Tangible Communication of Emotions with a Digital Companion for Managing Stress: An Exploratory Co-Design Study

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ABSTRACT

The purpose of this research is to explore how an intelligent digital companion (agent) can support persons (human) with stress-related exhaustion to manage daily activities. In this paper, we explore in particular how information about a person's emotions can be communicated to the agent with means of non-verbal communication through tangible interfaces. The purpose is to explore how different individuals approach the task of designing their own tangible interfaces for communicating emotions with a digital companion, and the range of different preferences and expectations. Six participants were interviewed and created tangible prototypes during a co-creation workshop. The data was analysed using theories about human emotions and activity, and translated into a generic user model, an architecture for a multiagent system and interface design proposals. The results include increased understanding of how different individuals would like to express their emotions with tangible interfaces, and informed the design of the information models regarding representing emotions. The study illuminated the importance of personalisation of functionality and interface design to address the diversity among individuals, as well as the design of the adaptive behaviour of a digital companion. Future work includes further studies involving additional participants, the development of the stress management application and conducting user studies where prototypes are used in daily activities.

CCS CONCEPTS

• **Human-centered computing** → **User models**; *Participatory design*; Interface design prototyping; • **Computing methodologies** → **Multi-agent systems**; *Intelligent agents*.

KEYWORDS

Tangible user interface; Personalisation; Intelligent digital companion; Intelligent agent; Stress management; User modeling; Non-verbal interaction; Emotion; Co-design; Participatory action research; Human-agent interaction

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1 INTRODUCTION

Stress-related symptoms and exhaustion are an increasing effect of high work load in work and education often combined with responsibilities for family. Long-term sick-leave due to mental health problems where a large proportion of these sick-leaves are attributable to psychosocial stress has become an increasing concern in industrialized countries [36]. Further, among the student population emotional and physical symptoms such as fatigue, depression, and anxiety can be attributed to stress [15]. Furthermore, stress not only affects the mental and physical wellbeing in individuals but also society as whole [21]. The way people experiences stress varies between situations, and how stress is triggered varies from person to person. It is essential to educate people about stress coping strategies to prevent increasing levels of stress that can result in serious health problems [2]. In order to promote a healthy lifestyle and wellbeing it is important to understand various factors that result in stress for an individual. We are surrounded by technologically advanced devices such as a smartphones, tablets, or laptops. eHealth applications designed for promoting healthy behaviour change have become more accessible and possible to install in such devices [1]. There are health applications for monitoring sleep and physical activities in daily life, that provide statistics on activity patterns and some analyses of quality, e.g., sleep quality [31][37][28]. More advanced applications targeting behaviour change can be found in research on persuasive technologies [32], where more personalised advice are aimed to promote behaviour change, and sometimes followed by theories about motivation and behaviour change [29][9][34][3].

Various topics are focused, such as smoking, physical exercise and nutrition, which are typical topics where there is clear evidence-based information that can be communicated to the person as reasons for changing a certain unhealthy behaviour [32] and improving wellbeing. Stress-related symptoms and exhaustion represent the results of a more pervasive kind of behaviour, since they arise from the sum of all the activities and concerns of a person in their daily life, and are therefore difficult to identify and address through the kind of digital applications solutions available today. In order to build behaviour change applications it is necessary to keep physical and mental wellbeing of the user's at the core during the design and development phase [10]. However, to build evidence-based applications for improving health aimed at supporting behaviour change, expert knowledge about health as well as factors for behaviour change need to be integrated as base for the system's behaviour and advices, and validated. Moreover, this knowledge needs to

be adapted to the particular situation, needs and preferences the individual may have, as well as the individual's emotional state

in order to give optimal suggestion/feedback tailored to the situation. Evidence-based and other reasons for changing behaviour may be possible to formulate in arguments based on logics that can support decisions made during the day. However, in daily activities we are facing emotional aspects of activities that may have stronger influence on the choices we make. This research aims to explore how information about contextual emotions situated in an activity can be communicated and enrich a digital stress-management application.

The results of this study will be fed into the development of a socially intelligent digital companion as a tool for persons diagnosed with stress-related exhaustion to manage their stress. Since the digital companion is aimed to be socially intelligent [4], personalised, and adaptive, it needs models of the individual it aims to support, their environment and their emotions. Emotions play a vital role in stress according to cognition-focused therapy [8], and compassion-focused therapy [18]. Hence, it is of interest for clinical experts, researchers and designers to gain information about the emotional state a user and its association with the context (environment) the user is in and relationship with experienced stress.

The study presented in this paper focuses on building a tangible agent as an interface between the user and a digital companion, taking into account the user's physical world and the companion's digital world, to communicate the emotional state of the user. This is done through applying a generative r[27, 35] combining participatory action research [24] by using co-design workshop as a generative tool, involving target users. The reason for this approach is to explore the range of different experiences and viewpoints individuals may have to increase the understanding of how different individuals would like to express their emotions with tangible interfaces. Based on the information communicated via this tangible agent, the companion agent is expected to provide support (suggestions) with empathy towards the user and offer them assistance (feedback) to reduce the stress in a given situation as a means of digital support for improving their wellbeing. This may be done by different means, visual, verbally and non-verbally, and through different modalities, however, this is subjected to future studies.

2 BACKGROUND

2.1 Emotions

Emotions play a vital role in stress according to cognition-focused therapy [8], and compassion-focused therapy [18] that are used to introduce stress coping strategies to persons experiencing stress. Hence, it is of interest for clinical experts, researchers and designers to gain information about the emotional state a user and its association with the context (environment) the user is in and relationship with experienced stress. Understanding emotion is of both practical and theoretical importance. It plays an important role throughout our lifespan; emotions enrich the experience with either pleasurable or unpleasurable qualities. Emotions are composed of behavioral, expressive, physiological and subjective feelings [14]. Our emotions are also affected by the environment, context and situation we are in, which make the study of emotions complex. Computers may benefit from knowing about user's emotions [20] and may enhance the system's effectiveness [39].

Characterising emotions is a way to understand emotion and theories of basic emotions are proposed by [16, 23] [33]. In this study, two models of emotions were applied: one is generic and one is applied in rehabilitation of stress-related exhaustion.

The eight primary emotions suggested by Plutchik [33] are used as a generic set of emotions in this study. The suggested eight primary emotions are the following: *joy, sadness, anger, fear, trust, disgust, surprise* and *anticipation* (Figure 1). In the model of emotions presented by Plutchik, the primary emotions are further paired as four sets of opposite emotions as joy and sadness; anger and fear; trust and disgust; surprise and anticipation. The model shows connectivity between the ideas of an emotion circle with a colour wheel, like that of the case of colours. Primary emotions can also be expressed at different degrees of their intensities. For each emotion, there are three degrees. For example, acceptance is a lesser degree of trust and anticipation is a more intense degree of trust. Plutchik's emotions can be mixed to form a new emotion. Composition of two emotions are called dyads; in this model 24 primary, secondary and tertiary dyads are theorised. For example, joy and trust are combined to form the emotion *love*. Composition of three emotions is called triads; for example, joy, trust, and anger are combined to create *jealousy*. The model builds into a wheel of emotions with four groups of the primary dyad, secondary dyad, tertiary dyad, and opposite emotions. It covers the broad spectrum of 56 emotions with 24 dyads and 32 triads (for the full model, see [33], the primary set of emotions applied in this study is shown in Figure 1).

Figure 1: Selected set of emotions based on Plutchik's wheel of emotions [33].

The primary set of the eight emotions from Plutchik's wheel of emotions is used for this study, because this wheel illustrates subsets and co-relation between different emotions in different intensity,

which could provide some information about connections between emotions brought up in the design workshop.

The categorisation of different types of emotions in Compassion-Focused Therapy is also applied in this study, which is presented in more detail in the following section.

2.1.1 Compassion-Focused Therapy.

Compassion-Focused Therapy (CFT) [18] is used by experts in stress-rehabilitation clinics to promote self-reflecting on emotions. According to CFT, humans are evolved with three primal types of emotion-regulation system: the *threat* (protection) system, the *drive* (resource-seeking) system, and the *soothing* system (Figure 2).

The threat system helps us in identifying a potential threat and seek response to overcome that threat. There are different responses to different threats. For example, the threat system made the human run whenever coming in close proximity to carnivorous animals, corresponds to a safety-seeking response. Moreover, anxiety is part of the threat system that corresponds to flight and fight response. The threat system is our dominant system and creates negativity bias, which means negative events are recalled more easily than positive events.

The drive system produces emotions such as anticipation and pleasure. This system fuels energy in an individual to strive towards specific goals and resources. For example, after finishing a task, we experience an emotion of relief and happiness of completing work.

The soothing system produces emotions such as calmness and safety. This system provides an emotional safe haven that is linked to being cared for or safe, it acts as a regulator for both the threat and drive systems. For example, whenever walking through a dark, narrow pathway one can imagine a safe world of one's imagination, providing them with feeling of safety.

In CFT the focus is on understanding the functions of a person's symptoms and difficulties regarding safety strategies, the relation of these emotion regulation systems, and aiming for a healthy balance between them. Part of the therapy is to increase the person's own awareness and give tools for managing the emotions and balance between them in daily activities.

The physiological, psychological, and behavioral characteristics of a specific emotion can be analyzed as possible design features that could be used in an application to increase the person's ability to cope with the threats and opportunities present in a situation [30]. In this paper CFT's model of emotion regulation systems is used as a base for detecting the three categories of emotions. This information can be used for analysing the balance between the three types of activities, and provide personalised advice to the individual.

2.2 Tangible User Interfaces

There are two main approaches to gather emotional information, objective and subjective [17]. Objective information can be collected by using sensors that record physiological data or facial recognition, whereas users themselves report subjective data. Both of the approaches have limitations. Techniques used for obtaining objective information (analysing sound, facial expressions, eyes gaze and head movement) may be obtrusive and prone to noise or requires secure infrastructure [13, 40]. Subjective information

Figure 2: The emotion-based drive systems of the compassion-focused therapy model, adapted from [18].

provided by the user may be less reliable, since the user may fail to report their emotions or feed false information to the system [26].

Tangible user interfaces (TUIs) are an example of ubiquitous computing, a technology that is embedded in the user's physical environment [38]. TUIs provide a channel to connect the digital space with the physical world by allowing users to manipulate digital information via interaction with physical objects [22]. What makes TUIs unique is that they can become a part of a user's daily life activity, because while interacting with TUIs the user does not necessarily need to have much knowledge about the digital world. TUIs design can take any form as an entity of the physical world, but when it comes to communicating information, the human needs to either have explicit knowledge about or intuitive sense how and what information is mediated, a kind of mental model of the communication task. For instance, if the habit of turning on the light in a room is to push a button on the wall, the new way to, e.g., use a particular gesture, or move an object in a specific way needs to be internalised cognitively in the person for him or her to be able to do the task. This motivates the application of a participatory action research methodology in this study to explore what kind of TUIs a person may create that they anticipate that would suit him or her.

The interaction with TUIs that we are focusing on in the study presented in this paper is of non-verbal nature, in the form of touch and similar manipulations.

3 METHODS

This study aimed to explore how a physical agent in the form of a tangible smart object may work as a mediator of interaction between a user (human) and a digital companion (agent). The purpose was to explore how different users envision their tangible interface and how different emotions can be communicated with different interactions with the tangible interface. Based on the design of a tangible interface and the interaction performed through it by users during a stressful situation, the digital companion can translate this interaction into specific emotion and give feedback as a form of coping strategy to help managing stress in that context.

The target group is highly diverse, since stress is a condition experienced by all to different extent, and people has different personality, reacts to different stressors, applies stress coping strategies differently and has different preferences towards tangible objects. At this exploratory phase, a generative research method [27, 35] is applied to combine participatory exercises with verbal discussion during the creative part of idea generation phase. To achieve the aim of this study, we conducted a co-design workshop as generative tool with the participants from the potential target group (people who experience some level of stress in their life). The aim was not to achieve one common design proposal, instead we expected a range of different proposals that would illustrate the range of diversity in the target group, to better inform the personalisation aims of the research project and therapeutic aims for rehabilitation of stress-related exhaustion.

The study aimed at exploring the following research questions:

- **RQ1:** How does different users build a tangible interface to communicate emotions with a digital companion?
- **RQ2:** What are the different actions(interaction) that a user wants to be able to do with the tangible item to convey emotions?
- **RQ3:** How does different users convey different emotions, is there any relationship between them?

3.1 Participants

A co-design workshop was held with a group of six participants. Some experience with stress was selected as a criterion for participation. The participants were between the age of 26 and 60 years old; three were female and three male. All had an academic background, with professions such as rehabilitation professional, information officer, project leader, and researcher. Five were full-time employed, and one was unemployed.

Figure 3: Participants working on prototypes during the co-design workshop

3.2 Procedure

The workshop was conducted in a laboratory with facilities of 3D printing, laser cutting, textile sewing, embroidery, prototyping, and other activities. The lab provided various material such as sensors and insulating materials (fabrics) of a broader range that were used

to help the participants and support their creative brainstorming process of building the tangible interface. Participants were allowed to use any materials, tools, and equipment available at the lab. Participants were given a small introduction of the laboratory and the facilities it provides, and examples of prototyping using soft materials available at the lab were also shown. Before the workshop, all participants were asked to read and sign an informed consent form, explaining the purpose of the workshop. The workshop was divided into two parts and lasted two hours. The first author lead the workshop, gave instructions, made observations and took notes. During the workshop participants were given access to the whole laboratory and provided their own working space to work on their creation to avoid any conflict/communication between participants to assure bias-free outcomes. Participants were given the freedom to express their creation in any way possible, be it by drawing or creating something physical.

During the first part of the workshop each participant individually created tangible interfaces and a set of interaction for different emotions. To help which emotion participants can communicate, a list of the eight primary emotions joy, sadness, anger, fear, trust, disgust, surprise and anticipation from Plutchik's wheel of emotions was provided to the participants [33]. This was done to help participants to reflect upon possible interaction styles for an emotion they may want to communicate through their created tangible interface.

During the second part, each participant demonstrated, explained and motivated the created tangible interface and interactions. After the explanation by the participant was done, other participants engaged in the dialogue about the design proposal and provided reflections.

After the workshop, the material and collected data were analysed. Voice recording made during the explanation phase of the workshop was analysed to understand and further make a detailed diagram of each proposed TUIs, ways of interacting with each TUI design and types of feedback received through each TUI. Relationships between different emotion types and ways of expressing them were also defined. The described theories about human emotions were applied in the analyses [18, 33]. The result of analysed data was used to inform the user model and design proposals.

4 RESULTS

In this section the results are presented, divided into presentation of the TUI prototypes that were created by the participants, results relating to methods for expressing emotions, and the enriched user model.

4.1 Tangible User Interface Prototypes

Six different tangible interfaces were prototyped by the six participants, each carefully designed by the individual to fit their perception of how they would need to communicate emotions with a digital companion in different situations. The prototypes created during the workshop are illustrated in Figure 4.

Each participant presented and motivated their design proposal and demonstrated their TUIs. The participants engaged in the dialogue about each design proposal and provided reflections. Based on their presentations and the dialogues, detailed sketches of these

Figure 4: Tangible interface outcomes from the co-design workshop

prototypes were made to illustrate all components they are made of to better understand the design and interaction performed through it; these detailed illustrations are shown in Figures 5, 6, 7, 8, 9 and 10. Each prototype is further described in the following, regarding shape, material, possible interactions perform using them and methods for communicating emotions.

Figure 5: TUI Prototype 1 sketch

4.1.1 Prototype 1. The concept of Prototype 1 was to have a small buddy that feels like skin when touched, giving it a feel of a living companion (like a pet animal). The rectangular wearable TUI can be made from soft rubber and slightly warm fabric, that contain a mixture of the soft and hard round object of various sizes. A user can interact with this by rubbing it against their hands, squeezing it with various degrees of force, hold, pamper it and by playing with the round object inside (Figure 5).

4.1.2 Prototype 2. Based on the concept of natural gesture, Prototype 2 is a small TUI that can go unrecognised. Made of a mesh material makes it durable to carry around. It consists of two main parts, an attached bead and one stand-alone pendant like a pin with another bead attached. In order to interact with this TUI the user

can wear it on his index finger and fidget with the attached bead with its thumb, they can make small gesture with the attached bead like making a small circle on a table, both beads can interact with each other making a click sound that may mean different things depending on the frequency (Figure 6).

Figure 6: TUI Prototype 2 sketch

Figure 7: TUI Prototype 3 sketch

4.1.3 Prototype 3. Prototype 3 is a TUI consisting of two major parts, a heart in the middle and loops of threads forming four arms. This TUI consists of four different colours of thread loop arms, for different emotions. To interact with this TUI the users can pull, twist, intertwine the threads loops or press the middle part that provides haptic and visual feedback (Figure 7).

4.1.4 Prototype 4. Prototype 4 is a TUI shaped in the form of a glove. It consists of three major parts: a thumb ring made of beads, cushion-like soft material filled in the palm area with pressure sensors, and different sizes of beads. To interact with this TUI, the users can rub their hands, fidget with the beads in the thumb rings, press the palm area and by playing with beads inside (Figure 8).

Figure 8: TUI Prototype 4 sketch

Figure 9: TUI Prototype 5 sketch

4.1.5 Prototype 5. Inspired by the thought that some smells and materials remind us of good memories, Prototype 5 is shaped in the form of a handkerchief and small tube-like a stick with two different colour section. To interact with this TUI, a user can use a pin to poke either of two coloured areas of the tube, rub the material on the stick, touch and feel the handkerchief, sniff it or just put it on the face to feel relaxed (Figure 9).

Figure 10: TUI Prototype 6 sketch

4.1.6 Prototype 6. The Prototype 6 is a small portable robot-looking doll with three major parts, head, body and additional accessory. Its head is like a pincushion, which consists of two pins as its ears. The body is made from squishy material like a Stress ball and the accessory consists of a pin with a small bead on it. A user can interact with this TUI by poking pins in its head, squeezing the main

body, pet, hold, fidget with the accessory or by glancing at this TUI (Figure 10).

4.1.7 Summary of TUI Design Proposals. Based on the results, a set of design proposals for TUIs were made. The following are key components:

- **Appearance:** The TUI can be of any portable form of accessory of convenient size, daily use fashion or functional item (hanging around the neck, handkerchief or a glove) or a portable toy. The TUI should blend with the surrounding artifacts according to the lifestyle of the user.
- **Features:** It is essential to let users decide their own interactions and association with emotions. This way the learning phase of using the artefact can be reduced and sooner become intuitive and natural to use, and intrinsic motivation may be promoted [3].
- **Materials:** The touch and feel of the TUI was considered being a key factor for the overall user experience. For the design of TUI, the use of smart textile is recommended [12]. This can be combined with small physical items which a person can fidget or play around to relieve stress. Combinations can also be made using natural textile of fiber filled with conductive material, fibers coated with conductive polymers or metal, and fibers spun with thin metallic or plastic conductive threads.
- **Sensors:** Capacitive pressure, resistive pressure, accelerometer, optical textile, temperature and humidity sensors can be use to detect the interactions described in the study [7, 19].

4.2 Analysis of Methods for Communicating Emotions

Plutchik's wheel of emotions [33] provided the following categories of emotions: trust (acceptance), anger, anticipation (interest), disgust, joy, fear, sadness, surprise. Conveying sadness though different gesture was not mentioned by any participants during the workshop, this is why sadness was not included during this analysis. Patterns of interaction styles were recognised among the participants' preferences, that could be divided into three emotions groups from these seven basic emotions. These groups are as follows:

- **Fear, Anger, and Disgust:** Fear is expressed by rapid, occurring interaction, for example, rapid fidgeting and clicking sound with the bead, rapid poking of a pin, or by making a tight fist gesture of hands. Similar gestures also express anger and disgust.
- **Joy, Surprise and Anticipation:** Joy and surprise consist of interactions that call for immediate attention of the digital companion (to share the happy feelings). Such interactions consist of rubbing and shaking.
- **Trust:** Trust is expressed by holding the TUI interface calmly or by making small interactions such as pat, small manipulations (calmly turning the beads or rubbing) and by playful interactions such as juggling of the TUI.

This categorisation also follows the categorisation provided by the Compassion Focused Therapy Model [18]. The threat (protection) system corresponds to the first category, the drive (resource-seeking) system to the second, and the soothing system contains trust.

4.3 User Model

Since stress management therapy to large extent concerns management of emotions and emotional reactions to situations and stressors, it was considered important to explore models of emotions to find instruments for detecting emotions non-verbally as complement to subjective assessments through questionnaires, which is the standard way to collect information about emotions in a particular situation. The information model of the user contains typically information relating to capacity, preferences, activities etc, but rarely about emotions related to activities and preferences. This work aimed to find constructs of emotions that could be useful in the agent's reasoning about what kind of support to provide the user.

The user model adapted for the stress management purpose extends a user model developed as part of our earlier work to incorporate emotions [5, 25]. The initial version of the user model is based on the International Classification of Functioning, Disability and Health (ICF) ¹. However, since ICF does not provide specific information about personal factors such as preferences and emotions relating to situations, this part of the user model was extended.

Since similar emotions specified in Plutchik's wheel model of emotions, such as fear, anger, and disgust, or joy, surprise and anticipation seem to be hard to distinguish, the three categories defined by Compassion-Focused Therapy that serve three main purposes will be used as the main categorisation, with the specific emotions as sub-classes. The three main categories and their purposes are *soothing emotions* (give rest and recovery), *drive emotions* (energy-raising emotions), and *threat emotions* (fight and flight emotions). According to therapists and experts on stress rehabilitation, one particular activity can serve more than one of the purposes (and trigger several emotions), which will make the connection of emotions to activities change over time and be uncertain. Therefore, the connection to activities will remain loosely coupled for now, only recording emotions to time and current activity when this information is available. At this stage, the sub-class of the ICF class *activity and participation* in the ontology called *leisure activity* was categorised as *recovery activity*, corresponding to the soothing purpose. In future work we aim to explore further the connection of emotions to activities in individual cases.

Following the distinctions made presented in previous section, we assume that the same sensors could be used for detecting different emotions, only distinguishing these by e.g., frequency, intensity, speed of input and location of the TUI, which will be different between individuals. Different interaction styles could also be distinguished and explicitly connected to preferences of an individual user.

¹International Classification of Functioning, Disability and Health - ICF: <https://www.who.int/classifications/icf/en/>

4.4 Proposed Agent Architecture

The results of this study will be used for building a multi-agent system to enhance communication between the human and the digital companion. The proposed architecture illustrated in Figure 11, consists of three agents: the companion agent embedded inside the digital environment of the stress management application, the human agent and the TUI agent, embedded in the TUI. The TUI agent and the companion agent are built using the BDI framework [11], providing each agent the basic constructs of intelligent agents: *beliefs* (the agent's knowledge about the user and a situation), *desires* (corresponding to its goals and their priorities), and *intentions* (corresponding to plans, also with priorities regarding how to act). The reason to build a distributed architecture including different agents is to allow the agents to have different belief bases and sets of goals and priorities, corresponding to their different purposes and roles [5, 6]. The TUI agent's main role is to manage the TUI, interpret the sensor input data into information about the emotions, communicate sub-sets of the information to the actor repository available to the companion agent, and provide input to the companion agent that may activate its reasoning and acting.

The human agent conducts activities in the physical environment, taking place in different contexts and situations. When sensing some emotion the human agent could interact with their personalised TUI, which activates the TUI agent to interpret the data and passes on information, and activates the companion agent. The companion agent then composes a situated user model based on the new and earlier information, and information about the current situation [5]. By connecting the information about the user with a knowledge base relating to stress and wellbeing, personalised feedback can be generated that is tailored to the situation and the ongoing activity, to the extent the system has information about the context. The companion agent then selects the modality in which to communicate the feedback with the user. This may be done non-verbally through the TUI, depending on what actuators are embedded, and/or via a graphical user interface (GUI) on e.g. a mobile phone. The TUI in turn could have its own feedback loop for the purpose to provide immediate affirmation of the user's actions as a kind of non-verbal support dialogue [5].

The proposed architecture builds upon our earlier work, utilising resources such as a knowledge base and generic user and activity models part of a platform for engineering knowledge-based systems [25].

5 DISCUSSION

The study presented in this paper aimed at exploring tangible, non-verbal methods for communicating emotions with a digital companion that may be useful in the context of managing stress. To acknowledge the complexity in supporting behaviour change and wellbeing in individuals, and the diversity in preferences and motives for adopting tools while conducting activities, a generative research method by using co-design methodology as generative tool was applied involving six persons with experiences from stress. The purpose was to explore a broad range of perspectives on emotions relating to stressful situations in order to expand the design space for personalisation of tangible user interfaces (TUIs) for communicating emotions.

Figure 11: Agent Architecture

The results show that the design of a TUI agent varies from person to person when given the opportunity to build their own TUI designs. Each individual provided motives for the design and behaviour of the tangible interface, that were typically rooted in their experiences in the past. They re-used such experiences of emotions and materials from situations and their stressors in the past for associating current emotions to, and for the purpose to be reminded about in the case of positive emotions. Consequently, the understanding of how different users envision their personal tangible user interface has increased during this study. However, the results also pose some challenges for further development. The continued participation of potential future users in the design and development process is clearly motivated by this study, to allow for diversity in solutions and approaches to supporting behaviour change. Further, since behaviour change is hard, participation in designing tools for managing stress and behaviour change may increase motivation and engagement in their own rehabilitation. TUIs with some generic functionalities can be formed based on the study, while some features could be allowed to be tailored by the individual, in particular, related to shape, material and colours. The behaviour of the generic functionalities could be tailored by the system, following preferences, types of emotions and types of activities. In particular, the appearance of the digital companion could be adapted following the individual's current emotional state and activity.

6 CONCLUSIONS AND FUTURE WORK

A study was presented that explored tangible user interfaces created by end users, designed for collecting data about the emotion a user experiences in daily activities. The purpose of collecting emotion data was to provide a socially intelligent and adaptive digital companion information to better personalise support to individuals who are diagnosed with stress-related exhaustion syndrome.

A co-design study was conducted with six participants who had experienced some level of stress. A workshop was held to learn about how different users envision their tangible user interface and how different emotions can be communicated with different interactions with the tangible interface. The results show that in the non-verbal form of interaction, similar emotions such as fear, anger, and disgust, or joy, surprise, sadness and anticipated become hard to distinguish. Therefore, in continued development, the emotion detection will be limited to the three categories specified by the Compassion-Focused Therapy.

The results also show that the different users envision their tangible user interface differently and its behaviour is based on their preferences and experiences. The major challenge in continued development is consequently to provide a set of tangible user interfaces that may fit the preferences of the users and that may adapt its behaviour.

The user model was extended with information relating to emotions and their connection to activity and situations, which will function as a tool for the cognitive companion to adapt its supportive behaviour. An agent architecture is proposed to illustrate the working of the human agent, the TUI agent and the companion agent.

To summarise, the results of the study presented in this paper contributed to increase the understanding of human's emotions, how they may be conveyed via tangible user interfaces and different ways to communicate an individual's emotions with a digital companion.

Ongoing and future work includes the development of a stress management application in the form of a digital companion that integrates tangible user interfaces. The application will be evaluated in user studies. We are particularly interested in further exploring how tangible interfaces can be adapted to individuals so that the communication becomes seamlessly integrated in daily activities and intuitive to each individual.

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