorithm 6.1.

Algorithm 6.1: Example of the clinical requirements for the task Hopeless Beck Questionnaire established in the xml configuration file. Clinicians may define constrains such as priority, dependence, and periodicity.

```
<?xml version="1.0" encoding="UTF-8"?>
...
<item>
        <description>
                <code>10000203</code>
                <snomed>NO</snomed>
                <name>Hopeless_Beck_Questionnaire</name>
        </description>
        <enable>YES</enable>
        <typeOfItem>OPTIONAL</typeOfItem>
        <priority>20</priority>
        <minFrec>2</minFrec>
        <maxFrec>3</maxFrec>
        <codeOfDataInDB>80000050</codeOfDataInDB> <!--Beck_Complete
            -->
        <repeatable>NO</repeatable>
        <constrains>
                <constrain>
                        <constrainDescription>
                                <code>10000011</code>
```

```
                    <snomed>NO</snomed>
                    <name>Welcome</name>
                </constrainDescription>
                <constrainType>BEFORE</constrainType>
            </constrain>
            <constrain>
                <constrainDescription>
                    <code>10000200</code>
                    <snomed>NO</snomed>
                    <name>Introduce\_PHQ9</name>
                </constrainDescription>
                <constrainType>BEFORE</constrainType>
            </constrain>
            <constrain>
                <constrainDescription>
                    <code>10000121</code>
                    <snomed>NO</snomed>
                    <name>Farewell</name>
                </constrainDescription>
                <constrainType>AFTER</constrainType>
            </constrain>
        </constrains>
</item>
...
</xml>
```

6.3.2 Emotional Module

Equally important to the contents of the sessions is how these contents are transmitted to the users in order to make them more receptive and promote an effective execution of the suggested activities and the disclosing of personal information such as thoughts and feelings. The use of empathic agents as the virtual peer of the user has been recently increased in applications to support change behavior and in cyber-psychology (Bresó, Martínez-Miranda, and García-Gómez 2016). As presented in different studies (Bickmore and Gruber 2010; Lisetti 2008) the conveying of empathic reactions from the virtual agent to the information provided by the user is a key characteristic to increase the acceptability of these virtual peers in the users. For this scenario we maintain the same idea and a VA have been also developed as the main interaction channel between the PrevenDep system and the target users.

The emotional layer of our system is the component responsible to generate the adequate emotions in the virtual agent to produce an empathic feedback based on the user's input at each cycle of interaction. This component has been adapted from the developments presented in the Chapter 4 by setting the set of basic emotions and the copying behaviors generated from the set of goals, preferences and action tendencies predefined in the virtual agent for this specific scenario. The events produced during the interaction with the user -i.e. the knowledge extracted in the cognitive layer- generates the specific emotional behavior of the VA. Most of the goals defined in the virtual agent are close related with the well-being detected in the user for the agent to produce an empathic reaction to the detected user's state.

6.3.3 Visualization Component

All the contents of a session produced by the cognitive and the session planning process, as well as the representation of the different styles of interaction formed by the different emotions produced in the emotional layer needs to be visually represented in the GUI which contains the embodied VA. Figures 6.3 and 6.4 shows the PrevenDep interface, first one shows the VA appearance and the second one an example of questionnaire. The VA has been developed as a talking head using a commercial tool called FaceShift (`www.faceshift.com`). This software captures the facial movements of a person in real time using a xbox 360 Kinect camera for the creation of a set of animated avatars. The results present a good level of realism and allow the representation of different emotional expressions. A set of video recordings was performed representing different facial expressions that are linked in real time with the corresponding emotion generated by the emotional layer. This allows the visualization of the empathic feedback provided by the VA at each cycle of interaction. Realism in the appearance and behaviour in a VA are key issues to achieve good levels of acceptability in the target users.

Figure 6.3: The graphical user interface with the virtual agent situated at the centre of the screen. This virtual agent conducts the session, providing questionnaires, recommendations or CBT'-based recommended tasks to the user

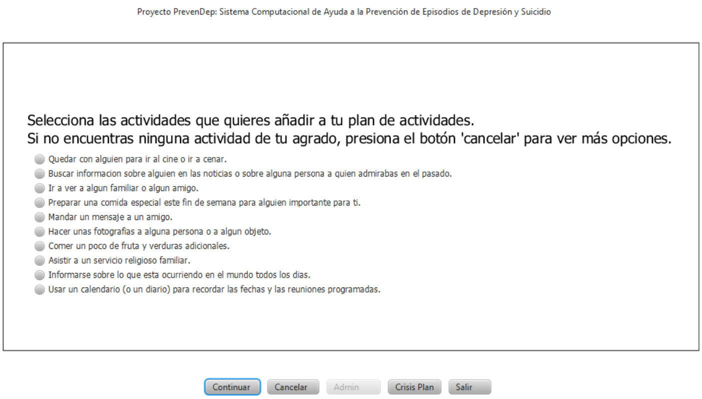


Figure 6.4: This screenshot of the PrevenDep GUI shows the Behaviour Activation questionnaire (ID10)

6.4 Case of study

The Framework presented in this Dissertation was integrated in another complete application evaluated in the context of a Spanish regional project entitled "*PrevenDep: Computational system to help in the prevention of depression and suicide*". This project that was performed to provide the necessary support to university students for detecting and preventing depression and suicide. University students are exposed to challenging and competitive environment in which they must to overcome new situations, stress, academic challenges, or social relationships. PrevenDep provides an empathic VA to support them by offering user-adapted activities based on CBT interventions (such as a *negative thoughts questionnaire*, which tries to identify and transform negative thoughts of the users into an alternative positive perspective; or the *configuration of an activity plan*, which agrees with the users few routine activities that should be performed during the week and that they must report).

6.4.1 Objective

The aim of the present Case of Study II is the assessment of the perceived acceptability and usability of the Framework developed in this PhD, which provides an advanced HCI for supporting depression. In this case, the system were adapted to focus on the prevention.

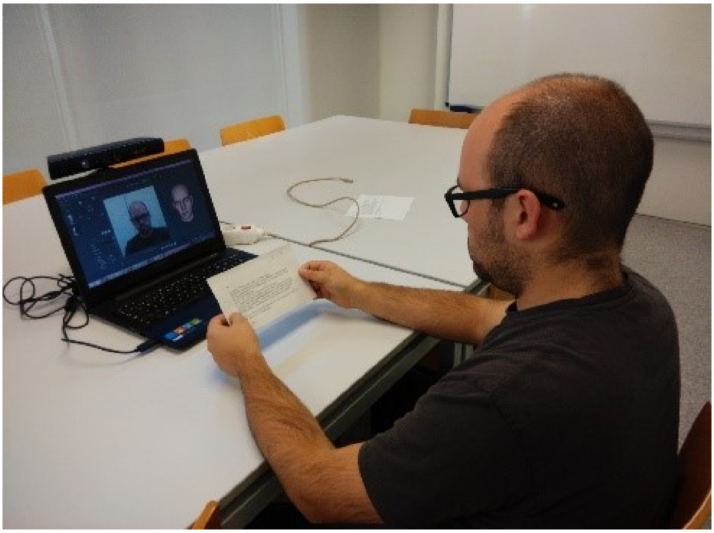


Figure 6.5: Recording a video using the Faceshift tool, which uses a kinect xbox 360 camera

6.4.2 Participants

The evaluation was focused on an expert group related with university community. A recruitment screening survey and consent form were posted by mail to approximately 100 professors, researchers and students involved in their final degree projects from four different locations: *Universitat Politècnica de València* , *Universitat de València* , *Universitat Jaume I* , and *CICESE-UT3* .

6.4.3 Evaluation

To carry out the evaluation, an explanatory website was developed where a set of videos containing several executions of different interactive sessions produced along several days showing the different contents and reactions from the virtual agent according to the user inputs. The visualization of the videos was as a prerequisite to complete the evaluation questionnaire. In order to measure the usability and acceptability of the system, we designed a questionnaire with a total of 22 questions (q1-q22), grouped into 6 different sections: 1) **demographic information**; 2) **system usability**; 3) **user acceptability** of the contents of the session that evaluates how appropriate the user considers the activities proposed by the virtual agent; 4) **user acceptability of the virtual agent** that evaluates the appearance and behavior of the virtual agent; plus two free text sections to write any feedback

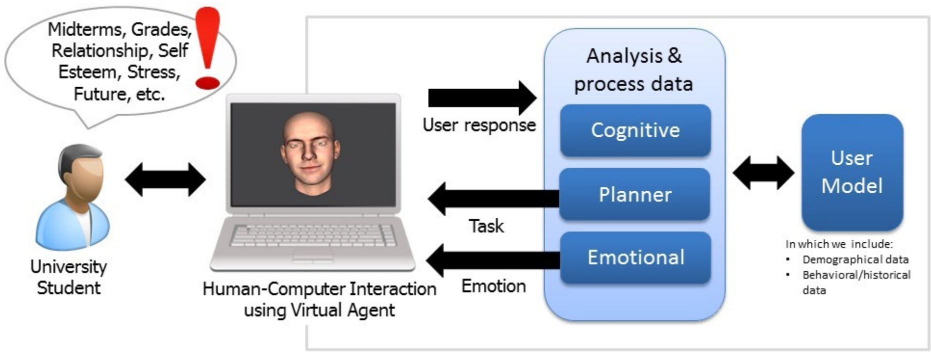


Figure 6.6: Figure 3: Overall architecture of the system in the PrevenDep project. An Empathic Virtual Agent + GUI form the visualization layer of the interactive sessions with a user. The core of the system is composed by the other three components: the cognitive, the session planning, and the emotional layers. The functionalities of all the layers are based on a dynamic user model, in which the system stores and updates all the information of the user for an adequate adaptation and personalization of the interactive sessions.

the participants wants to provide about the 5) session contents and about the 6) aspect and behavior of the VA (see Table 6.1).

The first section (Q1-Q3) collects the demographic data (age, gender and workplace) through three categorical questions. Jacok Nielsen, who is considered the world's leading expert on usability, recommends to interact with the users in order to assess the usability levels of the interfaces through their responses and experiences (Nielsen 1994). So, in the second section of the questionnaire we included ten questions (Q4-Q13) which correspond to the standardized System Usability Scale Questionnaire (SUS) (Brooke 1996). The SUS questionnaire was created by the Digital Equipment Corporation and it is mainly focused on the assessment of perceived usability (subjective aspects of usability) on any system. In the third section, three questions (Q14-Q16) are used to determine the acceptability of the most important features of the session planner: the adaptability (contents and length of the session) and variability (different contents between sessions). The questions in section number four (Q17-Q20) are used to identify the acceptability of the users regarding the appearance and behavior of the VA. Finally, in sections 5 (Q21) and 6 (Q22), two free text questions are used to collect any comments regarding the session planner and the VA.

The answers of each item in sections 2, 3 and 4 are defined on a Likert scale with values between 0 and 4, representing the degree of agreement with the statement as shown in Table 6.2.

Table 6.1: Questionnaire used in the evaluation with 22 questions grouped in 6 sections. First section (Q1-Q3) gathering demographical information. Second section (Q4-Q13) focuses in the usability. Third section (Q14-Q16) assess the acceptability regarding cognitive and planner layer. Instead, the acceptability regarding the VA was evaluated in section four (Q17-Q20). Finally, open comments about session contents and VA behavioural were obtained in section 5 (Q21) and 6 (Q22) respectively.

Section	Question
Demographic information	**Q1** - Please provide your age **Q2** - Please provide your gender **Q3** - Please provide the institution where you usually develop your work
Usability of the system	**Q4** - I think the target users will like to visit frequently the PrevenDep system **Q5** - I think that target users will find the PrevenDep system unnecessarily complex to use **Q6** - I think that the PrevenDep system is easy to use **Q7** - I think that the target users will need the support of an expert to use the PrevenDep system **Q8** - I think that target users will find the various possibilities of PrevenDep,fairly well integrated in the system **Q9** - I think that the user would find too much inconsistency in the PrevenDep system **Q10** - I think that most of the potential users will learn to use the PrevenDep system in a short time **Q11** - I found PrevenDep system very cumbersome to use **Q12** - I think that the target users will be very confident when using the PrevenDep system **Q13** - I think there is necessary to learn some previous things before using adequately the PrevenDep system
User acceptability of the session contents	**Q14** - I think the length of the sessions was adequate, allowing the user to complete the sessions on daily basis **Q15** - I think that the variability of the sessions was adequate, which motivate the,user to complete the whole sessions on daily basis **Q16** - I think that the content of the sessions was adequate and would motivate the,user to complete the whole sessions on daily basis
User acceptability of the VA	**Q17*** - The behavior of the virtual agent during the sessions seems aloof and distant **Q18** - The virtual agent inspires trust **Q19** - The virtual agent behaves emotionally stable. **Q20** - The behavior of the virtual agent motivates the daily use of the PrevenDep system
Contents of the session	**Q21** - Please discuss any unpleasant aspect about the contents of the daily sessions
Interaction with the VA	**Q22** - Please discuss any unpleasant aspect in the appearance and / or behavior of the virtual agent

Table 6.2: Likert codes used in sections 2, 3 and 4

Code	Response
0	Strongly Disagree
1	Disagree
2	Neither Agree nor Disagree
3	Agree
4	Strongly Agree

6.5 Results

The questionnaire was online during 15 days and a total of 60 participants accessed to the evaluation. From 60 participants, the 93.6% fully complete the evaluation questionnaire. Specifically, the participation in the first 20 questions was 96.4% and in the two last questions (Q21 and Q22) was 65.8%.

6.5.1 Quantitative findings

Regarding the answers to the demographic questions we obtained that the gender distribution included 26 (43.3%) women, 33 (55%) men, and one participant omitted this information (1.7%). Using the information of the gender, we checked the A.L.Baylor hypothesis (Baylor 2009) that stated that a virtual agent is usually rated higher by those participants with the same gender modeled in the VA. Nevertheless, in our evaluation we did not find any significant difference in the acceptance of virtual agent based on the gender of the participant.

The age distribution was 2 people (3.3%) under 25; 18 participants (30%) between 26 and 30; 15 people (25%) between 31 and 35; 12 participants (20%) from 36 to 41; 9 participants (15%) between 41 and 45; and 4 people (6.7%) over 46. Regarding the center of belonging, the majority was the UPV with 28 participants (46.7%); UJI with 13 participants (21.7%); 10 participants (16.7%) from UV; 5 individuals (8.3%) from CICESE; and 4 participants (6.7%) from others institutions. The normalized results are showed in the Figures 6.7, 6.8, 6.9.

The results from the usability questionnaire (section 2 of the evaluation questionnaire) are summarized in Table 6.3 showing for each question (rows) the response rate and the number of answers (columns). The questions and the meaning of the answers are those already introduced in Tables 6.1 and 6.2 respectively. The last column indicates the weighted average.

High rate responses to questions with even numbers (i.e. Q4, Q6, Q8, Q10 and Q12) represents a positive outcome of the feature evaluated in the system while low rates responses to questions with odd numbers (i.e Q5, Q7, Q9 and Q11)

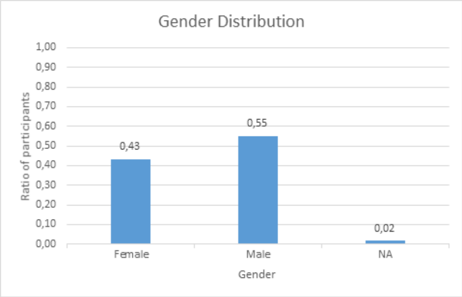


Figure 6.7: Participants gender distribution obtained from question Q1 of the questionnaire.

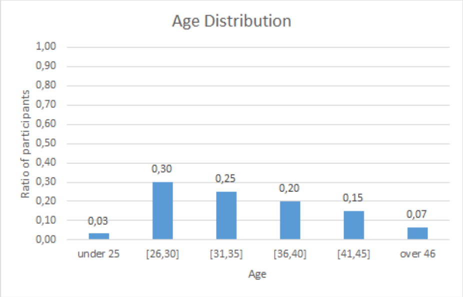


Figure 6.8: Participants age distribution obtained from question Q2 of the questionnaire

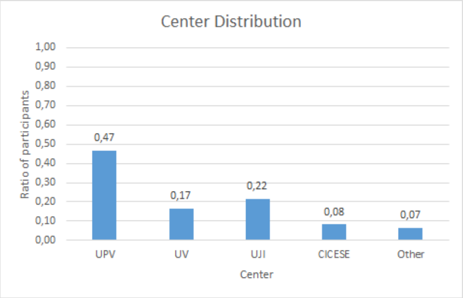


Figure 6.9: Participants center distribution obtained from question Q3 of the questionnaire

indicate a positive outcome on the evaluated feature. A positive normalization was performed over the questions with odd numbers by reversing the results and a threshold value (=2) was defined to graphically represent the obtained results. We can see in Figure 4 that the mean of the obtained responses passed the defined threshold.

The SUS questionnaire proposes a specific method to evaluate the obtained results. To calculate the score of SUS, we must separate the positive questions -1 (Q4), 3 (Q6), 5 (Q8), 7 (Q10) and 9 (Q12)- from the negative questions -2 (Q5), 4 (Q7), 6 (Q9), 8 (Q11) and 10 (Q13)-. For the positive questions, we updated their values from the obtained value minus 1. For negative questions, we used 5 minus the original value. Finally, we performed an arithmetic sum of all the updated values and multiplied them by 2.5 in order to normalize the final result between 0 and 100 . Based on more than 500 evaluations, Jeff Sauro (Sauro 2011) argues that the average score to assess the usability of a system should be a value of 68. A higher value means a usability level better than the average. Figure 5 presents the

Table 6.3: Results of the System Usability Scale Questionnaire (SUS) belonging to the second section of the questionnaire. Answers are coded using a Likert scale defined in the Table 6.2. The last column shows the weighted average responses (value from 0 to 4) and the number of participants

	0	1	2	3	4	Weighted Average
Q4	0% (0)	16% (9)	24% (14)	40% (23)	21% (12)	2.66 (58)
Q5	46% (26)	42% (24)	5% (3)	5% (3)	2% (1)	0.75 (57)
Q6	0% (0)	4% (2)	4% (2)	53% (30)	40% (23)	3.30 (57)
Q7	35% (20)	46% (26)	11% (6)	9% (5)	0% (0)	0.93 (57)
Q8	0% (0)	4% (2)	30% (17)	41% (23)	25% (14)	2.88 (56)
Q9	39% (22)	39% (22)	18% (10)	5% (3)	0% (0)	0.89 (57)
Q10	0% (0)	0% (0)	5% (3)	37% (21)	58% (33)	3.53 (57)
Q11	14% (8)	34% (20)	38% (22)	9% (5)	5% (3)	1.57 (58)
Q12	0% (0)	11% (6)	33% (19)	35% (20)	21% (12)	2.67 (57)
Q13	43% (25)	47% (27)	7% (4)	2% (1)	2% (1)	0.72 (58)

average result obtained from the collected responses corresponding to a value of 75.7 (gray line), which is above the average proposed by Jeff Sauro (orange line). Therefore we can conclude that participants in our evaluation rated the system with a high usability feature.

The obtained results from the questions of section three collect the participants' feedback regarding the suitability and variability of the sessions' contents. The question 14 (Q14) is focused on the assessment of the session's length. The produced length of a session is highly important taking into account that the system should adapt the length of each session according to the status (e.g. mood) detected in the user and at the same time meeting the clinician's requirements (i.e. the scheduling of certain activities a minimum number of times per week). Complementarily, question 15 (Q15) is focused on the perceived variability in the contents of the sessions. A strategy to maintain motivated the users with the use of the system is that the sessions do not offer a monotonous or repetitive content. Finally, question 16 (Q16) is focused to evaluate the perceived usefulness of the content of the sessions, i.e. how much helpful the activities or recommendations offered by the system are perceived. The results of this section are summarized in Table 6.4 and graphically presented in Figure 6.12. Similarly to the obtained results from section 2, we can see that the responses of the participants indicate positive results, particularly the assessment of the length of the session (Q14).

The objective of the questions in the fourth section of the questionnaire was very similar to the questions of the third section, but now focused on the evaluation of the behavior and appearance of the virtual agent. The building of a good rela-

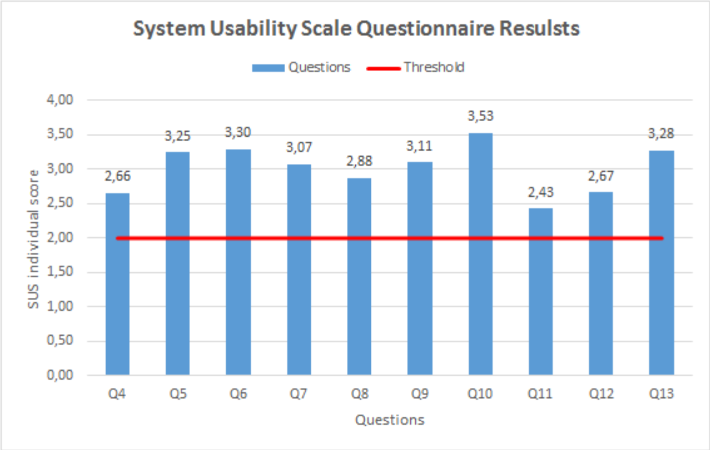


Figure 6.10: Graphical representation of the results of the questionnaire System Usability Scale (SUS), corresponding to the Q4-Q13 questions. Results from the questions with odd values (Q5, Q7, Q9 and Q11) were inverted (positive normalization) to facilitate the interpretation of the obtained results. All the results exceed the threshold meaning a good assessment in the perceived usability of the system

Table 6.4: Obtained results in section three of the questionnaire: assessment of the sessions' contents (Q14, Q15 and Q16)

	0	1	2	3	4	Weighted Average
Q14	0% (0)	2% (1)	9% (5)	55% (32)	34% (20)	3.22 (58)
Q15	0% (0)	14% (8)	31% (18)	31% (18)	24% (14)	2.66 (58)
Q16	0% (0)	0% (0)	34% (20)	34% (20)	31% (18)	2.97 (58)

tionship between a virtual agent and the user is essential to promote a continuous use of the system and a key ingredient to establish a therapeutic alliance that benefit the user. The four questions of section three of the questionnaire looked to obtain the feedback from the participants regarding the emotional behavior of the virtual agent (Q17, Q18 and Q19) and how much the virtual agent contributes to the motivation of the user to execute the system every day (Q19). The obtained results show a positive assessment in each of the features represented in the four questions (see Table 6.5 and Figure 6.13). The 66% of the participants disagreed or strongly disagreed with the sentence that defines the virtual agents as "distant and aloof" (Q17). Complementarily, the 57% of the participants perceived the virtual agent as trustworthy (Q18). For the 82% of the participants the virtual

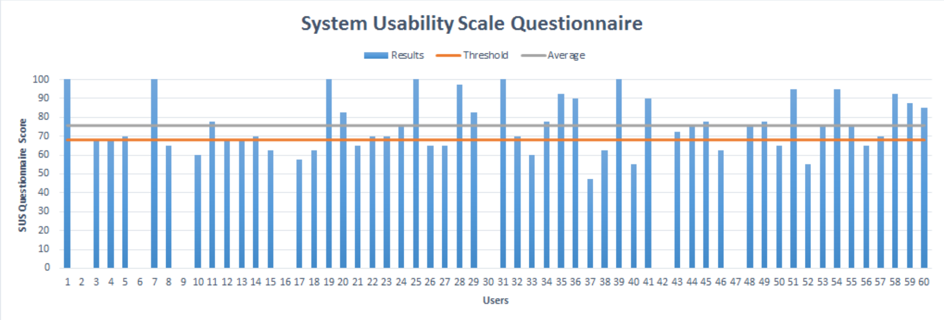


Figure 6.11: Graphical representation of the results obtained in section 2 of the questionnaire (perceived usability of the system). The results were obtained following the method proposed in (Richards 2009). Most of the participants correctly completed the questionnaire and the average of the results (gray line) is located above the average score proposed by Jeff Sauro (orange line).

agent was perceived as "emotionally stable" (Q19), and the 48% consider that the virtual agent is a decisive factor that motivate the use of the system (Q20).

Table 6.5: Obtained results related with the evaluation of the virtual agent (Q17, Q18, Q19 and Q20). *Question Q17 was formulated as negative approach, so the lower the value, the more positive is.

	0	1	2	3	4	Weighted Average
Q17*	26% (15)	36% (21)	14% (8)	24% (14)	0% (0)	1.36 (58)
Q18	0% (0)	16% (9)	28% (16)	36% (21)	21% (12)	2.62 (58)
Q19	0% (0)	5% (3)	12% (7)	41% (24)	41% (24)	3.19 (58)
Q20	2% (1)	10% (6)	40% (23)	22% (13)	22% (13)	2.57 (58)

6.5.2 Qualitative findings

Whereas the first 20 questions of the questionnaire have been designed to collect the perceived usefulness from the participants regarding the different features of the system, the design of the last two questions were thought to collect specific feedback that can be used to improve the functionality of the session planner (Q21) and of the virtual agent (Q22). Many comments were positive but also many of them addressed particular issues that can be improved before the execution of the pre-clinical trial of the system. Some of the most representative comments to improve the system related with the session contents are transcribed below:

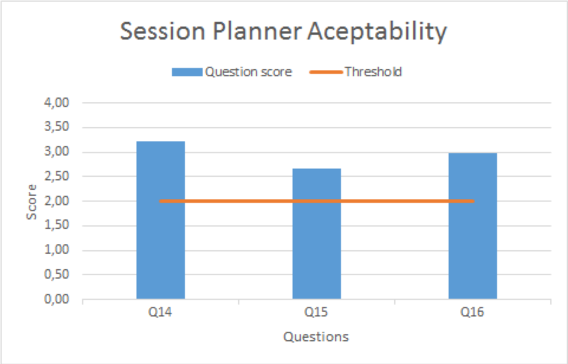


Figure 6.12: Graphical representation of the evaluation of the sessions' contents (Q14, Q15 and Q16)

Participant P51: *"Some questionnaires are too long and take up too much space. It would be convenient to divide them into several screens to prevent the rejection of the user. Additionally, the font size in the questions should be bigger to ensure readability and attractiveness of the appearance of the interface".*

Participant P50: *"I like the content but I miss questions related to the university environment. This system is focused on students, so why not ask things directly related with the university e.g. the exams?, trend of success or failure of the student?, number of registered credits (to know the pressure bearing)?, do you live alone?, combines study with work?, what are your study habits?, is everything done at the last minute?. I think that this kind of information is needed to better identify a risk of suicide".*

Participant P49: *"The sessions and their content seem appropriate, easy to understand, useful and necessary to assess important aspects related to depression".*

Participant P44: *"Sometimes I have the feeling that during a session there is more content related to assessment (questionnaires) that content related with therapeutic intervention (relaxing activities, more information, etc.)".*

Participant P36: *"Regarding the content of the sessions, I think it would be positive to include at the end of each of session, a question that explore the perceived utility".*

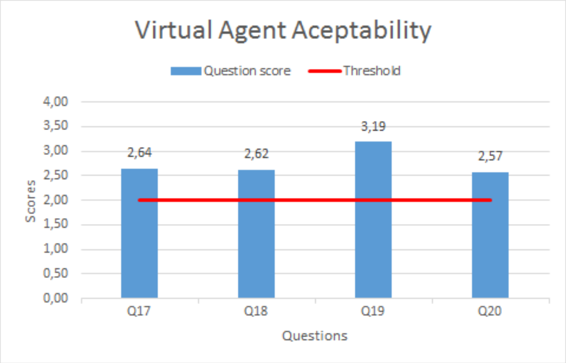


Figure 6.13: Graphical representation of results obtained in the fourth section of the questionnaire (Q17, Q18, Q19 and Q20). The value of the question Q17 had been normalized to positive version

> Participant P21: *"The appearance of the application is unattractive, which may have implications for adherence to the system. Several suggestions in this regard: It would be good that the questions and answers are read with voice; the virtual agent must be always present in the screen. Perhaps some questionnaires are too extensive. Finally, I recommend a control of achievements, for example, having visible information on progress in therapy".*

> Participant P4: *"In general, the content is adequate but the questionnaires were very long and boring, could do a little more interactive? I prefer that the virtual agent is placed always in the corner, interacting with the user. The user must interact using verbal communication".*

From the collected comments, we can identify that some of them are more focused on how the contents of the session are presented through the GUI (P4, P21, P37 and P51) and others in the contents of the sessions themselves (P36, P44, P49 and P50). From the first group we can use the provided suggestions to get a better GUI through the improvement of the controls (buttons, combo boxes, font size). As the current state of the technology does not allow a full natural language interaction free of errors, we decided to maintain the input from the user through the buttons and other controls such as combo boxes included in the GUI and not to receive the input from the user through natural language processing. From the second group of suggestions we can observe that more context-based questions (i.e. from the university context) needs to be included, as well as some question(s) about the perceived usefulness from the target users regarding the contents offered by the system. Moreover, we also observed that the inclusion of more therapy-based activities has been suggested.

Regarding the comments on the appearance and behavior of the virtual agent (Q22), we also obtained many useful comments. In general, many users acknowledge a suitable behavior in the virtual agent and most of the comments were related with the improvement of its appearance. The transcription of some of the received comments is the following:

> Participant P60: *"In general, the virtual agent behavior seems appropriate. The face looks nice and the expressive voice gives me confidence. The disadvantage that I see is some facial expressions (sometimes too expressive, overplayed, and there are some tics in the eyebrow)".*

> Participant P53: *"Displaying only the head on a black background does not seem to be a nice picture. I do not understand why the avatar is hairless. His tone of voice sounds negative. Did you think about the possibility of choosing between a male and female virtual agent? And the environment, why do not show a clinical site (as a therapy room with a table and chairs and perhaps a window where you could visualize a landscape outside)?, I think that would increase the effectiveness of the tool".*

> Participant P49: *"It is very good but can be improved a bit (need a shave and cleaning of teeth). I really like movements. It is the most convincing I've seen".*

> Participant P41: *"The virtual agent can be improved. I think it would be better if it would be more protagonist during the interaction (more talking and less read). I would like that it have hair, he was a little older and it should have shoulders (with a shirt or similar). I don't like his teeth. But overall I think it looks very real, I like the way it moves. Eyebrow movement is very good. But you have to work a bit, you have many possibilities".*

> Participant P37: *"Do you inspire more confidence with a bald man? Although I like it, I suggest that you consider the option that each user can configure his virtual agent".*

> Participant P21: *"The virtual agent has a warm and calm voice. However, I consider the appearance can be improved".*

Almost all of the comments suggested improvements to the appearance of the virtual agent more than to the perceived behavior. Although the Faceshifth software allows a fast prototyping of a realistic virtual agent, a deeper programming work is required to customize the appearance of the pre-defined virtual agent (i.e. get a set of virtual agents with different gender and age, adding a half or full body or even adding hair and clothes). The further improvement of the suggested features in the appearance of the virtual agent would even positively influence the perception of a more suitable behavior during the interactive sessions, which in turn could help to optimize the effectiveness of the system.

6.6 Discussion and Conclusions

This Chapter has detailed the evaluation of the Framework in a real environment focused in depression an suicide prevention thanks to the participation in the PrevenDep research project. The evaluation has been raised to asses mainly the perceived acceptability and usability of the Framework. This evaluation involved 60 participants who answered a questionnaire after watching a set of pre-recorded videos containing different interactive sessions.

The participants rated the usability of the system as highly positive (with a result 75.7 out of 100). The results obtained regarding the level of acceptability concerning the sessions' management (content, duration and variability) have also been positive, obtaining a score of 2.95 out of 4. Regarding the evaluation of the appearance and behavior of the virtual agent -as the main interface between the user and the system-, the participants also valued positively this component (getting a score of 2.75 out of 4).

We can summarize these acceptability results as a percentage of 70.9% reflecting that the participants have rated a high level of acceptability of the Framework. The results obtained from this pre-evaluation are good enough to deploy the system and make an evaluation with a set of potential real users, which is part of the future work. Additionally, we also plan to include some of the improvements identified by the participants, especially those suggestions to get a better GUI of the system. Once implemented, we will develop a pre-clinical trial enrolling a set of University students that fulfill some criteria to be selected.

Chapter 7

Conclusions and Future Work

The research reported in this Thesis is the result of more than four years of work. During this period, the acquired knowledge in multidisciplinary research and international collaborations have made possible the development of this work.

A sequential and incremental methodology has been followed in the work described in this Thesis. This has enabled the development of the described Framework and subsequent evaluation in different research projects (Help4Mood and PrevenDep). Thanks to incremental development based on the results from these evaluations, the Framework can be easily adapted to be further used to support the treatment or prevention of other mental health related pathologies. Unfortunately, the design and implementation of the pilots could not be managed only by the author of this Thesis. This process required the high involvement of the clinical staff, suitable locations, and appropriate ethical permissions. Ideally, evaluations should have been normalized in order to obtain comparable conclusions in the analysis stage. But unfortunately, sometimes the number of participants, the characteristics of evaluations, purposes, the software version, etc. could not be homogeneous (especially in the Case Study I). So some of the final conclusions of this Chapter or the conclusions from the evaluation chapters (Case Study I and II), were limited by these circumstance.

In addition to the publication of the current Dissertation, all the work done has allowed to conduct a series of scientific publications (described in Section 1.4 of Chapter 1) and the publication of a master's Thesis (Bresó 2014).

In this final Chapter, the author summarizes the conclusions of this research. Moreover, this Chapter checks whether the established objectives at the beginning of the research have been achieved and discusses the validity of the initial proposed hypothesis. Finally, some future research directions are indicated.

7.1 Conclusions

The main goal of this Dissertation is to test the hypothesis described in Chapter 1, which asserted that "***The use of a computational model that plans variable and adaptive daily sessions and generates appropriate empathic responses in order to interact with the user, will leverage the adherence, engagement, usability, and acceptability in Major Depression disorders***". This research work confirms that the presented Framework works well regarding to the generating variable and adaptive daily sessions, and in the generation of appropriate emotional behaviour in the virtual agent that helps to promote an empathic reactions towards the user. We confirmed through the obtained results from the evaluations that this contribution influence the adherence, engagement, usability, and acceptability of the users. Consequently, the development of our Framework has contributed to get improved interaction between man and machine in this particular domain.

As part of the final conclusions, the achievement of each of the initial objectives (see Chapter 1) is described as follows:

- The objective ***Obj1-Adaptability*** has been met using simulations in the internal evaluation of the Framework as is showed in Chapter 3. These simulations allowed to show that a system can be adaptive based on the user preferences, and also on the pre-defined clinical requirements. For this, when the user choose the session type (short, medium, or long), the Content Management Module adapts the actual length of the session depending on the degree of compliance with the existing restrictions.

  The opinion of participant P3.11 (showed in Table 5.15) is a very good example of this adaptive behavior. P3.11 only used the system twice in 28 days, and he selected short session in both cases. But the Framework provided him with long sessions in order to meet the minimum of executions of the tasks requested by the clinician. The median duration of his sessions was 17 minutes, bigger than the median that was 14 minutes. Hence, we can conclude that this management content ensured adaptive iteration during the personalized sessions.

  Additionally, the subjective feedback from the participants in both cases of study indicates that the users consider the Framework good enough adaptive. Specially when we increased the number of tasks and when the configuration of the scenario was less restrictive.

- The objective ***Obj2-Variability*** has been demonstrated through the simulations explained in the Chapter 3. Using two different scenarios configured by the clinicians (Flexible Vs. Restrictive), we demonstrated the variability of the Framework, that allows to personalise the interaction in order to prevent monotony.

The contents of the daily sessions offered to the user vary depending on the actions of the user and the configured scenario. This configuration allowed to determine the degree of variability that the system may provide to the user. So setting the configuration of the scenario, the clinicians could tune the degree of variability in order to adjust it depending on the preferences of the centre, patient, or even the stage of the disease. Moreover, the number of available tasks included in the Framework resulted responsible of the level of variability in the contents of the session. Additionally, a big set of activities, allowed more variability than a small set.

As in *Obj1*, the feedback from the questionnaires confirmed that the users appreciated the variability of the Framework (see Figure 6.12). Specially, when the Framework includes a high number of tasks (see Table 5.16).

- The objective ***Obj3-Usability*** was achieved in accordance to the definition from ISO 9241-11. We can assert that our Framework can be used by depressive patients (or persons in risk) as a technological-based support system to achieve their treatments (or symptoms) with high level of efficiency, easily, and satisfaction in the mental health domain.

  We obtained the measurement of the usability system using the System Usability Scale (SUS) in the second Case of Study (Q4-Q13 from Table 6.1) over 60 participants. Results showed a high usability perception by the participants in the evaluation (75.7%).

- The objective ***Obj4-Acceptability*** was deeply assessed in the second Case of Study using a questionnaire based on the Technology Acceptance Model (TAM). The acceptability results of the Content Management Module and the Emotional Module were satisfactory: 2.95 and 2.75 over 4 respectively.

  This feedback from real users was valuable because it helped to demonstrate that required functionality were suited to real-world circumstances.

- The objective ***Obj5-Engagement*** was also satisfactory. Table 5.20 shows that the users preferred the selection of long sessions. This means that they were motivated in the use of the Framework.

  Additionally, we measured user engagement using questionnaires presented in the Case of Study I with questions as Q4 from Table 5.8 and Q9 from Table 5.14; and in Case of Study II with Q16 and Q20 from Table 6.1. All of these results confirm the achievement of this objective.

The engagement is a concept very dependent on the perceived functionality of the system. Works as the presented in Bickmore et al. 2010 confirms that increasing the variability in the behavior of the VA, an increased engagement is obtained. So the *Obj2* is close related with *Obj5*. Additionally, the modeling of the emotional behavior of the VA presented in Chapter 4 provides a high level of realism that increases the user engagement also (Bickmore et al. 2010).

- Through the development of a dynamic management of the session content and the emphatic behavior of the agent provided by the the Emotional module, the presented Framework achieved high levels of adherence, which was defined as the objective ***Obj6-Adherence***. The assessment of the adherence is described in the pilots of the Chapter 4. In the second pilot the adherence was measured in 72%. Subjective user feedback from the last pilot (questions Q5 and Q11 from Table 5.14 were addressed for this purpose) and from the Case of Study II (see Q4 from questionnaire of the Table 6.1) reinforce these results.

  The adherence to the treatment is critical because it conditions the clinical outcomes (Calla 2013). Using virtual agents, other studies have studied longer-term interactions for up to six weeks and have found that even small amounts of social interactions between the virtual agent and the user encourages longer-term adherence to the promoted health program (Bickmore et al. 2010).

7.2 Future Work

The HCI and eHealth domains are hot research areas where continuous publications present new and interesting developments. This ensures that the Framework presented has great potential to continue to evolve. Much is the work that can be added to this Framework.

From the evaluations carried out in the two cases of study, some of the most interesting future work are presented below:

- Perform more and bigger evaluations in order to deeply assess the main functionalities of the system. Specifically, the cognitive change implementation of the emotional component.
- Expand the range of emotions (and its intensities) of the emotional component.
- Expand the set of available tasks in the planner component.

- Adapt the Framework to other mental health pathologies and evaluate if the results obtained in the major depression scenario are extended to the other pathologies.

- Improve the independence and the behaviour of the external component such as virtual agent interface, as has been done in the evaluation of the system in the Case of Use II (see Chapter 6).

- Implement the five families of emotion regulation (in the current Framework we have implemented two of them) proposed by Gross and assess if this contributes to a better model of therapeutic empathy.

- Adapt automatically the session lenght from the estimation of the patient stamina (instead user choice based).

- Investigate whether the regulation of negative emotions is enough to produce useful therapeutic empathy responses. At the moment, and following clinicians recommendations, we have concentrated on the regulation of negative emotions. Depending on the results collected from future evaluations, we would assess if there would be situations where even when the user is reporting a good input to a specific question, the VA should regulate its positive emotional responses reflecting on a more general assessment of current patient's condition.

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