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# CAKNA: A Personalized Robot-Based Platform for Anxiety States Therapy

Azizi Ab Aziz[a], Ali Saad Fahad[a], and Faudziah Ahmad[b]
[a]*Cognitive Artefacts Group, Human-Centred Computing Research Lab,*
[b]*Data Science Research Lab, School of Computing, Universiti Utara Malaysia, 06010 UUM Sintok, Kedah Malaysia*

**Abstract.** Anxiety can be defined as an unpleasant state of mental uneasiness or concern that causes physical and psychological discomfort. In this paper, we describe an interactive robot-based platform that is designed to be used to support of person with anxiety traits and states using non-medical treatments including mindfulness, relaxation, and muscle relaxation therapy. We describe CAKNA, whose design is based on theories in anxiety traits and states, social robots, and therapies, along with the results of a pilot study (with 24 respondents) exploring the effectiveness of our robot to support individuals with anxiety.

**Keywords.** Robot-based Therapy, Smart Living Application, Anxiety State and Trait, Interactive Systems

## 1. Introduction

In the domain of psychology, anxiety disorder is a term covering several different forms of a type of mental illness of abnormal and pathological fear and anxiety. This condition can be defined as long acting, future focused, broadly focused towards a diffuse threat and promoting extreme caution while approaching a potential threat to the individuals. For example, is common for someone with anxiety to also suffer depression or vice versa. Moreover, nearly one-half of those diagnosed with depression are also diagnosed with an anxiety states and traits. In order to alleviate this cognitive disorder, several computer-based systems have now been developed that allow individuals with anxiety issues to receive therapeutic care from the comfort of their time and places. Despite they are superior to no treatment; these computer-based systems are still less effective or have a gap compared to traditional face-to-face therapy sessions [1-5]. Issues such as social physical embodiment, fluid user interaction, intelligent support, and social feedbacks play important roles in designing a digital application / computer programme to reduce cognitive related problem, e.g. cognitive load, anxiety, social phobia, and unipolar depression[6-14]. To overcome those issues, robots offer an alternative solution as a medium to complement existing digital platforms in providing therapeutic tools of person with anxiety [7][10][13].

In this paper, the design of a robot-based anxiety management system that delivers therapies to reduce user's anxiety level is presented. In Section 2, the context of temporal dynamics of anxiety is described in some detail. The design of CAKNA (our robotic platform) is introduced in Section 3, whereas Section 4, more details of the types of therapies is discussed. Section 5 presents results from our pilot evaluation study. Finally, Section 6 concludes this paper.

## 2. The Domain Model: Temporal Dynamics of Anxiety States and Traits

Figure 1 gives a conceptual representation of the computational model developed in [15], which is based on the major theories about anxiety states and traits. This model serves as a backbone to analyse and predict potential anxiety levels.

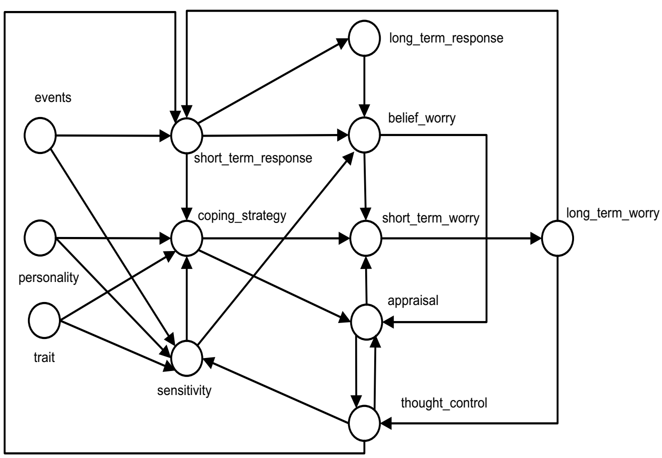


**Figure 1.** Conceptual Model of Anxiety Traits and States.

According to Well's model (*Meta-cognitive Model*), problematic worry develops over time. It begins with a tendency to use worry as a coping strategy for real or imagined threats. For example, avoidance coping (resulted from high traits in anxiety and negative personality) aims to avoid the *aversive somatic* and emotional experiences which naturally occur when being confronted with non-cognitive events (*external situations or physical symptoms*) and triggers anxiety responses. Higher sensitivity increases the formation of beliefs about worry and reduces the ability to cope accordingly [16]. However, the responses may increase (or decrease) the anxiety state according to the initial condition of the problems. During this stage, the coping strategy and individual's sensitivity will regulate the formation of short-term worry. It is imperative to acknowledge that the engagement in ineffective coping strategies provides a chance about the belief that is uncontrollable [17][19]. Therefore, it escalates short-term worry later experience a negative reinforcement spiral experience of worry that further reinforces the worry and reduces individual's appraisal ability [9][12].

This later increases the long-term worry that will influence individual's thought control over negative events (triggers). The intolerance to uncertainty serves to set off a chain of worrying, negative problem orientation, and cognitive avoidance [16][19]. In short, the following relations can be identified from the literature: (1) a series of psychological and physiological stressor events can lead to the formation of anxiety;

(2) low coping skills will increase the risk anxiety strait; (3) negative personality and personality traits factors aggravate the effect anxiety; (4) prolonged sensitivity will increase belief about worry; (5) good coping strategies and appraisal will reduce worry; (6) prolonged short-term worry will increase the risk of long-term worry in the future.

## 3. Design of the Robot-based Therapy for Anxiety

Our long-term goals are to develop a fully functional robotic platform to support cognitive therapy, which socially expressive robots are especially useful. As a first step, our goals for the work presented in this paper were twofold; first, to develop a low-cost robotic platform that runs on standard computing devices (such as smartphone or basic laptop) (physical design). Secondly, to incorporate this robot with specific analytics to determine types of therapy needed (software agent and software architecture).

### *3.1. Software Agent*

A basic element in the software agent is the integration of temporal dynamic model of anxiety (*domain model*) within it. By incorporating the domain model, the software agent gets an understanding of the processes of its environment [9].

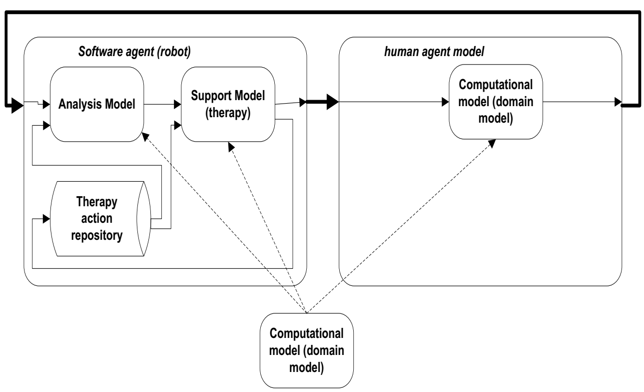


**Figure 2.** Overall Design of the Software Agent

From Figure 2, the solid arrows indicate information exchange (data flow) and dotted arrows the integration of the domain model within the software agent model. Within the software agent model, two main components have been distinguished, namely;

- *Analysis component*: To perform analysis of the human's states and processes by model-based reasoning based on observations and the domain model.
- *Support component*: To generate support actions for the human by (*model-based*) reasoning based on observations and the domain model.

In the analysis model, a set of different combination of several generated computational specifications is analysed. By analysing these combinations, the person's potential risk in anxiety can be monitored and predicted [9].

### *3.2. Physical Design*

The constructed robot is about half a meter tall and is designed to sit on a table or countertop. As seen in Fig. 3, there is also a small touch-enabled input screen (ASUS 7" smart tablet powered by Android version 4.4.2 KitKat) on the front to allow data entry. Off-the-shelf PC components are used for the computation abilities (Intel Core i3-4030U 1.90GHz processor, 4 GB RAM, Windows 10 64-bit Operating System, x64-based processor, and 444GB hard drive) and an inexpensive servo controller provides robot motion control.

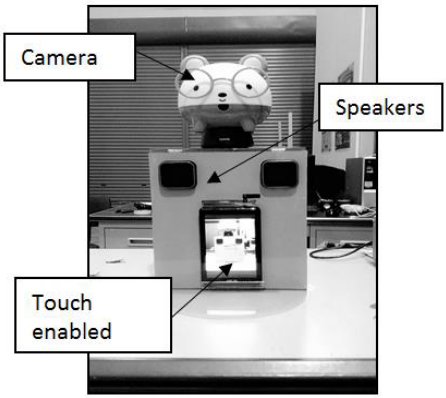


**Figure 3.** CAKNA Physical Design

The robot has one degree of freedom in the neck and two in the coupled eyes, allowing each a full range of horizontal motion (controlled by *Tenvis P2P* wireless network camera setting). A set of cameras is mounted above the eyes providing a view in front of the robot to the OpenCV face tracker. The CAKNA robot features custom LED mouth displays lip-synched to pre-recorded dialogue spoken using available text-to-speech voice. To measure anxiety, CAKNA utilizes self-report data obtain from the touch screen tablet and analytical results from the software agent module.

### *3.3. Software Architecture*

The main software system handles all input and output, maintains the overall state of the interaction with the user, and handles the flow of interaction based on input from the user. The overall architecture is depicted in Fig. 4.

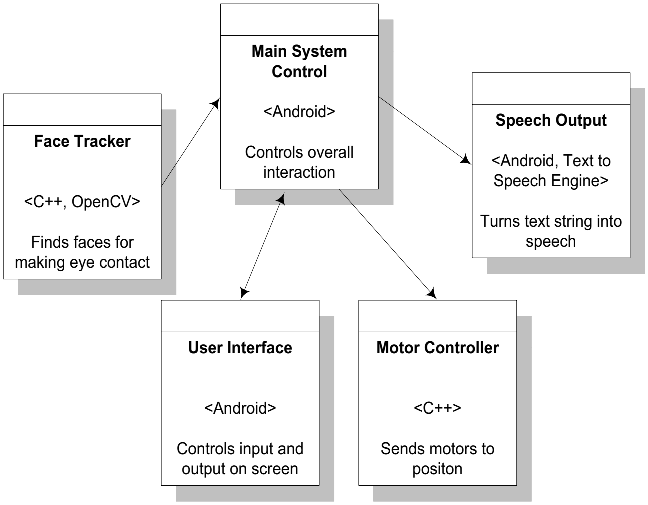


**Figure 4.** Software Modules

The motor controller codes was written using C++ utilizes an inexpensive servo controller provides motion control. The vision system on CAKNA runs on a set of cameras is mounted above the eyes. These cameras are providing a view in front of the robot to the OpenCV face tracker. The face tracker is implemented in C++ as a standalone piece of software that sends out an $(X,Y)$ coordinate set for each face found in a video frame (face tracker module). The action that the face tracker captures is eye contact that is maintained with a user.

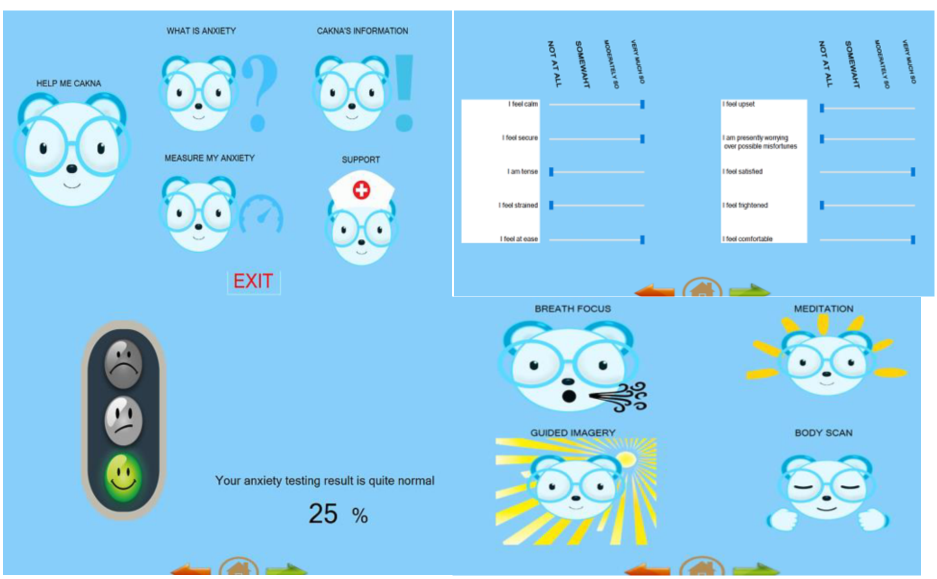


**Figure 5.** User Interfaces

The speech capabilities of the robot were created using an off-the shelf Android *text-to-speech* (TTS) class. The resulting application written in Android programming language was built as a standalone system that is activated when the user interacts with the robot. Upon receiving the input, it uses the API interface to convert a set of pre-programmed text into speech and plays the result over the robot's speakers. This user interface module is written in the Android programming language produces output screens based on the needs of the interaction for anxiety analytics and therapy management (as depicted in Fig. 5). The actual content of most screens is parameterized so that the main control code can determine the text or data to be shown on a given screen at runtime. User interacts with CAKNA by using a small touch-enabled input screen on the front to allow data entry.

## 4. Types of Therapy

To date, there is no actual cure for anxiety exists, but a number of studies showed that preventive measures could help avert anxiety in individuals who are at risk. Depending on the specific cause of the anxiety as well as on the individual's preferences, the treatment methods may include *behavioural therapy, physical therapy, relaxation therapy, mindfulness therapy, counselling* and *meditations* [19][20][21].

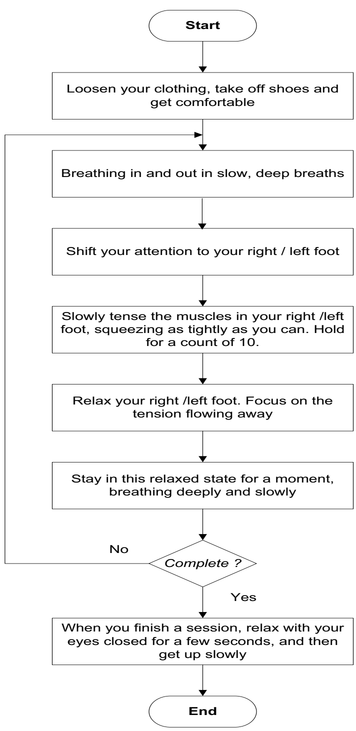


**Figure 6**. An Example of Body Scan Therapy

As a basic rule, these treatments are designed and administered at reducing the symptoms related to anxiety and assisting individuals in getting back their life [19]. CAKNA is designed to support self-therapies procedures to bring the anxiety level down. There are four types of therapies that were programmed on CAKNA, namely; 1) *deep breathing*, 2) *body scan*, 3) *mindfulness meditation*, and 4) *guided imagery*. Deep breathing exercises are an excellent and easy solution for anxiety relief. This method aims to target on a physiological level by automatically slowing individual's heart rate. The key of deep breathing is to breathe deeply from the abdomen and getting as much as fresh air (oxygen) into individual's lungs [21]. This later will improve oxygen concentration in bloodstream and gives the calming effects.

Another method is the body scan approach, which involves learning to mentally monitor tension in each specific muscle group in the body by deliberately inducing tension in each group (as shown in Fig. 6). This tension is then released with special attention paid to the contrast between tension and relaxation. Mindfulness meditation therapy allows individuals to become more aware of the stream of thoughts and feelings that they experience [21][22]. It involves sitting silently and paying to thoughts, sounds, and bringing attention back to normal. Guided imagery is another type of therapy related to the mind-body intervention aims to evoke and generate mental images that simulate person's sensory perceptions. There are two ways by which guided mental imagery is conducted; *voluntary* and *involuntary*. Involuntary involves the generation of mental imagery based on present sensory while voluntary imagery resembles previous sensory perception recalled from memory or the product of imagination [21]. Both processes require special guidance to avoid potential risk towards generating mental images that may severe individual's thought processes (e.g. post-traumatic stress disorder individuals may recall (*flashbacks*) the disturbing intrusive images based on their past experiences).

## 5. Pilot Evaluation Study

We conducted a pilot study to evaluate the acceptance and usability of our robot-based therapy among individuals with mild to moderate anxiety traits. Our participants were introduced to the procedures and applications through a series of discussion. The discussion covers some important topics about anxiety, symptoms, and some concepts in self-therapy to manage anxiety.

### *5.1. Participants and Measures*

Participants were recruited via online postings and based on voluntarily approach. Later, they received the Trait Anxiety Inventory (*T-Anxiety Form Y*), and were eligible to participate if they scored a cut point of 40 [17]. Range of scores for each test is 20-80, the higher score indicating greater anxiety proneness. In addition, only participants were not currently enrolled in therapy and not on medication were selected. Selected participants also received a State Anxiety Inventory (*S-Anxiety Form Y*) before and after interacting with the system / robot [18]. After the interaction process completed, participants filled out 4-*point forced-choice* Likert-type response scales to evaluate their current state.

**Figure 7.** Computer-based Therapy vs. Robot-based Therapy

All interactions with system/ robot were recorded (with consent) for review by our experts. The deep breathing exercises were used as a therapy tool to combat anxiety state among respondents. Figure 7 visualizes the position of the robot during our therapy sessions.

## *5.2. Quantitative Results*

We recruited 24 participants: 60 percent male, aged 19-23 (Mean 21.5, SD=1.6) years old and almost 83 percent of them had never tried any forms of therapy before. Pre-post testing conducted immediately before/following the PC-based and robot interaction to evaluate potential significance differences in anxiety level (*S-Anxiety Form Y*).

**Table 1.** Outcome Measures (S-Anxiety) from Pilot Study

| | **Pre-mean (SD)** | **Post-mean (SD)** | ***p*** |
|---|---|---|---|
| Comp-based Therapy (*n*=12) | 62.8(12.4) | 57.8(10.07) | 0.267 |
| Robot-based Therapy (*n*=12) | 63.3(11.2) | 36.9(5.1) | 0.045 |

From Table 1, it shows there is a significant improvement after using our proposed robot-based therapy (CAKNA) (as compared to the computer- based therapy (PC)).

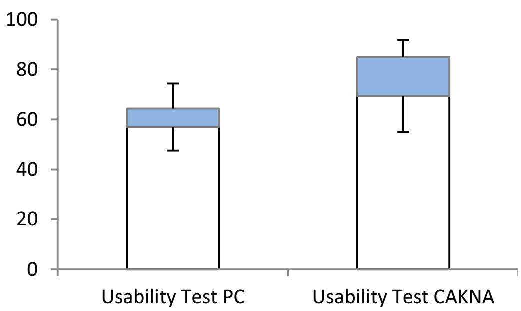


**Figure 8.** Usability Test

In addition, participants find CAKNA require almost no background knowledge about robotic technology to operate the robot, easy to understand interfaces, and easy to follow instructions (*Mean* = 75, *SD* = 5.5). Fig. 8 depicts the overall usability results from our experiments.

### *5.3. Qualitative Results*

In this study, all respondents reported that the robotic system was very easy to use. For example, one of the respondents (*RSP#5*) mentioned;

> "*I found it to be very easy and straightforward. I think that other people would not need support of a technical person to be able to use this robot*."

When asked about how the system helps them to control their anxiousness, only one of the respondents (RSP #9) felt that the "machine-like" voice seems a bit weird. However, the same respondent also mentioned other than that, everything was nice and looking forward to use this robot again in the future. In addition, all respondents were told that they are allowed to terminate the session early if desired. None of the respondents chose to terminate the therapy session early.

## 6. Conclusions and Future Work

In this paper, we explore the use of a robot-based anxiety management system that is responsive to user interaction. The designed robot integrates a software agent, physical robot design, and software modules. The dedicated support actions tuned to the circumstances are generated based on the analysis (from a software agent), thereby taking into account guidelines adopted from anxiety management programmes. Additionally, we demonstrate the potential implementation of such a robotic system through our pilot study in which people with anxiety state interacted and followed the therapy session. Currently, we are expanding our experiments using control groups and different types of therapy sessions. In addition, we are investigating possible more human-like voice to support more fluid human-robot interaction in the future. Furthermore, we are planning to build an adaptive bio-feedback system connected to a user for real-time anxiety level analysis over multiple sessions.

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