The Version of Record of this manuscript has been published and is available in the International Journal of Human-Computer Interaction. Date of publication online: 10 Sep 2018.
DOI: https://doi.org/10.1080/10447318.2018.1509540

TANGAEON: Tangible interaction to support people in a mindfulness practice

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Abstract

Recently, Tangible and Embodied Interaction (TEI) approaches to support people in mindfulness practices have been proposed in the literature, but they have scarcely explored the use of real natural elements in the interaction. In this paper, we first present TANGAEON, a TEI system that augments the AEON mindfulness mobile app with an interactive, water-filled glass container. Second, we evaluate TANGAEON by contrasting it with two traditional mindfulness techniques and with AEON. TANGAEON obtained better results in terms of achieved mindfulness, perceived level of difficulty, and degree of pleasantness than the two traditional techniques. Moreover, considering all techniques, participants achieved the highest level of mindfulness with TANGAEON, and rated it as the most pleasant and preferred approach to practice. These results suggest that the use of TEI based on a natural element can offer a novel and effective way to help people approach and practice mindfulness, and to augment existing mindfulness apps.

Keywords: mindfulness, tangible interaction, visualization, user study, naive meditators.

1. Introduction

In the last two decades, researchers have increasingly explored how to enable users to interact with computational objects within the real world, giving birth to the Tangible and Embodied Interaction (TEI) paradigm (Dourish, 2004; Hornecker, 2011). TEI systems can exploit the tactical and physical skills that people normally adopt to interact with the world, which can lower the mental effort required to interact with a computer (Dourish, 2004; Shaer & Hornecker, 2010).

However, despite the numerous contexts of application, very few approaches offer users the possibility to have a tangible representation of or interact with their internal states, see e.g. (Gromala, Tong, Choo, Karamnejad, & Shaw, 2015; Roo, Gervais, & Hachet, 2016; Sas & Chopra, 2015). These systems might be employed to support people in carrying out practices, like meditation, that require them to observe or be aware of their inner experience, such as thoughts, feelings, or emotions. For example, one of the exercises to cultivate mindfulness, a psychological process that is attracting an increasing interest from the scientific community due to its health benefits (Brown, Ryan, & Creswell, 2007; Chiesa & Serretti, 2011; Keng, Smoski, & Robins, 2011), requires users to mentally observe their own thoughts as they originate, manifest, and disappear (in the following, *distancing from thoughts*) (Kabat-Zinn, 1990). The sustained practice of such exercise helps people achieve a state called *decentering*, which consists of a detached and non-evaluative stance towards one's internal experience (Safran & Segal, 1996; Wells, 2005). However, people with no or minimal experience with meditation (hereinafter, *naive*[1] *meditators)* can find it difficult to practice distancing from thoughts, due to the lack of related physical or external cues, and the fact that thoughts are impermanent (Kabat-Zinn, 1990, 2005). As a result, they might be discouraged to continue in the practice of mindfulness, thus losing the opportunity to receive its positive benefits, which, in the specific case of decentering, consist in a reduction of

[1] Although it is common in the HCI literature to refer to users that are new to a task with the term "novice", in this paper we use the term "naive" to indicate people with no or minimal experience with meditation, consistently with the research literature on meditation, see e.g. Moore and Malinowski, (2009), Soler et al. (2014), and Thompson and Waltz (2007).

negative emotional states such as anxiety, worry, and ruminative thinking (Hoge et al., 2015; Querstret & Cropley, 2013).

On the contrary, a TEI system for interacting with their inner thoughts might make it easier for people to focus on such mental states, as well as keep them engaged in the mindfulness practice. The aim of our research is to explore how tangible and embodied interaction can be used to support people in the practice of mindfulness, and in particular to provide a representation of and allow users to interact with their intangible and impermanent thoughts. To this purpose, we first took inspiration from Ephemeral User Interfaces (EUIs) (Döring, Sylvester, & Schmidt, 2013b), i.e. interfaces that contain elements that last only for a limited time, such as water or sand, to develop a tangible and embodied interaction system, which extends the AEON interactive mobile mindfulness app (Chittaro & Vianello, 2014), offering users an ephemeral representation of passing thoughts. Then, we evaluated the usefulness of the proposed system in helping people practice mindfulness by contrasting it with two traditional techniques for distancing from thoughts (a mental and a paper-based technique), and with the original AEON app.

The remainder of the paper is organized as follows: Section 2 introduces the concepts of TEI and EUIs. Then, it reviews related work on interactive mindfulness practices based on tangible and embodied interaction. Section 3 describes the motivations, the design process, and the functioning of our TEI system that extends the AEON app. Section 4 illustrates the experimental evaluation we carried out, whose results are reported in Section 5 and discussed in Section 6. Finally, Section 7 draws the conclusions and outlines future work.

2. Related work

2.1. Tangible and Embodied Interaction (TEI)

The notion of tangible and embodied interaction became relevant since the work of Weiser (Weiser, 1991), who envisioned the embedding of computers into objects and devices constituting the fabric of people's everyday life (*Ubiquitous Computing*). Nowadays, the term refers to those systems that are embedded in and digitally augment real space, with the purpose of reacting to the user and/or enabling them to interact with the digital world by manipulating physical objects (Dourish, 2004; Hornecker, 2011). In particular, for such approaches the word "tangible" emphasizes the material manifestation of their interface and its embedding in the environment, while "embodied" highlights the fact that the interaction with them is socially and physically situated (Shaer & Hornecker, 2010). One of the early examples of TEI systems is provided by Tangible User Interfaces (TUIs) (Ishii & Ullmer, 1997), i.e. interfaces that can take different forms and employ different materials, and can be used as input and/or output devices to represent and/or manipulate digital information, or to provide users with feedback on the completion of their physical or digitally computed actions (Ullmer & Ishii, 2000). Recently, their extension for enabling sensing and interacting with the surrounding environment has been made possible by the inclusion of low-cost microcontrollers, e.g. sensors and actuators – giving rise to the Physical Computing paradigm (O'Sullivan & Igoe, 2004). In the last 20 years, TEI systems have been proposed in different domains, such as education, problem solving, information visualization, entertainment, and programming – see e.g. (Swallow & Thompson, 2001) for early examples and (Shaer & Hornecker, 2010) for a more recent review.

2.2. Ephemeral User Interfaces (EUIs)

Recently, the literature has proposed a novel kind of TEI systems, i.e. Ephemeral User Interfaces (EUIs), which have been defined as "interfaces that contain at least one UI element that is intentionally created to last for a limited time only. The durability of the UI element is determined

by its intrinsic material properties in combination with its surrounding ecosystem. While their ephemeral UI element(s) exist(s), ephemeral user interfaces provide a rich and multisensory user experience. They may deliberately be designed to offer only partial or imperfect user control" (Döring, Sylvester, & Schmidt, 2013a; Döring et al., 2013b).

EUIs represent unusual tools for interaction in comparison to the ordinary technical and durable materials of computer technology. Indeed, they are made by non-permanent materials, such as food, fire, cloud, jelly or soap bubble, that can assume specific meanings and evoke specific feelings according to the cultural context of their user (Döring et al., 2013b). Such ephemeral elements can be adopted as input, e.g. for controlling a device, and output, e.g. for displaying the computed result of user actions.

However, their current application is confined to playful and emotionally engaging interactions, such as ambient installations or devices for controlling music or lights – see (Döring et al., 2013a; Sylvester, Döring, & Schmidt, 2010) for a summary.

2.3. Interactive mindfulness practices

Mindfulness has been defined as the psychological process of paying attention to one's internal and external experience with a curious, open, and non-judging orientation (Bishop et al., 2004; Kabat-Zinn, 1990). Initially associated to meditation techniques that originate from Eastern traditions (Gunaratana, 2002; Kabat-Zinn, 1990), since the 1970s it has been included into interventions for enhancing physiological and physical health (Chiesa & Malinowski, 2011; Keng et al., 2011), and several studies have documented its positive effects, see e.g. (Brown et al., 2007; Chiesa & Serretti, 2011; Keng et al., 2011) for reviews.

In recent years, the interest around mindfulness has increased, also in the HCI community, which started to develop *interactive mindfulness practices* (Chittaro & Vianello, 2014), i.e. computer-

based approaches to support people while they are practicing mindfulness techniques – see e.g. (Sliwinski, Katsikitis, & Jones, 2015) for a review of mindfulness apps or games. Two approaches (Chittaro & Vianello, 2014; Glück & Maercker, 2011) aim at supporting people in practicing distancing from thoughts. The interactive practice developed by Glück and Maercker (2011) was part of a web-based mindfulness training. The app showed participants a cloud on a blue sky background. To interact with it, they had to recognize any distressing thought, feeling or sensation that arose in their mind, label it non-judgmentally (e.g. acknowledge that one feels angry by simply labelling the internal image with "anger"), and imagine placing it on the cloud. Then, by pressing the spacebar, they could see the cloud move across the sky and slowly wander out of sight. Although this interactive practice might offer participants a visual metaphor for distancing from thoughts, it provided only a very primitive level of support, since users had to carry out most of the assigned task mentally. For this reason, it was found to be more difficult than the traditional non-interactive techniques that were taught in the intervention.

The interactive practice proposed by Chittaro and Vianello (2014) was instead based on a mobile app, called AEON. The app allows users to enter their thoughts into a smartphone, and then visualizes them as written in ink on a parchment under water. Users can interact with the app by moving their finger anywhere on the screen, producing dynamic waves that progressively dissolve the written thought. In this way, the app offers users an external visualization of their thoughts and of the thought disappearing process, helping users remain focused on the thoughts and possibly evoking the sensation that each thought is impermanent. The effectiveness of this interactive practice in supporting naive meditators achieve decentering has been evaluated with three different studies. In (Chittaro & Vianello, 2014), the authors contrasted AEON with two traditional techniques that are not based on technology. Results revealed that participants achieved higher levels of decentering with AEON than with the two traditional techniques. Moreover, participants perceived AEON as the more pleasant and less difficult technique to practice, and rated it as their

preferred approach. In (Chittaro & Vianello, 2016b), a 5-weeks qualitative study was carried out to understand users' perceptions in using the app for ameliorating worry. Results revealed that the prolonged usage of the app helped most participants experience decentering from their worries. Finally, in the study described in (Chittaro & Vianello, 2016a), a questionnaire to assess decentering was included in the public AEON app available through on-line app stores, and a 4-week quantitative evaluation was carried out. Participants could take part into the study by downloading the app and answering the questionnaire at the first launch of the app, after two weeks of use, and after four weeks of use. The analysis of participants who answered all three mindfulness questionnaires revealed that naive meditators increased their level of decentering over time. Results outlined also that the app was perceived as useful and beautiful by participants, and its usage elicited positive feelings.

Researchers have also proposed interactive mindfulness practices based on tangible and embodied interaction, which employ some form of biofeedback mechanisms. We briefly describe such systems in the following.

In particular, some of these approaches aim at supporting users practice *mindful breathing*, i.e. a mindfulness exercise that requires people to focus on their breath (Baer, 2003). Examples include immersive installations, e.g. The Meditation Chamber (Shaw, Gromala, & Seay, 2007) and Sonic Cradle (Vidyarthi, Riecke, & Gromala, 2012; Vidyarthi & Riecke, 2014), a virtual reality app (Shamekhi & Bickmore, 2015) and a tangible design that resembles a stuffed animal (Aslan, Burkhardt, Kraus, & André, 2016), both called Breath with Me. Common to all these approaches is the use of a chest band to sense users' breathing pattern (and also other physiological sensors in the case of The Meditation Chamber) and to provide video, audio, or tactile feedback as result. Interestingly, a more recent system (HU) (Zhu, Hedman, Feng, Li, & Osika, 2017) employs a natural element to support such exercise. It consists of a lighted vapor diffusor that guides users'

breathing through vapor pulses, which are emitted at a predefined frequency. Moreover, by using an earlobe pulse sensor, the system detects users' heartbeat, which is then used to change the brightness of the diffusor's light and emit a background sound, respectively. For example, a fast heart rate turns the light bright and increases the tempo and volume of the sound, while a slow heart rate turns the light dim and decreases the sound's volume and tempo. However, such approach offers users only a limited interaction with the natural element, since they cannot act on it to change the internal status of the system.

Other TEI-based interactive practices focus instead on supporting the *body scan* exercise, i.e. a mindfulness practice that requires people to sequentially focus on the sensations that arise from the different inner and outer parts of their body (Kabat-Zinn, 1990). Examples include Mindfulness Spheres (Thieme et al., 2013), Hold my Heart (Aslan et al., 2016), and RelaWorld (Kosunen et al., 2016). The first two approaches consist of tangibles in the form of a 12-cm sphere or a real heart, respectively. By using metal disks or a pulse sensor, they detect users' heartbeat and translate it into visual and tactile feedback. RelaWorld is based instead on virtual reality. Through a head mounted display, it shows an avatar that visually guides the focus of the user by sequentially highlighting different parts of its body. Moreover, by using EEG sensors, the system determines users' level of concentration and makes the avatar levitate, as well as increase the opacity of an energy bubble visualized around it (in a similar way, RelaWorld supports another exercise that requires people to focus their attention on fixed points on the screen).

Different TEI approaches target *walking meditation* i.e. a mindfulness technique that requires users to combine breathing with walking, e.g. (Feltham, Loke, van den Hoven, Hannam, & Bongers, 2014; Yu, Wu, Lee, & Hung, 2012). In particular, Yu et al. (2012) proposed two systems for such exercise, i.e. the Walking-Aware System (WAS), which consists of a pair of shoes equipped with three force sensors, and the Breathwalk-Aware System (BAS), which employs also a respiratory sensor. Through a mobile app, both approaches provide walking (WAS and BAS) and breathing

(BAS) guidance and feedback to users.

The system described in (Feltham et al., 2014), i.e. Slow Floor, focuses only on providing awareness of walking. It consists of a pressure-sensitive surface that translates footsteps' force and weight to four different sounds recorded in a rural and domestic setting, such as the sound of crackling outdoor fire or a car at distance.

In summary, although the above described systems target different mindfulness techniques, their common feature is that they offer users visual, audio, or tangible cues for their inner sensations or body postures. In this way, they can be of support to people, and in particular naive meditators, who can direct their attention or redirect it on such cues when their mind has wandered away during the practice of mindfulness.

Finally, other proposed TEI systems do not target any specific mindfulness exercise, but aim at helping people focus on and be aware of their inner states, e.g. Virtual Meditative Walk (Gromala et al., 2015), MeditAid (Sas & Chopra, 2015), and Inner Garden (Roo et al., 2016). We describe these three approaches in the following.

Virtual Meditative Walk (Gromala et al., 2015) is an immersive virtual environment in which the user can walk through a forest and mountainous scenery, and specifically targets chronic pain patients. The system allows users to interact through a movable stereoscopic VR viewer, and uses galvanic skin response sensors to detect people's level of arousal and change the virtual environment accordingly. For example, when the level of arousal decreases, virtual fog dissipates and background sounds become more audible and spatial, while in the opposite case fog becomes thicker and closer and sounds less audible. The aim of the system is to help people learn how to achieve and be aware of a stable meditative practice, which can be helpful in reducing chronic pain. A preliminary study with chronic pain patients showed that participants who used the system while

listening to audio-based mindfulness training perceived a reduction of pain, in contrast to participants in the control group who only listened to the audio tracks.

MeditAid (Sas & Chopra, 2015) employs instead a wearable brain-computer interface with EEG sensors and headphones (or earphones) and can be used to practice different mindfulness techniques while sitting, such as mindful breathing and distancing from thoughts. In particular, the system employs the EEG signal to try to recognize users' meditative states. Such signal is then sent to a computer that translates it into the frequency of monaural and binaural beats played into the headphones. In the case of binaural beats, it is also used to change pitch. For example, when the user is progressing through a deeper meditative state, which reflects a quieter mind, the pitch of the beats lowers. On the contrary, when the user is moving towards a wakeful state, which indicates a busy or wandering mind, the pitch increases. A study with naive and experienced meditators showed that participants, and in particular naive meditators, achieved a deeper meditative state when using the system with the binaural feedback than with the monaural one or no feedback at all, during a 10-minute meditation session. Interestingly, some participants mentioned the usefulness of the system in helping them recognize when they were lost in their thoughts and subsequently in keeping track of them, thus suggesting that it could support the practice of distancing from thoughts.

Finally, Inner Garden (Roo et al., 2016) consists of an augmented sandbox with polymeric sand, i.e. a mix of natural sand and a polymer, that can be reshaped at any time. The sand is augmented with dynamic graphics from an overhead projector that displays a mini-world made by grass, trees, and water. Users can interact with Inner Garden by reshaping the sand and, whenever they stop, a new mini-world is generated, which starts evolving on its own, based on users' physiological parameters for the growth speed and overall health. Breathing and its variability, sensed with an elastic breathing sensor, influences the movement of the sea and speed of the day and night cycles, respectively, while frustration and meditation states, both sensed with EEG sensors, control the

weather and vegetation conditions, respectively. For example, a high frustration level will make clouds travel fast and increase their density, possibly triggering a storm, while a low frustration level will make low-density clouds move slowly, creating a sunny day atmosphere. A high meditation level will instead make the grass and trees grow faster for a certain duration after a meditation session. In general, if a user is experiencing a high level of stress, (s)he will see her/his world drying out, e.g. trees withering without sunlight, while doing breathing exercises and lowering stress helps to restore balance to the user's world. However, this system has not been formally evaluated yet, and thus its effectiveness in promoting mindfulness remains unknown.

In conclusion, although such approaches aim at providing people with external cues to make them aware of their internal (meditative) states, none of them offer users a visualization of their inner thoughts and/or the possibility to interact with them.

3. The proposed approach

3.1. Design process and motivation

To design our TEI-based interactive practice for distancing from thoughts, we first looked at the existing approaches in the literature that specifically aim at supporting the practice of such technique, i.e. (Chittaro & Vianello, 2014; Glück & Maercker, 2011), which we described in Section 2.3. In particular, we focused on AEON, given its documented mindfulness and user experience benefits. On the contrary, Glück and Maercker (2011) found that their web-app was not easier than traditional techniques, probably due to the fact that it requires users to carry out most of the exercise mentally.

The metaphor for distancing from thoughts implemented by AEON provides instead users with an external visualization of their thoughts and of the distancing process, as well as the possibility to interact with them and control such process. This interactive practice employs a water simulation

that is based on the fact that an important consequence of mindfulness practice is the realization that most sensations, thoughts, and emotions fluctuate, or are transient, passing by "like waves in the sea" (Linehan, 1993, cited in Baer, 2003). Other than helping people achieve decentering, such simulation was found to provide users with a pleasant experience while they were interacting with the app, as well as evoking in them the sensation that each thought is impermanent (Chittaro & Vianello, 2014).

We then considered extending AEON into a TEI system that uses real water as a natural element that acts as a mediator, following insights from Döring (2013b). The resulting system (Tangible AEON, TANGAEON for short) consists of a glass container filled with water placed over a tablet running a version of AEON modified to support the ephemeral interaction with real water.

In this way, TANGAEON aims at offering naive meditators a tangible and embodied experience and at the same time an ephemeral representation of the passing of their thoughts. Indeed, since its interactive practice is implemented in such a way that the interaction with real water controls the disappearing process of thoughts, it could provide users the sensation of acting directly on their thoughts, in addition to possibly offering users a pleasant and playful experience.

Moreover, the transient nature of the fluid, which continuously changes the environment created by the fluid together with the effect of user's gestures on it, might act as a visual metaphor for the ephemerality of people's inner thoughts, and possibly evoke in them the feeling that thoughts are impermanent. As a result, this tangible and embodied experience with real water could engage naive meditators more in the practice of distancing from thoughts than the interaction with simulated water of the AEON app, thus better helping them achieve decentering.

However, we also reasoned about the possible negative effects that TANGAEON might introduce in the interactive practice. First, the sensory stimuli introduced by the new interface could distract users from the focus required to practice distancing from thoughts. For example, people could become concerned about spilling water, or by the effects on the skin of keeping their fingers in

water, i.e. conditions that might hinder people's achievement of a decentering state.

Second, keeping hands in water could also make the experience less pleasant for users. For example, it could be perceived as less convenient than using the touchscreen. Moreover, people may not like the physical sensation of wet hands and fingers, or – as previously mentioned – worry about the possible issues of having to physically handle real water. Finally, since interacting with an app by physically moving water is unfamiliar with respect to using a touchscreen, there might be a risk that the TEI-based interactive practice could be perceived as more difficult to use than AEON.

For such reasons, we decided to contrast TANGAEON with the AEON app, and with the two traditional mindfulness techniques employed in the original AEON study (Chittaro & Vianello, 2014). We describe this new study in Section 4.

3.2. TANGAEON components

TANGAEON comprises two components: (i) the water-based interface, and (ii) a tablet version of the AEON app, modified to support the new type of interaction.

The water-based interface consists of a glass container, filled with water, placed over a tablet with a front camera (Figure 1).

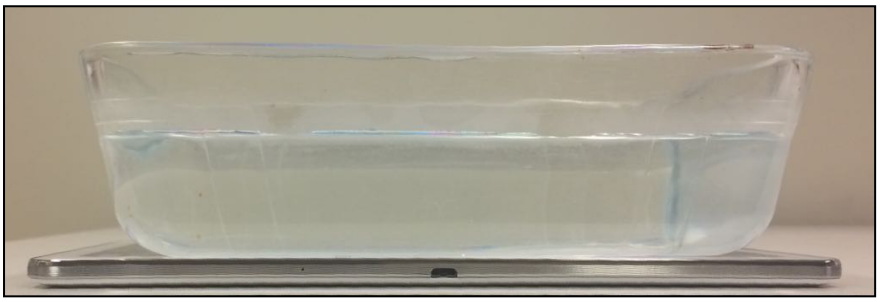


Figure 1: Physical components of TANGAEON.

The tablet app modifies the AEON app described in (Chittaro & Vianello, 2016a), developed with the Unity development environment (Unity Technologies, 2005). It is organized around exactly the

same two screens, i.e. “Thoughts List”, and “Practice”. The “Thoughts List” screen (Figure 2) shows the list of thoughts previously stored by the user. Before placing the tablet under the glass container, users can enter thoughts by pressing the “New Thought” button in the top-left of the screen and writing a maximum of 140 characters in the text area that appears, while they can delete one or more entered thoughts by first selecting them on the list and then by pressing the “Delete” button in the top-right of the screen. To practice distancing from thoughts, users have first to select from the list the thoughts they want to distance from, and then tap the button at the bottom-right of the screen to make the app switch to the “Practice” screen. Then, they have to place the water-based interface over the tablet.

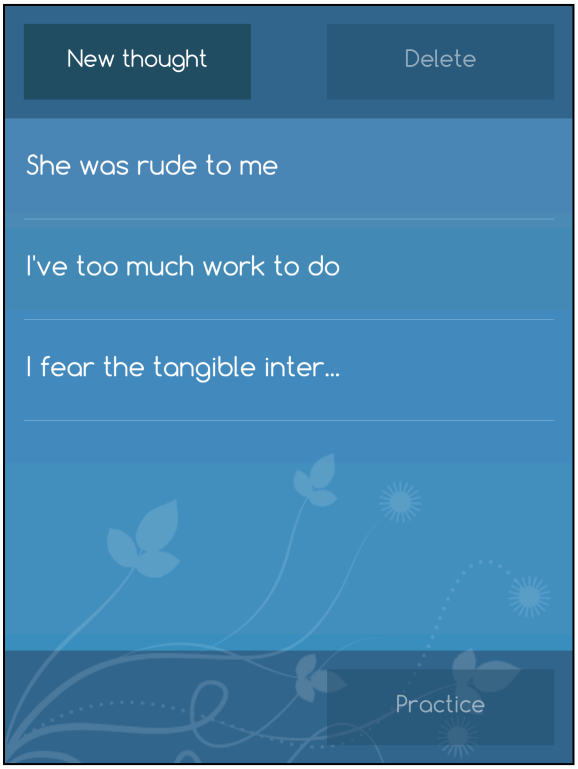


Figure 2: The “Thoughts List” screen.

The “Practice” screen shows the first selected thought as written in ink on a parchment (Figure 3), Unlike the original AEON that recognized users’ practice actions on the touchscreen, the modified app uses the tablet front-camera to detect water movements that are the result of users’ gestures in

the water-based interface. For such purpose, it implements a basic background subtraction algorithm for motion detection (Benezeth, Jodoin, Emile, Laurent, & Rosenberg, 2008), which we describe in the following.

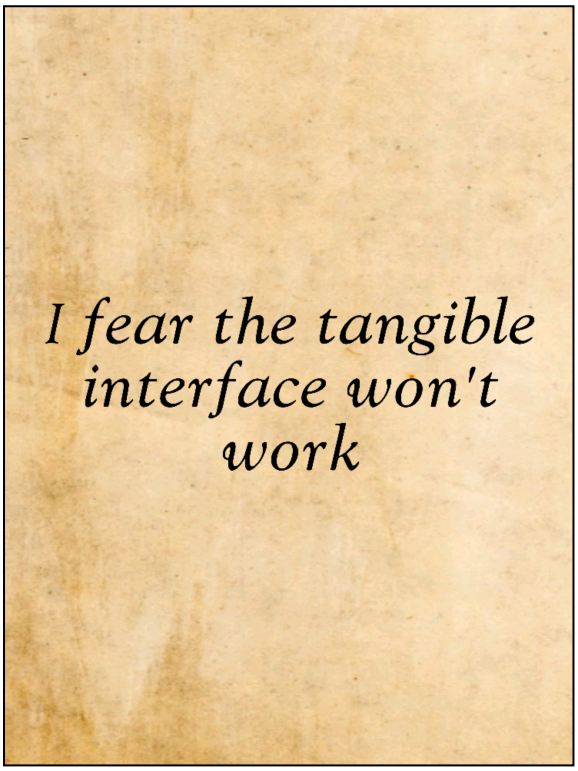


Figure 3: The "Practice" screen.

The algorithm operates in a loop that starts by calculating an average image from five consecutive frames captured by the tablet front-camera (hereinafter, *the background*), and then by computing the difference between the sixth frame (*the current frame*) and the background. Both calculations are performed pixel per pixel, and after the difference between the current frame and the background, a resulting pixel is marked as a *moving* one if its value is larger than a predefined threshold (*pixel threshold*). The algorithm then checks if the amount of moving pixels is bigger than another predefined threshold (*frame threshold*), which considers the size in pixels of each captured camera frame. If it is bigger, the algorithm detects the presence of motion, and starts a routine (*dissolving routine*) that makes the level of opacity of the written thought decrease according to the

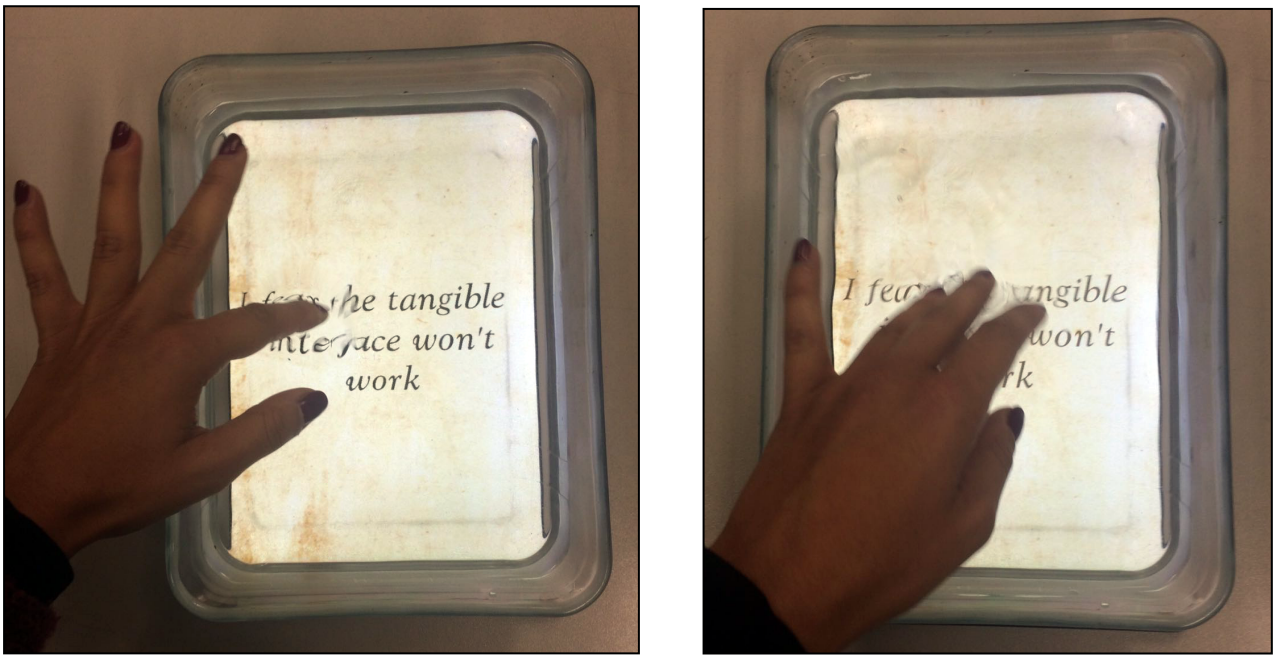
same non-linear function used in the original AEON app, which assures that a thought does not dissolve quickly after a few users' actions, but does it slowly and gently. If the amount of moving pixels is not bigger than the frame threshold, such routine is stopped, and the level of opacity of the written thought does not change. In both cases, the algorithm restarts its loop.

To assure that the time needed with TANGAEON to completely dissolve a written thought does not differ from the one required by the original AEON app, both the pixel and the frame thresholds, as well as the time needed by the dissolving routine to complete have been fine-tuned (during this process, both apps were running on the same version of the tablet to compare the times). The tuning process focused also on identifying false positives, i.e. situations in which a motion was detected by the algorithm but the user did not perform any gesture on the water-based interface, e.g. (i) when the glass container was placed over the tablet at the beginning of the interactive practice, causing water movements, or (ii) the user was seated in front of the tablet and the movements of his/her head or limbs were in the field of view of the tablet front camera. For such reasons, the algorithm was set to (i) wait two loops before enabling the dissolving routine for calculating a more stable background, and (ii) discard the pixels at the very bottom part of both the background and the current frame, respectively.

Finally, given the high frame rate of modern tablets front-camera, and the number of computations needed to detect motion, the algorithm was set to discard a small number of frames between each algorithm loop, to avoid introducing slowness in the dissolving routine that could affect the overall user experience. As an additional measure to avoid false positives, the algorithm stops the dissolving routine (if running) when saving the frames for the background after the discarded ones.

In summary, users can freely interact with the natural element in the water-based interface, e.g. by touching with their fingers the water surface or by dipping the fingers in the water and moving them anywhere inside the glass container, to trigger circular (Figure 4a) or more chaotic (Figure 4b) waves. In this way, users have control on the thought dissolving process, i.e. by deciding at which

pace to dissolve the written thought and/or take time to observe each thought while it is disappearing. Then, only after a thought is completely dissolved, the “Practice” screen switches automatically to the next selected one.



(a) (b)

Figure 4: Triggering a circular wave (a) or more chaotic waves (b) with the water-based interface.

4. User Study

The goal of this within-subjects study was to assess the effectiveness of TANGAEON in helping naive meditators achieve decentering. In particular, we chose to replicate the setting of the original AEON study (Chittaro & Vianello, 2014), which includes the AEON app and two traditional techniques not based on technology, and add TANGAEON as a fourth condition. The two traditional techniques are:

- *Cloud imagery (CLOUD):* i.e. a mental task in which users have to think of their thoughts as printed on clouds floating in the sky. Users have to allow clouds to occupy their own space and observe them as they pass by (Wells, 2005).

- *Card-tossing (CARD)*: i.e. a task in which users have to write their thoughts on cards, pick up the cards one a time, look at each one and then toss it into a wastepaper basket (Hayes, Jacobson, Follette, & Dougher, 1994).

As in the original AEON study (Chittaro & Vianello, 2014), the inclusion of the CLOUD and CARD techniques is justified by the fact that they are well-known traditional approaches for practicing distancing from thoughts. In particular, CLOUD resembles the original mindfulness practices and consists of a mental exercise. CARD offers instead thought externalization and can provide users with a non-digital tangible and embodied interaction.

Unlike those two techniques, AEON can be considered as a modern approach for practicing distancing from thoughts, which exploits capabilities of smartphones to offer thought externalization and interaction with a simulated natural element. Compared to the two traditional techniques, it was found to be more effective, simple, and pleasant to use for naive meditators (Chittaro & Vianello, 2014).

TANGAEON aims at drawing upon the advantages of AEON and extends the tangible and embodied interaction with a real natural element.

Overall, all the four techniques included in the study provide participants with a diverse range of methods for practicing distancing from thoughts.

In this new study as in the original one, the different techniques are compared in a controlled laboratory setting, and we include the same measures for the level of decentering, perceived level of pleasantness, and difficulty. In addition, given the sensory stimuli introduced by TANGAEON, we consider the level of arousal elicited by each technique as an important outcome to assess.

According to Keng et al. (2011), a lab environment permits to have greater control over independent variables and can lead to stronger conclusions about causal effects, since it allows to

more easily isolate mindfulness practice from other elements typically present in clinical intervention programs – see e.g. (Keng et al., 2011) for a list of mindfulness studies carried out in the lab. Recently, such settings have also been employed by other HCI researchers to evaluate their proposed TEI approaches to support mindfulness, e.g. (Gromala et al., 2015; Kosunen et al., 2016). We chose a within-subject design to compare the four techniques (CLOUD, CARD, AEON, TANGAEON) based on these two main considerations: (i) it follows the same design we adopted for the original AEON study, and thus allows one to better compare and discuss the obtained results, and (ii) it ensures that such results will be less influenced by the variance in participants' predispositions, e.g. their personality, mental or physical status, which will be approximately the same across the study conditions (MacKenzie, 2012). In our specific case, such predispositions can include participant's familiarity with meditation techniques or technology use. On the other hand, a between-subject design might point out differences across the four techniques that are instead due to the inherent variability of the participants belonging to the different groups (MacKenzie, 2012). However, also a within-subject design might present limitations, such as the possibility that the skills learned by participants while practicing with one test condition can be applied to the subsequent ones, thus improving their performance (*learning effect*) (MacKenzie, 2012), or that the effect of performing a task on participants' physiological or psychological states can persist when performing the other tasks included in the study – problems that do not apply to a between-subject design since participants in each group will be exposed only to one condition.
We describe the actions we took to prevent the above-described and other possible issues of a within-subjects design in the Procedure section (Section 4.4).

As we already outlined in Section 3.1, the tangible and embodied experience offered by TANGAEON might better support naive meditators in the practice of mindfulness than AEON (and the two traditional techniques). However, it could present some aspects that might hinder the

practice of mindfulness by naive meditators, instead of helping them. Moreover, no study so far has thoroughly investigated the effectiveness of a TEI interactive practice based on a real natural element. In view of the above considerations, the study of the effects of TANGAEON on naive meditators was exploratory in nature.

4.1. Participants

Participants were recruited through direct contact among (i) university students, researchers, professors, and staff of a university department, and (ii) people from other occupations or schools, outside the academic context. They were asked if they were willing to participate in a study of four different techniques aimed at distancing from worries. To identify naive meditators, we followed the criteria by Lau et al. (2006), who considered as naive meditators those participants having no experience at all or less than eight weeks of experience of daily practice with mindfulness or any form of meditation (including yoga, tai chi, and qi-gong). Thus, we asked participants if: (i) they had ever attended a course on or were practicing any form of meditation, e.g. mindfulness, yoga, tai-chi, qi-gong; (ii) they had ever practiced or were practicing daily meditation techniques for at least eight consecutive weeks. Participants who answered (i) negatively both questions, or (ii) affirmatively only the first one were considered as naive meditators, and thus included in the study. In total, we recruited 35 participants, and 33 of them met the above described criteria. We then discarded one participant because TANGAEON crashed during the trial, due to water accidentally spilled on the tablet surface. Thus, the final sample consisted of 32 naive meditators (*19 M, 13 F*), whose age ranged from 19 to 50 ($M=30.31$, $SD=9.00$). Fifteen of them were attending a two-year course on web and mobile app development at a higher education regional institute, twelve of them were from the academic context (2 master students: 1 in literature and 1 in communication; 4 PhD students in computer science; 6 teaching staff of the computer science department), and five from other contexts (3 office workers, 1 bartender, 1 high-school teacher). One participant was left-

handed, and 31 of them were right-handed. On a self-report scale ranging from 1 (low familiarity) to 7 (high familiarity), participants reported to be very familiar with mobile touchscreen devices (*M=6.03, SD=1.49*).

4.2. Measures

4.2.1. Decentering

The level of decentering was assessed with the 7-item Decentering subscale of the Toronto Mindfulness Scale (TMS) (Lau et al., 2006). The subscale emphasizes awareness of one's experience with some distance and disidentification rather than being carried away by one's thoughts and feelings. Items are rated on a 5-point Likert scale from 0 ("not at all") to 4 ("very much"). Scores on the subscale are summed and the total score ranges from 0 to 28. The subscale was translated into Italian and its internal reliability was measured with Cronbach's alpha, α=.76 (CLOUD), α=.66 (CARD), α=.70 (AEON), α=.73 (TANGAEON).

4.2.2. Pleasantness

The degree of pleasantness of each technique was measured with the Pleasure dimension of the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994), which consists of 5 graphic depictions that range from a smiling, happy figure to a frowning, unhappy figure. Pleasantness is rated on a 9-levels Likert scale, formed by the 5 pictures and the 4 spaces between them, where the happy figure corresponds to 9 and the unhappy figure to 1.

4.2.3. Arousal

The level of arousal elicited by each technique was assessed by the Arousal dimension of the SAM, which consists of 5 graphic depictions that range from an excited, wide-eyed figure to a relaxed,

sleepy figure. Arousal is rated on a 9-levels Likert scale, formed by the 5 pictures and the 4 spaces between them, where the excited figure corresponds to 9 and the relaxed figure to 1.

4.2.4. Difficulty

The level of difficulty of each technique was assessed by three questions ("I found it difficult to practice this technique," "I found it hard to practice this technique," "I found it complicated to practice this technique."), which are rated on a 7-point Likert scale from 1 ("strongly disagree") to 7 ("strongly agree"). To obtain a composite measure, the sum of the three items was averaged for a single mean score, α=.86 (CLOUD), α=.80 (CARD), α=.79 (AEON), α=.79 (TANGAEON).

4.2.5. Preference

Preference was assessed by a question that asked participants to list the four techniques in order of preference, with no ties allowed.

4.3. Materials and apparatus

To allow participants to practice the CARD technique, decks of 11x15 cm cards were prepared. Each deck consisted of three numbered white cards interleaved by two card-shaped sheets of carbon paper. Each participant received a deck in which the cards were numbered with a "1", a deck numbered with a "2" and a deck numbered with a "3". Usage of these materials is described in Section 4.4.

Both AEON and TANGAEON were run on a Samsung Galaxy Note 8.0 tablet equipped with a 8.0'', 1280×800 pixels screen. During usage, the device was in portrait mode, placed on a 74 cm-high table, 10 cm far from the bottom border of the table, and 65 cm far from the left border. The device was placed over a mat to avoid sliding. For TANGAEON, a glass container filled with water

was placed over the tablet to provide the water-based interface. The dimensions of the container were 20x15x7 cm, and the water level was 5 cm.

4.4. Procedure

The study was based on a within-subjects design with the distancing from thoughts technique (CLOUD, CARD, AEON, and TANGAEON) as independent variable. The order of presentation of the experimental conditions was counterbalanced to prevent learning effects.

Participants were individually taken to a quiet room, and briefed about the nature of the study. Then, they were asked to think of three worries they had been having in that period of their life, without disclosing them.

Afterwards, participants were provided with three deck of cards and asked to write the first worry on the upper card of deck numbered “1”, the second worry on the upper card of deck numbered “2”, and the third worry on the upper card of deck numbered “3” (the experimenter remained seated in a distant position from which it was impossible to read the worries written on the cards). Thanks to the carbon paper in the decks, this produced three written cards for each worry. Participants were then asked to remove the clips on each deck and organize the cards in three new decks, each one made by three cards with the first worry on top followed by the second and the third worry beneath. All the written worries in each deck were faced downward and the three identical decks were placed on the table separately. Participants were also informed that they could take away all the cards with them at the end of the experiment.

After the preparation of the decks, the experimenter showed participants the AEON and TANGAEON apps, and explained them how to enter and delete worries in them. Participants were then asked to enter in both apps their three worries, and to select them from the list following the same order they chose for the cards (also in this case, the experimenter were unable to see the entered worries and informed participants that at the end of the experiment they could delete the

worries from the app). All these preparation activities were carried out before the execution of the experimental tasks so that at the beginning of each condition participants had all the necessary materials ready to practice distancing from thoughts. Moreover, before each condition, the experimenter explained in detail the technique to practice and was available to clarify possible doubts. Then, to lower participants' level of arousal and help them focus on the experiment, a video with relaxing images and music was shown in a dim light. Participants could close their eyes and only listen to the music if they preferred.

After the video, participants were asked to practice the technique on the three worries for three times, by following in each repetition the same order they decided for the worries at the beginning of the experimental procedure – this was done to exclude the possibility that using different worries for each condition might affect the results, due to the diverse influence they can have on participants. To sum up, in each condition participants practiced the distancing from thoughts technique three times on each worry.

As explained in Section 3.2, since TANGAEON requires the placement of the glass container over the tablet, to free participants from the burden of removing and placing it again after the deletion of each worry and the end of each repetition, the app was set to automatically switch on the next selected worry once the current one was completely dissolved, and to automatically start the next repetition. This was also done for the AEON condition.

For TANGAEON, the experimenter assured participants that the water basin had been emptied and filled again with fresh water before the current experiment session. The experimenter also checked that the temperature of the water was around 33° to exclude confounding effects of possible changes in water temperature on pleasantness results. Indeed, according to Cabanac et al. (1971; 1972), a thermal stimuli can be perceived as pleasant or unpleasant based on human internal temperature, and 33° can be considered as the neutral tepid point of thermal sensation (Hardy, 1952, cited in Cabanac et al., 1972). For the CLOUD condition, since the experimenter had no way of

observing if participants possibly skipped a repetition of the three worries, they were asked to say the number of each completed repetition at the end of it. To avoid introducing a confounding factor in the experiment, they were asked to do the same also in the other three conditions.

Finally, for the CARD condition, in each repetition, participants used one of the deck of cards they had previously organized, picked up one card at a time from it, looked at the worry on the card and then tossed it into a wastepaper basket.

Each session started when the participants said ”Ready”, and finished when they said the number of the last repetition. At the end of each session, participants were asked to fill out the questionnaires for measuring (i) decentering, (ii) pleasantness, (iii) arousal, and (iv) difficulty. At the end of the last condition, participants were also asked to list in order of preference the four techniques.

Finally, participants were briefly interviewed to get comments on the techniques. More specifically, they were asked to freely express any difficulty or impression concerning each technique. After thanking participants for their participation, to reassure them that the worries they wrote remained private, they were invited to take with them the cards they had previously tossed in the basket, and to delete their worries from the applications. Overall, carrying out the procedure took between 40 minutes to one hour and a half, because each participant could try the four techniques at his/her own pace.

5. Results

5.1. Decentering

Figure 5 shows the mean level of decentering for the four conditions. The data was subjected to a Kolmogorov-Smirnov normality test, which showed no significant deviation from the normal distribution. The data was analyzed with a one-way ANOVA with Huynh-Feldt correction, which revealed a significant effect ($F(2.67, 82.78)=4.13$, $p<.05$, $\eta_G^2=.06$). The effect was then investigated with three *t-test* comparisons with Holm correction, which contrasted TANGAEON

with the other three techniques. The post-hoc analysis revealed a significant difference ($p<.05$) between TANGAEON ($M=17.13$, $SD=4.46$) and CLOUD ($M=14.56$, $SD=5.10$), and a significant difference ($p<.01$) between TANGAEON and CARD ($M=14.34$, $SD=4.44$), with participants achieving a higher level of decentering with TANGAEON than with the two traditional techniques. The average decentering for AEON (M=16.09, SD=4.37) was in between CLOUD and TANGAEON.

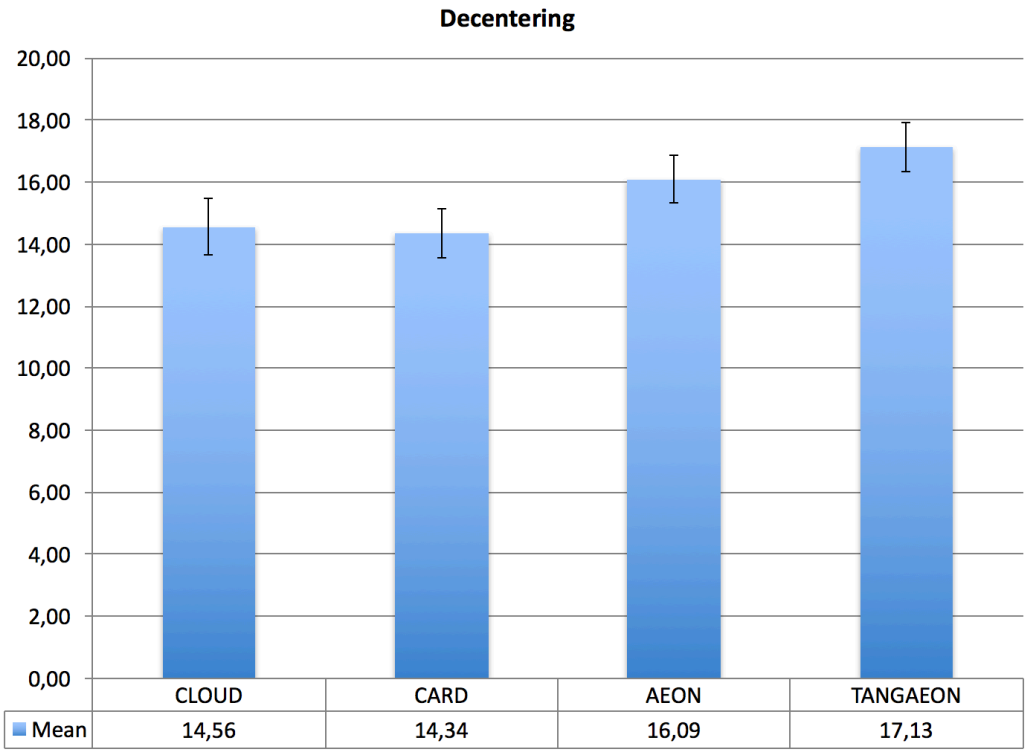


Figure 5: Mean level of decentering (capped bars indicate ±1SE) achieved by participants after practicing each technique, i.e. Cloud imagery (CLOUD), Card-tossing (CARD), the AEON and TANGAEON apps.

5.2. Pleasantess

Figure 6 shows the mean degree of pleasantness for the four conditions. The scores were analyzed with Friedman's test, which revealed a significant effect $\chi^2(3, N=32)=16.79$, $p<.001$, Kendall's W=.17. The effect was then investigated with three Wilcoxon signed-rank test comparisons with

Holm correction, which contrasted TANGAEON with the other three techniques. The analysis revealed a significant difference ($p<.05$) between TANGAEON ($M=6.69, SD=1.77$) and CLOUD ($M=5.47, SD=2.17$), and a significant difference ($p<.01$) between TANGAEON and CARD ($M=5.25, SD=2.21$), with participants perceiving TANGAEON as more pleasant to practice than those two techniques. The average pleasantness for AEON ($M=6.31, SD=2.01$) was in between CLOUD and TANGAEON.

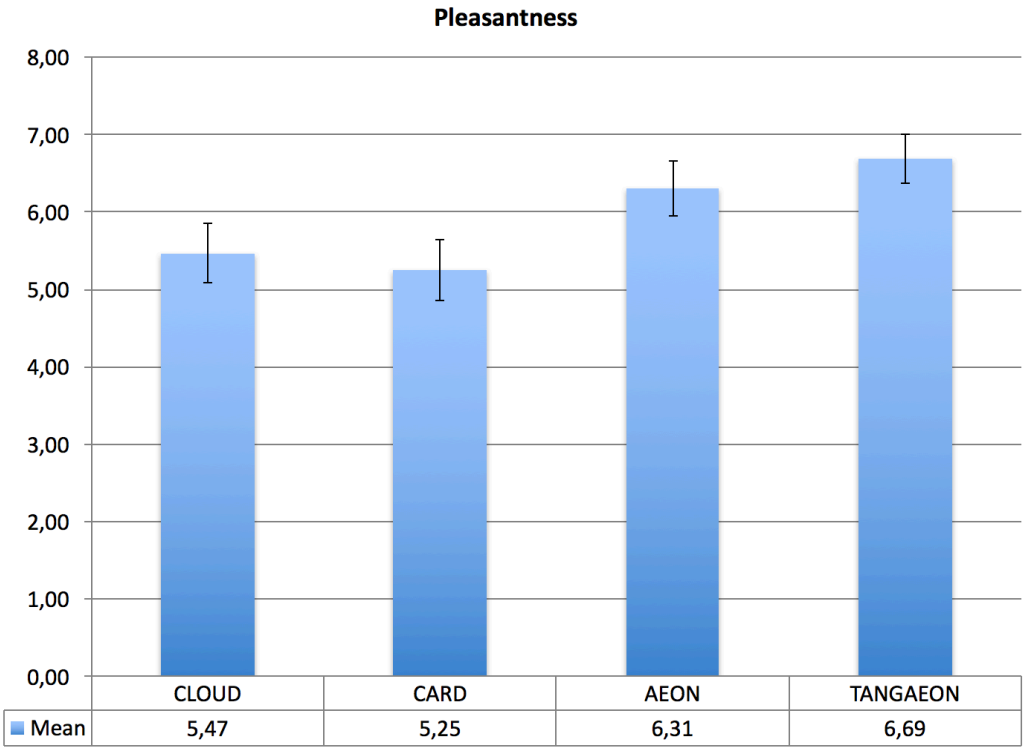


Figure 6: Mean degree of pleasantness (capped bars indicate ±1SE) perceived by participants after practicing each technique, i.e. Cloud imagery (CLOUD), Card-tossing (CARD), the AEON and TANGAEON apps.

5.3. Arousal

Figure 7 shows the mean level of arousal for the four conditions. The scores were analyzed with Friedman's test, which revealed a significant effect $\chi^2(3, N=32)=18.26$, $p<.001$, Kendall's $W=.19$. We then employed three Wilcoxon signed-rank test comparisons with Holm correction to contrast TANGAEON with the other three techniques and investigate the main effect. The post-hoc analysis

revealed a significant difference ($p<.05$) between TANGAEON ($M=3.19, SD=2.09$) and CARD ($M=4.59, SD=2.15$): participants' level of arousal was higher while practicing CARD than while practicing TANGAEON. The average level of arousal for CLOUD ($M=3.84, SD=2.03$) was in between CARD and TANGAEON, while the average level of arousal for AEON ($M=2.84, SD=1.94$) was the lowest.

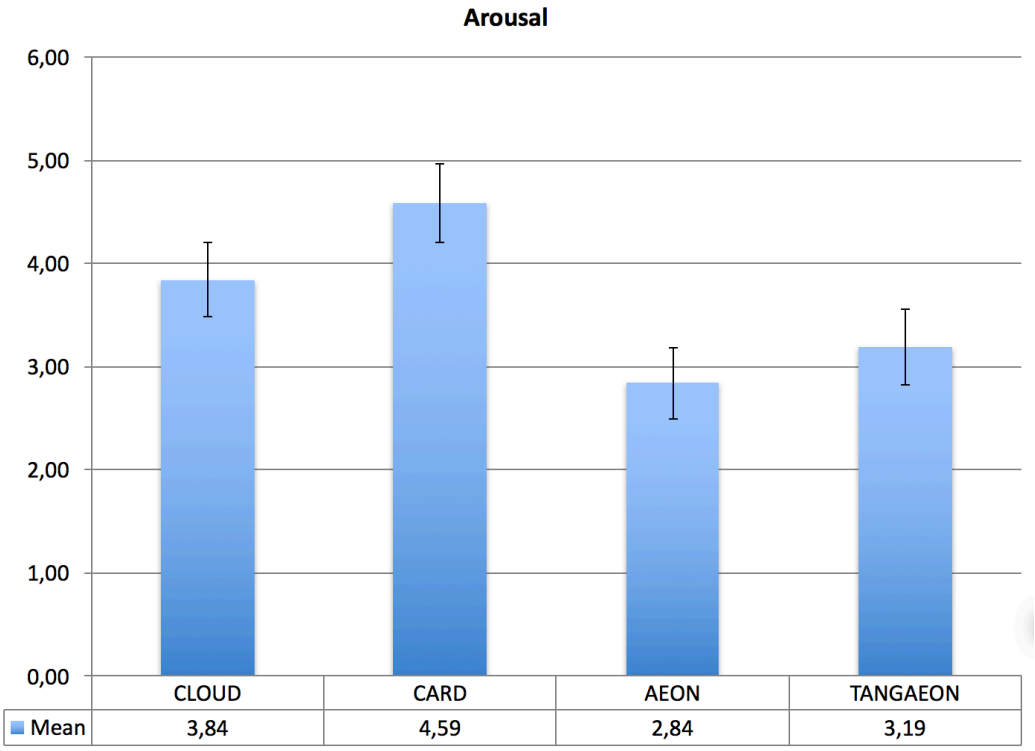


Figure 7: Mean level of arousal (capped bars indicate ±1SE) elicited in participants by the four techniques, i.e. Cloud imagery (CLOUD), Card-tossing (CARD), the AEON and TANGAEON apps.

5.4. Difficulty

Figure 8 shows the mean level of difficulty for the four conditions. The data was subjected to a Kolmogorov-Smirnov test of normality, which revealed a significant deviation from the normal distribution. Thus, we employed Friedman's test to analyze the scores, which outlined a significant effect $\chi^2(3, N=32)=26.50$, $p<.001$, Kendall's $W=.28$. The effect was then investigated with three Wilcoxon signed-rank test comparisons with Holm correction, which contrasted TANGAEON with

the other three techniques. The analysis revealed a significant difference ($p<.001$) between TANGAEON ($M=1.90, SD=1.07$) and CLOUD ($M=3.68, SD=1.80$), and a significant difference ($p<.05$) between TANGAEON and CARD ($M=2.54, SD=1.39$), with participants perceiving TANGAEON as less difficult to practice than CLOUD and CARD. The average level of difficulty for AEON ($M=1.83, SD=0.98$) was the lowest.

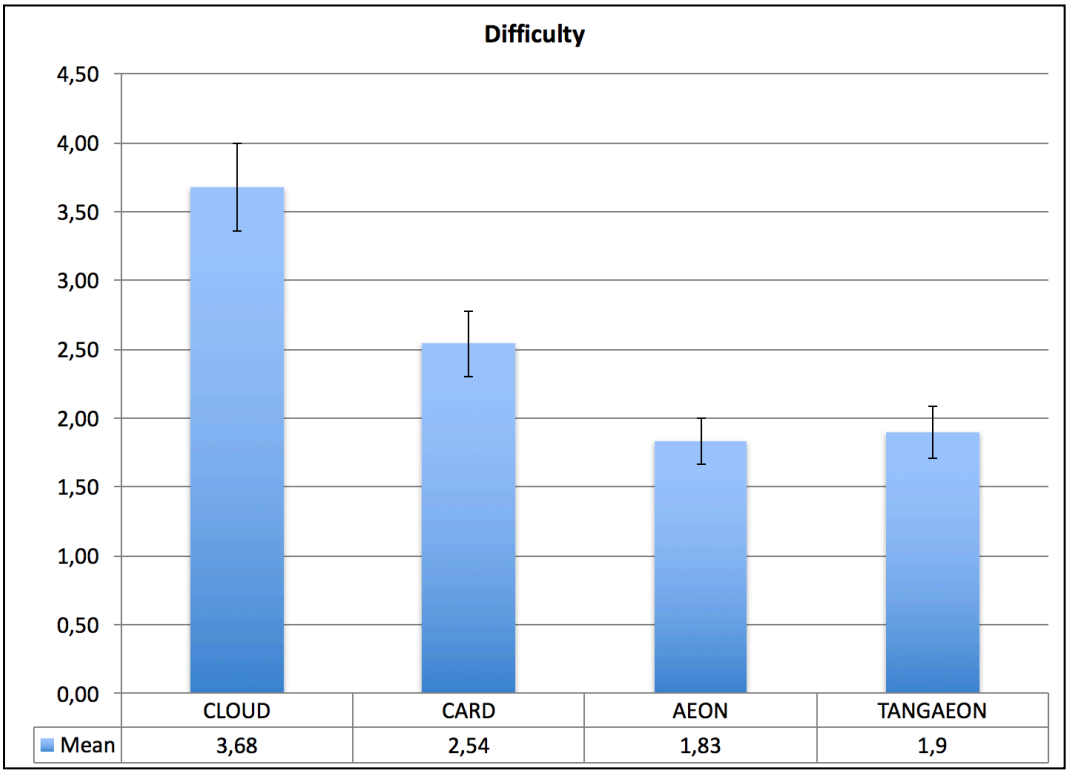


Figure 8: Mean level of difficulty (capped bars indicate ±1SE) perceived by participants after practicing each technique, i.e. Cloud imagery (CLOUD), Card-tossing (CARD), the AEON and TANGAEON apps.

5.5. Preference

Prior to the analysis, the techniques in each participant's order of preference were scored as following: 4 points for the most preferred one, 3 for the second, 2 for the third, and 1 for the last one.

Figure 9 shows the mean preference score for the four conditions. The scores were analyzed with Friedman's test, which revealed a significant effect $\chi^2(3, N=32)=15.19$, $p<.01$, Kendall's $W=.16$. We then employed three Wilcoxon signed-rank test comparisons with Holm correction to contrast TANGAEON with the other three techniques and investigate the main effect. The post-hoc analysis revealed a significant difference ($p<.01$) between TANGAEON ($M=3.16, SD=0.99$) and CLOUD ($M=2.09, SD=1.12$), and a significant difference ($p<.01$) between TANGAEON and CARD ($M=2.09, SD=1.09$): TANGAEON received higher ratings from participants than CLOUD and CARD. The average rating for AEON ($M=2.69, SD=0.97$) was in between CARD (and CLOUD) and TANGAEON.

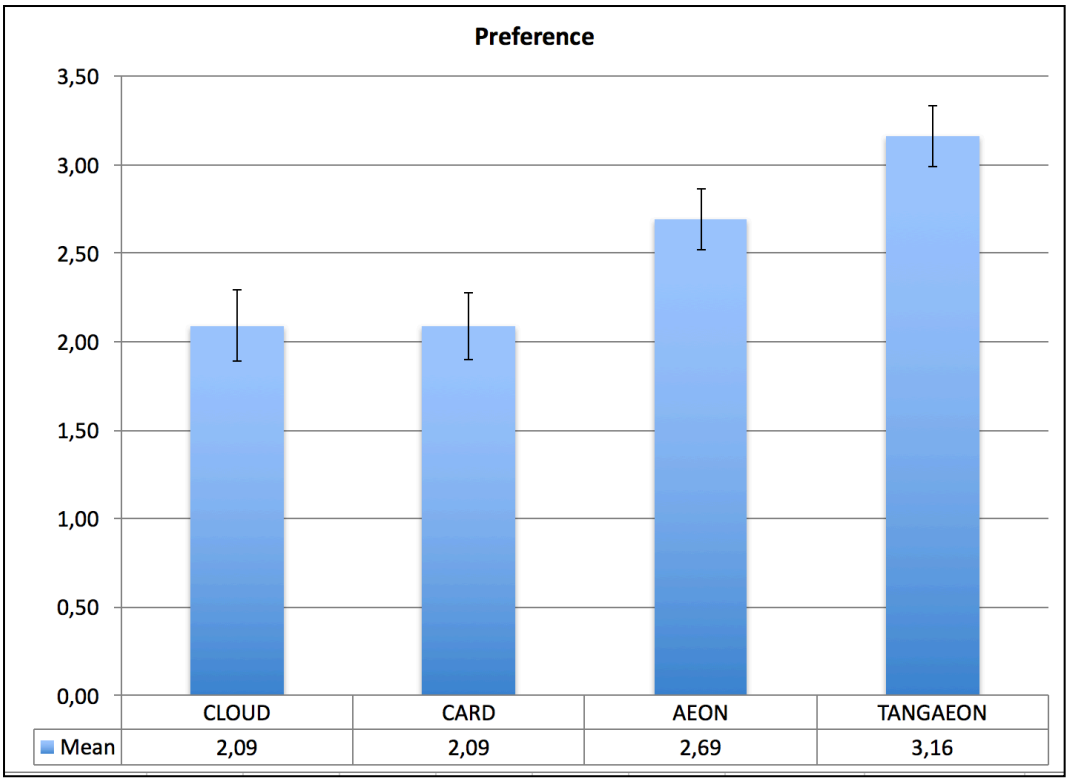


Figure 9: Mean level of preference's score (capped bars indicate ±1SE) expressed by participants after practicing each technique, i.e. Cloud imagery (CLOUD), Card-tossing (CARD), the AEON and TANGAEON apps.

6. Discussion

6.1. Decentering

The analysis revealed that participants achieved the highest level of decentering while practicing distancing from thoughts with TANGAEON, and the post-hoc contrasts outlined that it was significantly more effective than CLOUD and CARD. Moreover, although the difference between AEON and TANGAEON did not reach statistical significance, participants' level of decentering with TANGAEON is encouraging.

Overall, this result indicates that the inclusion of the water-based interface into AEON did not distract participants from the focus required to practice mindfulness, a possible risk we described in Section 3.1. On the contrary, TANGAEON further highlights the effects of an interactive practice over traditional mindfulness techniques. In addition to the level of support that the AEON app can provide users with, i.e. an external visualization of their thoughts and of the disappearing process (Chittaro & Vianello, 2014, 2016a, 2016b), another factor that could explain TANGAEON promising result is the real natural element of its interface. Indeed, as in the case of EUIs (Döring et al., 2013b), this could have brought its natural meaning as well as its related aesthetic experience into user interaction. In our case, as we hypothesized in Section 3.1, the real water waves could have evoked in participants the feeling that the waves are impermanent as their inner thoughts, in addition to engage and capture more users' attention with their ripples, their resulting effects on the written thought, and the stimuli they provided on participants' hands.

Evidence on such positive effects of the real natural element emerges also from participants' observation and comments. Indeed, six participants seemed particularly engaged in the practice, e.g. by dipping (both) hands at different depths, touching the bottom of the container, and/or moving them everywhere inside the glass container. Moreover, two other participants explicitly mentioned that TANGAEON helped them concentrate, for example:

I'm not used to practicing any meditation or relaxation technique, and I've never been interested in doing that. Using this app [TANGAEON] gave me the possibility to stop and concentrate. It's something very relaxing, the water is a perfect medium. I felt like a child again, when I spent many hours staring at the goldfish bubbles and getting lost in that observation. It was really nice.

Overall, the above considerations could hint at why in this new study TANGAEON resulted to be more effective than both traditional techniques – it must be noted that in the original AEON study (Chittaro & Vianello, 2014), only the difference between AEON and CARD reached significance – and why our conjecture about possible drawbacks of TANGEON vs. AEON did not materialize in actual use.

6.2. Difficulty

Participants perceived TANGAEON to be significantly less difficult to practice than CLOUD and CARD. As in the original AEON study (Chittaro & Vianello, 2014), the better performance of TANGAEON with respect to CLOUD could be explained by the higher level of support that TANGAEON's external representations offer users with respect to traditional techniques – *computational off-loading*, see (Rogers, 2004; Scaife & Rogers, 1996). Indeed, TANGAEON allows users to see and interact with their thoughts, while CLOUD requires them to carry out the entire distancing from thoughts exercise mentally. As it emerged from participants' feedback, this factor could have helped them better concentrate on their thoughts, and thus perceive TANGAEON as less difficult to practice. On the contrary, CLOUD could have required participants a higher effort to mentally visualize their thoughts. This could be reflected in some participants' observations, since two of them closed their eyes while practicing with it (one subsequently moved also his hands as a mean to drive away his thoughts), and another participant explicitly remarked:

"*[TANGAEON] was very nice. I failed to execute the technique with the clouds [CLOUD] very well, because I found it extremely difficult to imagine something impalpable as the clouds and [imagining] that my thought was inside them. Instead, the use of this app [TANGAEON] was much simpler, and helped me overcome such mental block. The thought was physically there, I could see it, and I even had the ability to touch it."*

The difference between TANGAEON and CARD is new with respect to the original AEON study (Chittaro & Vianello, 2014), which did not find a statistically significant difference between AEON and CARD. This is an interesting result, because both TANGAEON and CARD offer participants a tangible experience, while AEON provides only a touchscreen-based interaction. A possible factor that explains the higher level of support provided by TANGAEON could be the material of its interface, which could have offered users a more *intuitive interaction*. According to Hurtienne and Israel (2007), a technical system is intuitively usable if "the users' unconscious application of pre-existing knowledge leads to effective interaction". In our case, participants could have found more natural and engaging (as highlighted in the previous Section) to dip and move their hands into the water than picking up the written cards and throwing them away – or move their finger anywhere over the touchscreen in AEON.

Furthermore, although both techniques can give users the perception of directly manipulating their worries, TANGAEON could have offered them a more *lightweight* and *direct manipulation.* As outlined in (Hornecker & Buur, 2006), lightweight manipulation refers to "a style of interaction, which gives constant feedback and allows users to proceed in small steps, express and test their ideas quickly", while the directness of manipulation refers to "the relation between the manipulation of interaction devices and the acted-upon objects as well as eventual effects". Indeed, by acting on the real water to dissolve the visualized thoughts with TANGAEON, participants could have received a continuous and more direct feedback on their actions (both visual and tactile), as

well as felt to be more in control on the thoughts' disappearing process. On the contrary, with CARD participants could not see a written thought anymore once they threw away the card, thus losing the possibility to act on it again and see the effects of their actions.

Overall, such factors could explain the better level of support provided by TANGAEON, which made participants perceive it as less difficult to practice than the two traditional techniques.

The above described considerations can also contribute to explain the fact that TANGAEON was not found to be more difficult to use than AEON, as we were concerned about (see Section 3.1).

6.3. Pleasantness

TANGAEON received the highest pleasantness ratings, and the post-hoc contrasts outlined that it was significantly more pleasant than CLOUD and CARD. In addition to the considerations outlined in the previous two sections, other factors that could explain this result are the natural element of the water-based interface and its properties. Indeed, according to Döring et al. (2013b), a natural ephemeral element could provide users with much richer textures for interaction, as well as integrate the fascinating phenomena that nature offers. This can also include the positive effects that nature and a natural element can have on people, such as stress reduction, relaxation and an overall restoration in energy and well-being (Bates & Marquit, 2011). Such considerations are in line with the observation of six participants and their comments, which refer to the interaction with the real water as pleasant, beautiful, relaxing, and peaceful. For example, one participant said:

[Practicing with TANGAEON] was really beautiful. I've never been used to concentrate on a thought, practicing any technique of this sort. The effect of the water was a bit playful and a bit mesmerizing, it gave me a feeling of relaxation and concentration.

On the contrary, as remarked by the original AEON study (Chittaro & Vianello, 2014), CARD and CLOUD could have failed in eliciting the same feelings in participants, due to their required abstract mental task (CARD), or tedious and less attractive motor activity (CARD).

Interestingly, such result is also in contrast with our concerns in Section 3.1, since no differences were found between TANGAEON and AEON. Again, this could be due to the same positive effects that a real (TANGAEON) and a simulated natural element (AEON) can have on people, as we described above.

Finally, this result and the ones described in the previous two sections, can also explain why TANGAEON did particularly well in terms of preference ratings.

6.4. Arousal

The analysis outlined that participants' level of arousal was highest with CARD, and it was significantly higher when they were practicing with such technique than when they were practicing with TANGAEON. This result could be due to the feelings that the manual activity required by CARD elicited in participants. Indeed, according to Hummels et al. (2007), the physical gestures employed to interact with an artefact can convey emotions and expression. In our specific case, the movement of taking the pieces of paper and throwing them away could have been perceived as a more aggressive (or negative) action than moving hands in the water.

Such considerations are also reflected in the observations and comments of four participants. For example, one of them said:

I found it particularly irritating to use the cards. The tearing and rolling up gestures couldn't help but make me nervous, it increased my feeling of uneasiness and worry toward the thoughts, and made me aggressive in expressing it. It was really difficult to keep myself calm while I was doing that [practicing CARD]. The water, instead, gave me a feeling of relaxation and peacefulness.

Another one of those four participants explicitly referred to the meaning of the different gestures she carried out:

When I was using the cards, I had the impression of having to find a different way of acting according to the thoughts I wanted to distance myself from. If it was something for which it is not

possible to find a solution, I chose to tear it up, if it was something that I can solve in some way, I tried to strike it out with the pen and then throw it away.

Finally, a possible explanation for the fact that the level of arousal elicited by CLOUD and AEON was not significantly different than the one elicited by TANGAEON, could be that all those three techniques require participants no (CLOUD) or a low amount (AEON) of manual activity.

7. Conclusions

The purpose of this study was to explore the effectiveness of a tangible and embodied approach to interactive mindfulness practice, created by augmenting the AEON app (Chittaro & Vianello, 2014). We replicated the original AEON study (Chittaro & Vianello, 2014) on naive meditators, adding TANGAEON as a fourth condition.

Results showed that TANGAEON was able to obtain statistically significant improvements – in terms of achieved decentering, level of difficulty, and degree of pleasantness – over the two (CLOUD, CARD) traditional mindfulness techniques in the study, and it was also the preferred approach for users. Interestingly, the benefits of the water-based interface we hypothesized for TANGAEON prevailed, and its potential drawbacks we had reasoned about did not materialize with users.

Moreover, compared with the original AEON study, TANGAEON further highlighted the effectiveness of the proposed interactive practice compared with traditional practices. Indeed, in addition to replicating the results obtained in the original AEON study, the TEI-based interactive practice obtained stronger results in terms of effectiveness and simplicity: in the original AEON study, AEON obtained a statistically significant difference only with respect to CLOUD for both measures, while in this study TANGEON was perceived as significantly more simple and effective than both CLOUD and CARD.

Overall, the obtained results suggest than an interactive practice based on tangible and embodied interaction that uses a real natural element can be a novel and effective tool to encourage naive meditators approach mindfulness. In line with the consideration on ephemeral materials outlined by Sylvester et al. (2016), our study suggests that the inclusion of a real natural element in a TEI-based interactive practice can offer users a pleasant and engaging experience, i.e. factors that can help them remain focused while practicing mindfulness and thus receive more benefits from it. Interestingly, as we described in the related work, other researchers have recently started to explore the use of such elements in their proposed TEI interactive practices (Roo et al., 2016; Zhu et al., 2017). Moreover, such consideration could also be extended to TEI system that target other contexts which require users' sustained attention, e.g. learning applications, although the choice of the natural element and mode of interaction should be carefully considered and their effectiveness investigated.

A limitation of the current study is that several participants were from the academic context, and most of them were studying computer-related topics (at university or higher education level). This could limit the generalizability of the results to other types of users. Thus, future studies should repeat the evaluation with individuals from other educational backgrounds and contexts. Future studies should also take into account the inclusion of experienced meditators, as recently done in the explorative workshop described in (Aslan et al., 2016), although this needs some considerations. Indeed, as pointed out in (Chittaro & Vianello, 2014), a technological support might be more hindrance than help for experienced meditators, who can have long ago discarded the technological support (audio CDs, tapes, and files) used in the early stage of practice. However, they can still provide useful comments on our TEI-based interactive practice based on their experience.

In our future work, we will explore the possibility of replacing the textual representation of the thought with a background image that users can upload into the TANGAEON tablet app and dissolve with their action in the interactive practice. This might provide a more familiar way for

people to express their thoughts, similar to what happens in social network platforms, e.g. Snapchat or Instagram, in which users share their experiences with static or moving images.

We are also considering to explore the use of the water-based interface for interacting also with the menu and text input screens of the TANGAEON's tablet app, e.g. by mapping the length of users' gestures to predefined menu functionalities and using voice input for allowing them to enter their thoughts (in this case, the thought representation for the interactive practice will be limited to text). For example, if the app is in the "Thoughts List" screen and the user triggers chaotic waves in the water-based interface, e.g. by performing a long diagonal movement, (s)he will be prompted to enter a new thought by saying it. The user could confirm the insertion by triggering a small circular wave, e.g. by performing a tap gesture in the water-based interface, and then could (i) switch to the "Practice" screen by triggering another circular wave, or (ii) enter another thought by triggering chaotic waves. However, the usability of all these new functionalities should be carefully evaluated.

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