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An interactive thought visualization tool for insomnia treatment

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Abstract

Insomnia is the most prevalent sleep disorder, characterized by chronic problems with the initiation and/or maintenance of consolidated sleep. Emotional distress and sleep-related dysfunctional thoughts are common reinforcing factors of insomnia. A method to overcome emotional distress is by challenging irrational thoughts throughout practice which will be effective for the patients to adopt healthier thoughts. This well-established principle is an important part of Cognitive Behaviour Therapy for Insomnia (CBTI). We designed a tool intended to create awareness on dysfunctional thinking patterns by providing visualizations and conceptualized as a web-based platform. Thoughts are released via mobile application and collected on a cloud-based system and then visualized based on frequency and emotional intensity. Initially, a cultural probe study was carried out where participants who perceived to have sleep problems recorded their thoughts for seven days, and then shared their experience in a post interview. The concept was visualized with an interactive mock-up, evaluated with usability studies and clinical expert interviews. The results showed that the tool is easy to use, visualizations are clear and has potential to be an educative platform for cognitive part of insomnia therapy. Based on the results, requirements are settled and design is finalized. The next step is to conduct validation studies by using a fully functional prototype and investigate the tool's effect on the treatment of insomnia related disorders.

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1. Introduction

Insomnia is defined as difficulties with initiating and/or maintaining sleep or a feeling of non-restorative sleep, leading to adverse consequences on daytime activities (e.g. tiredness, irritability, concentration problems) [1]. Insomnia is a prevalent disorder affecting up to 10% of the population [16] and it becomes chronic when the concurrent symptoms exist at least three times a week and present for the previous three months or more.

In general, multiple factors contribute to insomnia which could be categorized as behavioral and cognitive-emotional. Behavioral factors are improper lifestyles such as excessive caffeine consumption, prolonged bedtimes. Cognitive - emotional factors are having an aroused state of mind, sleep – related anxiety such as too much worry about not getting sleep. Eventually, such emotional distress can result in a self-triggering state through negative conditioning and lead to a vicious cycle [6].

Insomnia is a treatable disorder through both non-pharmacological and pharmacological interventions (e.g. benzodiazepine, non-benzodiazepine) [15]. Although pharmacotherapy is often used by medical experts, the gold standard method is Cognitive Behavioral Therapy for Insomnia (CBT-I) [6]. CBT-I is the combination of several components: sleep hygiene education, sleep restriction therapy, stimulus control therapy, relaxation training and cognitive therapy [18]. Despite the proven effect of CBT-I, the contribution of individual components and their effect on the treatment outcome are not precisely known [11].

The cognitive part of CBT-I is developed to address and reduce irrational thoughts and emotional distress. Cognitive restructuring is a standardized method used to modify undesired sleep-related thoughts by challenging irrational thoughts and replace them with alternative rational ones [18]. Thought challenging schema is a traditional way for dealing with vicious thoughts, patients write down their thoughts on a paper and a possible alternative thought and then they discuss with the therapist. Even though it is an effective process, it requires extra effort for the therapists since they have to devote their time and interpret the results.

The traditional way of delivering CBT-I is a costly procedure for healthcare institutions and patients in terms of time and money. The waiting lists within the hospitals are long because of the discrepancy between ratio of therapists and patients. Effective digital healthcare solutions could make CBT-I delivery more effective. Additionally, digital systems can add other benefits such as unlimited availability, tracking progress and regular reminders [7].

Information visualizations is a convenient way to provide feedback which allows many possibilities to represent complex information a straightforward and efficient manner. Furthermore, it could help to summarize a complicated concept in a short time since the eye senses a visual scene in less than 150 milliseconds [19]. Moreover, color coding is handy for representing emotions that emotions since colors perception have an affective dimension which would facilitate information processing [14].

The main objective of this study is to design a digital tool for people who suffer from insomnia by providing personalized reflection over their thought patterns. Since people with insomnia disorder have excessive worry and irrational thoughts about their sleep, providing a tool that could reflect someone's thoughts visually would also help people to become aware of the distortions in their thinking patterns. The tool is expected to serve as an educative tool and have a positive effect on cognitive aspects of insomnia treatment.

The current paper describes the design and the development process of a novel though visualization tool. The paper is organized as follows: related work is described in Section 2, the methodology is described in Section 3, results are described in Section 4, findings are discussed in Section 5, and finally conclusion and future work are described in Section 6.

2. Related Work

Some of the existing CBT-I tools on the market are Sleepio [8], Shut-I [17], Go! To Sleep [3] and CBT-I Coach [12]. These applications deliver CBT-I by providing education about the relevant knowledge, keep track of data and provide progress on statistics such as sleep efficiency. The first three delivers the therapy in weekly sessions where a different aspect of the therapy is covered in the content. For cognitive components, the information that CBT-I provides stay in theoretical level and there are not many customized reflections for thought patterns.

Some of the existing mood journals on the market are Moodnotes[1], T2 Mood Tracker[2], Stigma[3], Mood Panda[4] and Daylio[5]. With using these applications, users can report their moods, and its intensity anytime anywhere. Mood journals process the registered emotional states and provide visualizations about mood trends in form of bar and line charts. However, these visualizations are oversimplified (e.g. happy, unhappy, neutral) and offer basic interactions which are a limited opportunity for users to engage with the tool.

To our knowledge, little is known about the effect of mood journals within the context of insomnia and there is only a limited amount of validation studies for its effect anxiety based disorders [2]. The existing study is novel in terms of visualizing the registered thought patterns within the context of insomnia.

3. Methods

In this study, we addressed several research questions listed as follows. (1) In which ways would a thought visualization tool be applicable for insomnia therapy? (2) To which extent could such thought tool help to create awareness of people's common thinking patterns?

The investigations were carried out in steps: a cultural probe study, prototype development and then user studies. The cultural probe study was conducted to get insight into the thought recording experience. Furthermore, user studies and interviews with clinical experts have been carried out with an interactive mock-up to investigate the ease of use and the potential clinical value of such tool for insomnia therapy.

3.1. Cultural Probe Study

Special booklets were prepared as cultural probes [9] and conducted to get insight into the thought recording experience. The booklets were distributed to eleven participants (seven females and four males) who are university students aged between 18 to 24. All the participants reported having insomnia related sleep problems. The booklets contained the sections for *thought description*, *emotional strength*, *intensity*, *time*, *date*, and *location*.

The participants were instructed to record their thoughts and the associated feelings (e.g. "I am not sure if I am able to finish my report tonight") for seven days. This duration was chosen because it is long enough to get familiar with the process while maintaining the motivation. Afterward, participants were interviewed about their experience.

This post interview conducted in semi-structured form, the list of topics was prepared in advance and turned into questions during interviews. Participants voices were recorded with their permission, and later the audio pieces were transcribed into text. Open coding methodology was used to categorize the data, commonalities were identified and coded, and the themes were extracted from the defined patterns. In total 7,68% of the transcription contained the questions and comments of the interviewer.

3.2. Prototyping

A thought recording tool so called "ThoughtCloud" is designed as a web-based system: a mobile application and an online web platform. By using the mobile application, users can register their thoughts. The registered thoughts are collected on a cloud-based system and the information processed and visualized based on its type, self-reported intensity and time. By using the online platform, users can view the thought visualizations anytime from any device.

ThoughtCloud is expected to facilitate the ability to gain reflective skills over one's thinking patterns and to create awareness of irrational thoughts which is a major step for recovering from insomnia. Furthermore, increasing such

awareness is also expected to increase the control over emotional distress and unrealistic thoughts about sleep and other issues.

The concept was developed over two design iterations. In the first iteration, screenshots of the mobile application were designed and shown for feedback to the students and faculty staff in the affiliated research lab. See Figure 1 for an early version of thought visualization screen layout. Based on this input, the physical layout of the visualizations was improved. An interactive mock-up was created and used as a testing tool for user studies.
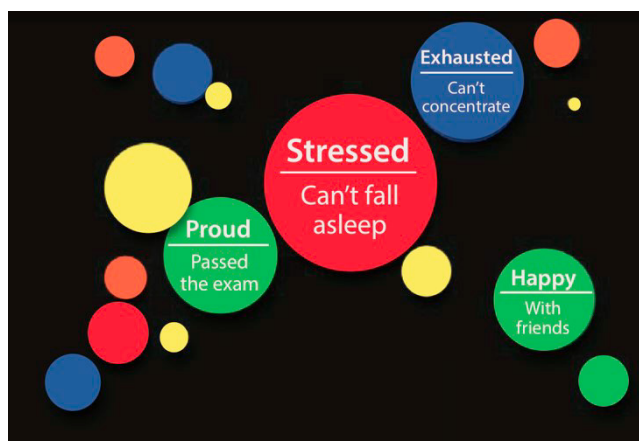

Fig. 1. An early version of thought visualization screen layout.

3.3. Testing

Two different user studies were carried out: a usability study and interviews with clinical experts. In general, the goal of the user studies was to investigate three aspects of the tool: usability and the clarity of the information and its possible application in clinical settings.

For the usability study, the participants were the same eleven people who also participated in the cultural probe study. Usability of the prototype was tested with thinking aloud protocol [13] and filling out a systematic usability scale (SUS). A task based scenario was given to all of the participants, and they were instructed to think out loud while interacting with the application. Ideas and concepts that are mentioned were noted down, common ones are listed and considered for the usability of the application. Then the participants filled out SUS [4] which is a standardized survey with ten ranking questions.

Afterward usability testing, interview with clinical experts were carried out to get insight into the potential clinical value of the tool. Three experts participated in the study: a sleep therapist (psychologist), a sleep researcher (medical doctor), and an applied psychologist. The interactive prototype was presented to the clinical experts, discussion points were given regarding the possible ways to integrate ThoughtCloud to insomnia therapy and tools potential benefits and side-effects on the patients.

4. Results

4.1. Cultural Probe Study

Thematic structural analysis [10] was carried out to organize the qualitative data. Table 1 lists the themes and sub-themes derived from the analysis. The results have shown that most mentioned sub-themes were, its difficulties (11,36%), the way of recording (5,25%) and the motivating factors (3,91%). Overall, results showed that despite thought recording is perceived as a tedious process for the participants, it was mentioned that curiosity was a major factor to continue reporting thoughts.

Table 1. Themes and sub-themes derived from the interviews of cultural probe study (coverage amount of each sub-theme within transcriptions are shown as percentage).

Themes	Sub-Themes	Description	Example Quotes
Awareness	Becoming Aware (1,33 %)	Expressing thoughts regularly increase awareness and it gets easier and more accurate over time.	"You are more conscious about what causes your emotions. "
Feelings	Positive (1,34%)	It is playful to see recorded patterns and find out the dominating thoughts throughout days.	"I find it funny that there are days that there really is a main topic."
	Negative (0,30 %)	Going over the negative records can make you feel negative.	"If you are doing something negative and you have something negative in mind the situation can get more negative."
Motivation	Motivating Factors (3,91%)	Curiosity is a major factor to continue about what comes out.	"I was not only recording for the sake of the research, I was also interested in it myself and what comes out from the recordings".
	Motivating Self (3,76%)	Keeping the book on the table, making photos, carrying the booklet everywhere with them.	"Because I keep it around, it was easy to remember to fill it in, but I forgot to do it during weekend."
Feasibility	Practical (4,46%)	Picture and text combination is practical despite writing down is sometimes tedious.	"For photos you see the environment, and for book you write these thoughts in a diary."
	Difficulties (11,36%)	To remember to carry the book, to commit writing all the time, realizing and reporting emotions behind thoughts and its intensity.	"I find it quite a challenging to link thought and emotion together."
	Way of Recording (5,25%)	Tangible (booklet) is a good self-reminder, mobile would be more organized.	"Such a book is useful, you have everything packed together. An app could also be an option, you can take pictures and take notes without effort."
Changes	Thought (0,76%)	More conscious about emotions, especially about where they come from.	"Now, I am more aware of my emotions."
	Behavior (2,34%)	Writing down thoughts does not change their behaviors.	"No, I do not think my behavior is changed by writing them down."

4.1.1. Testing for usability

The average SUS score was 86% which is an indication for the tool to be user-friendly. Verbal feedback was also gained from the participants, and it showed that; (1) The colours and buttons were easy to understand. (2) The intensity of emotions was not easy to comprehend. (3) Representing emotions by red and green may not be a realistic way to visualize because some emotions are not too extreme to be classified as black and white. (4) Pictures and the text messages of the thoughts made the display unnecessarily crowded. Interviews with clinical experts.

To analyse the results, transcriptions were developed from the audio recordings, which were categorized based on open coding methodology. The transcriptions were evaluated through a hierarchical analysis process which was chosen to be best to capture the essence [5]. Three thematic categories were emerged from the qualitative analysis: *Potential Usage*, *Advantages*, and *Disadvantages*. The results are described in Table 2.
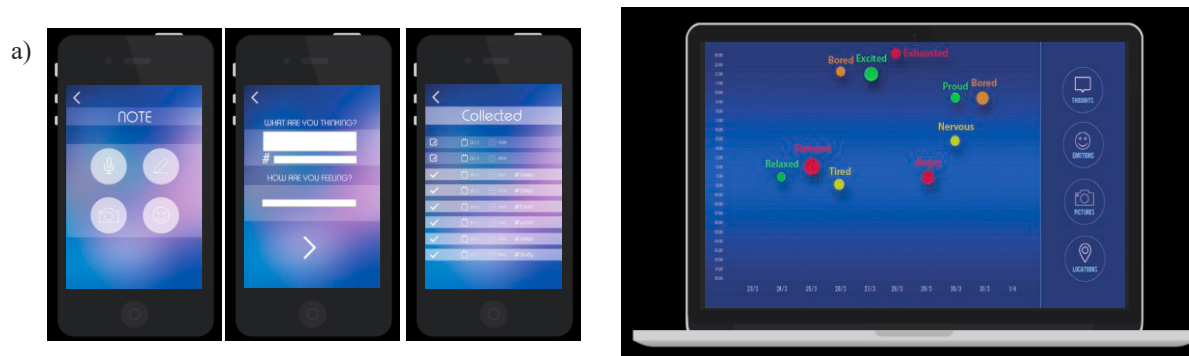
Fig. 2. ThoughtCloud Tool. (a) Mobile application for thought recording (b) Web based platform for thought visualization.

4.1.2. Final Design

Based on the findings from the interviews and usability studies, the layout of the screens and the interactions were re-designed. Furthermore, new screens were added both to mobile application and online platform. *Mobile Application*: Each thought is labeled by adding a hashtag. Additionally, a note-taking option is added so that users can complete registration of the thoughts anytime during the day. Finally, the element to register emotional intensity changed to a slider. *Visualization Display:* Hover and a searching option were added so users can search thoughts using hashtags. Furthermore, now it is possible to hide the pop-up windows, and a login option was added to increase the security of the system.

Table 2. Findings from interviews with experts about the potential clinical application of ThoughtCloud tool.

Themes	Description	Example Quotes
Potential Usage	The tool could be a preventive tool to increase the reliance and decrease the need to therapy. Sleep therapist could filter down the visualizations and expose them gradually to patients over sessions.	"You could place it in the waiting room. Because it could work preventive. This app could increase self-reliance and the decrease the need for therapy."
Advantages	Can help to extract certain themes, help to detect patterns that are not obvious, and provide an overview to the patients.	"It gives a helicopter view, most of the time, you cannot get it yourself".
Drawbacks	People with insomnia are more pessimistic than good sleepers, having biased thinking patterns. Reporting about negative situations and getting a reflection could make patients more pessimistic.	"People with insomnia are simply pessimistic, they may totally ignore the positive entries and focus on the negative ones".

5. Discussion

The present paper describes an iterative design cycle of a though visualization tool. The purpose of the tool is to assist people while they are coping with insomnia related sleep problems. The study was planned as two phases, settling down the requirements and testing for validation. Currently, the first phase of the study is completed and the requirements of the final design are settled through several steps.

In the final design, "note taking" and "hashtag labeling" options were added with having an intention to combine the best elements of social media, which would make the tool highly personalized therefore have the potential to influence a person's health and well-being.

The interviews with three clinical experts highlighted that the tool could be used to get more information about patients in an efficient way. A major drawback of the tool could be that insomniacs are pessimistic by their nature and

they could have biased attention with negative though visualizations. Therefore, it is important to conduct validation studies to make sure of the tools potential side effects.

A limitation of this study was not being able to get feedback of the design from insomnia patients. Further evaluations are necessary to understand whether the tool could be used as an educative tool to train patients to identify potential fallacies on their thinking patterns.

6. Conclusion and future work

The present paper described the design and development of a novel though visualization tool called ThoughtCloud which would assist users during their treatment for the cognitive aspects that underlie the initiation and maintenance of chronic insomnia. Currently, requirements of the final design are settled through an iterative design process. The next phase of the study will be focused testing the effect with a real-time prototype which would provide further insights into the tool's potential effect and side effects. When validated for its effect, ThoughtCloud could be a digital cognitive training tool which would help people to identify their sleep related and other distorted thinking patterns, and it could also be a common solution for other anxiety based disorders.

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