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Evaluation of a mobile mindfulness app distributed through on-line stores: A 4-week study

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Abstract

Recently, interactive approaches aimed at helping people practice mindfulness have appeared in the literature. However, the few available user studies for such approaches focus only on short-term effects and are carried out in a lab or in a similar artificial setting. In this study, we aim instead at assessing the effectiveness of a mobile mindfulness app when used by people in their everyday contexts and over a prolonged period of time. People could participate in the study by downloading the app from Apple's App Store as well as Google Play and by answering a mindfulness questionnaire at three pre-set times over a 4-week period. Moreover, the app automatically collected usage data each time it was used and qualitative feedback at the end of the study. Results reveal that users with no or minimal experience with meditation significantly increased their level of mindfulness over the 4-week study period. Moreover, the qualitative feedback provided by participants indicates that the app was positively perceived as beautiful and its usage elicited positive feelings in most of them. We discuss possible factors that could have contributed to the obtained results. Finally, we analyze how many users abandoned the study and at what times, comparing such data with other studies based on app stores distribution, and giving possible reasons.

Keywords: mindfulness, mobile app, research in the large, longitudinal study, in situ study, app stores, meditation, naive meditators, experienced meditators, mindfulness training

1. Introduction

Mindfulness has been described as the awareness that arises through "paying attention to the present moment on purpose and nonjudgmentally" (Kabat-Zinn, 1990). A fundamental component of mindfulness, called *decentering*, is "the ability to observe one's thoughts and feelings as temporary, objective events in the mind, as opposed to reflections of the self that are necessarily true" (Safran and Segal, 1996) and "a state of awareness of internal events, without responding to them with sustained evaluation, attempts to control or suppress them, or respond to them behaviourally" (Wells, 2005). Decentering is considered particularly important in the literature because it can be helpful in reducing negative emotional states, such as anxiety, worry and ruminative thinking, by helping individuals realize that their thoughts are impermanent events in the mind, see e.g. (Hoge et al., 2015; Querstret and Cropley, 2013). Typically, decentering is achieved by practicing techniques that require individuals to be aware of their thoughts and to observe them while they pass by, without acting or grasping on them, and without trying to suppress them (hereinafter, we refer to this kind of practice[1] as *distancing from thoughts*).

Unfortunately, distancing from thoughts, as any other mindfulness practice can be difficult for people with no or minimal experience with meditation (in the following, *naive*[2] *meditators*) (Kabat-

[1] We use the term "practice" to refer to the act of performing meditation exercises, consistently with studies of mindfulness interventions, see e.g. (Chiesa and Malinowski, 2011; Keng et al., 2011) for reviews.

[2] While we are aware that the term "novice" is used in HCI to indicate users that are new to a task, in this paper we use the term "naive" to refer to people with no or minimal experience with

Zinn, 2005; Segal et al., 2002). This fact has captured the attention of the HCI community that has started proposing new, computer-based interactive approaches to help people practice mindfulness, e.g. (Thieme et al., 2013; Vidyarthi et al., 2012). In (Chittaro and Vianello, 2014), we proposed a smartphone app, called AEON, specifically aimed at helping people practice distancing from thoughts, and we evaluated it with a lab experiment. The study contrasted the app with two traditional techniques for distancing from thoughts that are not based on technology. AEON obtained better results in terms of achieved level of decentering, perceived level of difficulty and degree of pleasantness.

However, although the evaluation showed that AEON can help people in achieving decentering, it was carried out within a lab setting and it measured only short-term effects. These limitations are typical threats to the external validity of a study and are common to all studies of computer-based mindfulness proposed in the literature so far. A lab, or a similar artificial setting, does not reflect the many different contexts and situations in which a mindfulness application can be used by people in their everyday life. In general, although such settings allow researchers to control for unsystematic variables and thus increase the internal validity of a study, the obtained results cannot be easily generalized to other contexts, and there is a need to conduct studies that can include the real-world contexts of use (Henze and Pielot, 2013; Henze et al., 2013).

For these reasons, we carried out a 4-week study aimed at assessing the effectiveness of the AEON app when used over a prolonged period of time in the users' everyday contexts.

The paper is organized as follows: Section 2 briefly reviews recent research on computer-supported mindfulness techniques and introduces the "research in the large" approach to evaluation. Section 3

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meditation, consistently with meditation studies, see e.g. (Moore and Malinowski, 2009; Soler et al., 2014; Thompson and Waltz, 2007).

presents the method for the current study, whose findings are illustrated in Section 4 and discussed in Section 5. Finally, Section 6 draws conclusions and outlines future work.

2. Related work

2.1. Computer-supported mindfulness

Mindfulness techniques were historically associated to Eastern meditation practices that have their roots in Buddhist teachings (Gunaratana, 2002). From the 1970s, independently of any specific circumscribed philosophy or system of practices, such techniques began to be included in manualized interventions for treating a variety of psychological and physical problems in clinical and non-clinical populations (Chiesa and Malinowski, 2011; Keng et al., 2011). The first intervention of this kind was the Mindfulness-Based Stress Reduction program (MBSR) (Kabat-Zinn, 1990), i.e. a 8- to 10-week program in which a group of up to 30 participants meets weekly for 2–2.5 h sessions together with an all-day (7–8h) intensive session usually held around the sixth week. MBSR includes several exercises to help practitioners cultivate mindfulness, such as distancing from thoughts (see Introduction section) and *mindful breathing*, i.e. a practice that requires practitioners to direct their attention to the sensations of breathing and to be aware of it in each moment. When practitioners note that the mind has wandered away, they simply have to observe non-judgmentally what has happened and to bring the attention back to breathing (Baer, 2003). For a more detailed description of MBSR and other mindfulness-based interventions, see (Chittaro and Vianello, 2014).

Recently, the HCI community has started proposing computer-based approaches aimed at supporting people in mindfulness practices. In the following, we focus on the approaches that turn

mindfulness exercises into novel experiences in which the user interacts with the computer application during the practice (*interactive practices*, in the following).

The Meditation Chamber (Shaw et al., 2007) and Sonic Cradle (Vidyarthi et al., 2012) propose interactive practices for mindful breathing. They both consist of immersive installations in which users can interact via their respiration (and also via other physiological parameters in the case of the Meditation Chamber) to control visual or audio content respectively. In this way, they offer users a tangible target to focus their attention on and invite its re-direction if it has drifted away. The Meditation Chamber, which comprises also muscle relaxation techniques, was shown to be effective at promoting relaxation, see (Shaw et al., 2007), while the qualitative study described in (Vidyarthi and Riecke, 2014) revealed that by using Sonic Cradle participants experienced some subjective elements typical of mindfulness meditation, such as reduced thought and clarity of mind. Moreover, participants described their experience with Sonic Cradle as relaxing and desirable, while experienced meditators suggested it was easier to engage with Sonic Cradle compared to their prior experiences with meditation.

The Mindfulness Sphere (Thieme et al., 2013) relies on heartbeat rather than breathing perception as an object of user's attention. The system is specifically aimed at introducing mindfulness in an intervention targeting women with a dual diagnosis of Learning Disability and Borderline Personality Disorder. It consists of a 12-cm diameter sphere that can sense the heartbeat of the user who touches it and translates it into visual and tactile feedback through multicolor LEDs or soft vibrations. However, this interactive practice was not formally evaluated and thus its effectiveness in promoting mindfulness remains unknown.

Finally, Yu et al. (2012) proposed two systems to support users in practicing *walking meditation*, i.e. a mindfulness practice that focuses attention on breathing combined with walking. More specifically, the technique requires users to slowly walk by lifting the foot with heel first while breathing in, and land the foot with toes first while breathing out. The first system (Walking-Aware

System, WAS) aims at enhancing users' awareness of walking and consists of a pair of shoes equipped with three force sensors, while the second system (Breathwalk-Aware System, BAS) aims at fully supporting walking meditation by introducing also respiratory sensors. For both systems, the interactive practice is supported by a mobile app that provides walking (WAS and BAS) and breathing (BAS) guidance and feedback. Results of two studies (Yu et al., 2012) showed the effectiveness of WAS and BAS in increasing user's awareness of walking and support the practice of walking meditation, respectively.

Unfortunately, all the computer-based mindfulness approaches surveyed above require special hardware and settings that are scarcely accessible to the general public.

For this reason, we opted instead for smartphone platforms to increase the opportunities and the contexts in which users can practice, as our mobile app can run without additional equipment on common smartphones that follow users everywhere. The app, called AEON, aims at helping users practice distancing from thoughts and was first proposed in a previous paper (Chittaro and Vianello, 2014) that included a lab study. To the best of our knowledge, that study was the first to formally evaluate a mobile mindfulness app, while none of the mindfulness apps available on online stores, such as Apple's App Store or Google Play, has undergone such scientific scrutiny, as remarked in a recent review of mindfulness apps (Plaza et al., 2013).

AEON allows users to enter their thoughts into the smartphone and then visualizes them as written in ink on a parchment under water. Users can interact with the water by moving their finger anywhere on the screen. In this way, they produce dynamic waves that progressively dissolve the written thought. The water simulation aims at offering users a tangible visualization for a mindfulness exercise that does not rely on physical sensations as mindful breathing or walking meditation do. Moreover, it aims at evoking in users the sensation that each thought is impermanent.

To evaluate the effectiveness of the app in helping users achieve decentering, in (Chittaro and Vianello, 2014) we contrasted the practice of distancing from thoughts with AEON and with two traditional techniques that are not based on technology. Results revealed that AEON was able to produce a better level of decentering, measured with the Toronto Mindfulness Scale (Lau et al., 2006), as well as better ratings in level of difficulty and degree of pleasantness. Finally, it was also the approach most preferred by users.

In addition to the above described interactive practices, it must be noted that some researchers are using computers to teach mindfulness in the context of courses that follow an e-learning paradigm. In particular, some studies investigated the use of web pages, e.g. (Boggs et al., 2014; Krusche et al., 2013, 2012; Thompson et al., 2010), web-enabled smartphones, (Kristjánsdóttir et al., 2011; Ly et al., 2014; Nes et al., 2012) or smartphone apps (Ahtinen et al., 2013; Carissoli et al., 2015; Lappalainen et al., 2014; Lim et al., 2015; Morris et al., 2010; Yang et al., 2014), for presenting mindfulness-related teaching materials. However, such courses do not offer any interactive practice to users (in the following, we refer to them as *non-interactive practices*).

Only the web-based course proposed by Glück and Maercker (2011) contained a small interactive practice. The web application showed participants a blue sky with a cloud that slowly wandered out of sight when they pressed the spacebar. Participants 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 labeling the internal image with “anger”) and imagine placing it on the cloud, watching it wandering out of sight. However, participants found this interactive practice to be more difficult than the traditional non-interactive techniques that were taught in the intervention. This could be due to the fact that this interactive practice provided only a very primitive level of support, giving users the burden to carry out most of the assigned task mentally.

This brief review of the literature on computer-supported mindfulness highlights two different situations. On one side, there are a few studies that showed the efficacy of interactive practices in helping naive meditators achieve mindfulness, but they consist of evaluations carried out in a lab or in a similar artificial setting that assess only short-term effects. On the other side, there are studies conducted over a prolonged period of time in everyday settings, but they analyze traditional practices taught without computers, see (Keng et al., 2011) for examples, or using computers only to provide teaching materials at a distance, see the previous examples in this section. Learning to practice traditional mindfulness techniques can be difficult for naive meditators (Kabat-Zinn, 2005; Segal et al., 2002), which can lead them to abandon the practice soon or to not obtain benefits from it. Interactive practices can instead offer experiences aimed at making it easier and more pleasant to approach mindfulness, as our previous study has shown.

These considerations highlight a shortcoming in the current literature on computer-supported mindfulness, since no interactive practice has been evaluated in participants' natural settings over a prolonged period of time. Such kind of study would allow investigating long-term effects of interactive practices. Moreover, the obtained results would have a greater ecological validity than those of the evaluations carried out so far (Miller, 2012). If an interactive practice is based on a smartphone app, the study could be carried out by employing *research in the large*, a methodology we introduce in the following section.

2.2. Research in the large

Research in the large is a methodology that embeds a research apparatus into a mobile app (hereinafter, *research app*) and makes it publicly available on app stores, such as Apple's App Store or Google Play, to attract a possibly large number of users (Poppinga et al., 2012). Mobile apps can collect data from users as well as from devices and send it to the researchers through the Internet. In this way, researchers can gain data for statistical analysis, run studies with a heterogeneous sample

of participants and observe behavior in naturally occurring user contexts (Böhmer and Krüger, 2014; Henze and Pielot, 2013; Miller, 2012).

Although proposed only recently, research in the large has already been used for several studies – see Böhmer and Krüger (2014) for a review. In particular, this research methodology has been successfully employed for (i) proving the concept behind a research or acquiring additional insights, e.g. (Buddharaju et al., 2010; Wang, 2009; Zhai et al., 2009), or (ii) improving the design of a system following a user-centered design approach, e.g. (Karpischek et al., 2011; McMillan et al., 2010). For example, Buddharaju et al. (2010) developed an app for measuring users' calories spent due to their walking activities through the iPhone's accelerometer. By making the app publicly available, they were able to collect a large amount of data about users' body mass index and physical activities and prove the reasonability of their concept. McMillan et al. (2010) made a mobile game publicly available and, by collecting a huge amount of users' quantitative and qualitative data, they were able to redesign it. Other studies employed research in the large for investigating a general research question or a research question inherently related to smartphones and apps usage, e.g. (Böhmer and Krüger, 2014; Böhmer et al., 2011; Budde and Michahelles, 2010; Do et al., 2011; Ferreira et al., 2011; Girardello and Michahelles, 2010; Henze and Boll, 2010; Henze et al., 2011b; Sahami Shirazi et al., 2011; von Watzdorf and Michahelles, 2010). For example, Sahami Shirazi et al. (2011) investigated the feasibility of real-time opinion sharing about TV shows through an iconic mobile user interface. To this purpose, they published a mobile app during the soccer world cup 2010 and run a 4-week observational study. Results show the feasibility of their approach and reveal that the use of the app created a sense of connectedness among users worldwide. Ferreira et al. (2011) focused instead on understanding users' smartphone-charging behavior. For this purpose, they published a mobile app that runs in background and collected data for 4 weeks. Results reveal different patterns of users' battery charging behavior and allow the authors to propose methods to improve users' experience with their battery life.

Finally, in addition to the above described purposes, other studies aimed at informing the research approach and providing guidelines for other researchers, i.e. (Blunck et al., 2013; Coulton and Bamford, 2011; Cramer et al., 2010; Ferreira et al., 2012; Henze et al., 2011a; Kranz et al., 2013; Pielot et al., 2011; McMillan et al., 2013; Miluzzo et al., 2010).

In particular, these studies identified some challenges that must be taken into consideration when adopting this research methodology, such as the fact that research apps can be used in unpredictable ways or for a short period of time, or that it is difficult to obtain qualitative feedback from participants.

The possibilities offered by research in the large have been recognized and exploited also in psychology (Miller, 2012). For example, it has been successfully used to conduct a cognitive psychology experiment (Dufau et al., 2011) or a psychology listening test (Bless et al., 2013). Interestingly, Killingsworth and Gilbert (2010) employed such research methodology to collect happiness and mindfulness reports from a large number of users, while Runyan et al. (2013) used it to deliver a behavioral assessment and intervention aimed at increasing self-awareness. However, the mobile apps used in such studies were only aimed at prompting specific questions to participants and did not provide any support to mindfulness practice. To the best of our knowledge, no study so far employed research in the large to evaluate a mobile mindfulness app.

3. Study

The goal of the present study was to evaluate the effects of using the AEON app in everyday contexts for a 4-week period of time.

We employed a research in the large paradigm: participants could take part in the study by installing the app and accepting the study conditions that were shown after the first launch. To measure the level of participant's mindfulness, we included into the app a mindfulness questionnaire that assessed decentering. Participants were asked to answer the mindfulness

questionnaire three times: (i) after acceptance of the study conditions (START), (ii) two weeks after (2WEEKS), and (iii) four weeks after (4WEEKS) the acceptance of the conditions. Finally, at the end of the four weeks, the app proposed to fill out an optional qualitative questionnaire.

Since AEON was designed with naive meditators in mind, we also included a short initial questionnaire to distinguish naive meditators from people with experience with meditation (in the following, *experienced meditators*). This distinction allows us to investigate possible differences between the two categories of participants.

3.1. Hypothesis

Since our previous evaluation of AEON revealed that the app can help people achieve decentering during a short usage session, we hypothesized that the prolonged use of the app could help them cultivating such mindful state and improving it over time. In particular, we expected participants' level of decentering to grow after two and then after four weeks of app use.

The study of effects on experienced meditators was instead more exploratory in nature. Indeed, experienced meditators might already show high levels of decentering at the beginning of the study, and using the mobile app might not necessarily be beneficial to them, because, if they are already well trained in mentally practicing distancing from thoughts, a technological adjunct that introduces to the practice might be more hindrance than help.

3.2. Materials and Apparatus

The AEON app was originally developed on the iOS platform for our initial lab experiment (Chittaro and Vianello, 2014). For the current study, we ported the app to the Unity development environment (Unity Technologies, 2005) to make it multi-platform (Android and iOS). In this way, we extended the potential population of participants, as the two platforms might have different

types of users (Cramer et al., 2010), while providing an identical visual appearance and behavior of the app on the two operating systems.

The app is organized in two main screens. The initial one is the "Thoughts List" screen (Figure 1), which shows the list of thoughts previously stored by the user into the app. Since some specific thoughts can be recurrent, this function was conceived to be of help for users in working immediately with them as they arise without having to re-enter them in the app each time.

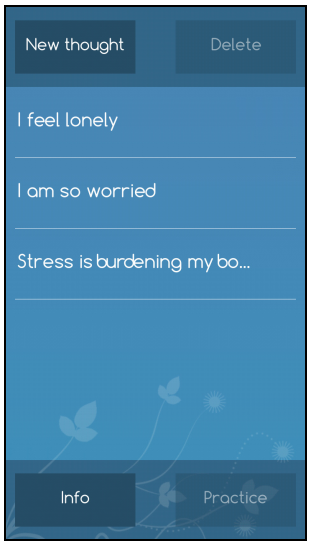


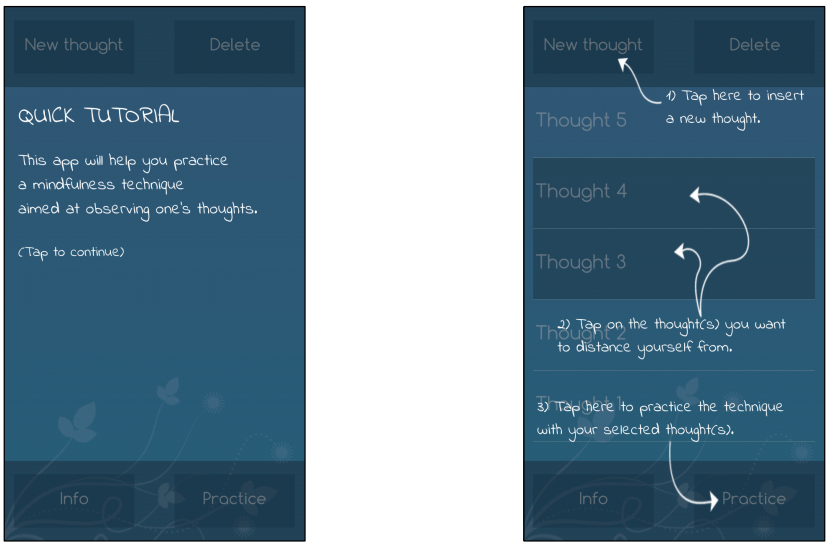
Figure 1: "Thoughts List" screen.

The two buttons at the top allow the user to enter or delete thoughts in the list. Users can enter a thought by pressing the "New Thought" button and writing a maximum of 140 characters in the text area that appears. This choice was inspired by the length that popular communication tools, such as Twitter, offer for entering single thoughts in a computer. Users can instead delete one or more thoughts from the list by first selecting them and then by pressing the "Delete" button.

The two buttons at the bottom allow the user to receive information about app usage (shown in a "Info" screen) or to launch the interactive practice. To practice distancing from thoughts, the user has first to select the thoughts (s)he wants to distance herself/himself from, by touching the

corresponding rows on the list and then tap the “Practice” button at the bottom-right of the “Thoughts List” screen.

These instructions were provided to users by a quick tutorial shown the first time they launched the app (see Figure 2a and 2b).



(a) (b)

Figure 2: Tutorial of the “Thoughts List” screen. First page (a); second page (b).

When the user presses the “Practice” button, the app switches to the “Practice” screen, which initially displays the first selected thought as written in ink on a parchment placed under water (Figure 3).

Figure 3: "Practice" screen.

In the interactive practice, users can touch any point on the screen, triggering a circular wave (Figure 4a), or move their finger anywhere over the screen, triggering more chaotic waves (Figure 4b). In this way, users can choose when and where to trigger waves and how strong the waves are, dissolving more or less ink (a quick tutorial presented these instructions the first time users entered the practice screen, see Figure 5). In particular, to dissolve a thought, users must cover with the finger a distance equal to seven times the diagonal of the screen (a single tap action counts as one seventh of the diagonal). The amount of covered distance makes the level of the opacity of the written thought decrease according to a non-linear function, which ensures that a thought does not dissolve quickly after a few users' actions, but does it slowly and gently. In this way, users can have enough time to observe each thought while it is disappearing.

(a) (b)

Figure 4: Triggering a circular wave (a) or more chaotic waves (b) in the "Practice" screen.

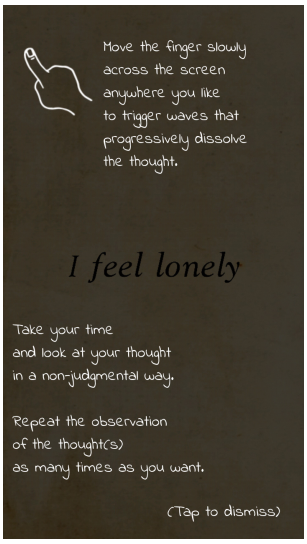


Figure 5: Quick tutorial for the "Practice" screen.

Each user can dissolve a thought at his/her own pace. Then, after the thought is completely dissolved, they can choose to move to the next selected thought by swiping with two fingers from the right to the left border of the screen. To align the interactive practice to the traditional distancing from thoughts exercises (Chittaro and Vianello, 2014), such swiping action is disabled when a thought is not completely dissolved. Indeed, distancing from thoughts requires users to fully observe the process of thought, i.e. when each thought originates, manifests and disappears. We also chose not to make the app automatically switch to the next selected thought, to avoid providing a possible disrupting experience to users.

If the dissolved thought was the last of the selected ones, the swipe action makes the app return to the "Thoughts List" screen. If the user wants to re-start the practice with the same selected thoughts, (s)he just has to tap the "Practice" button again. If the user wants to return back to the "Thoughts List" screen from the interactive practice, (s)he can do it at any moment, by swiping with two fingers from the bottom to the top border of the screen.

The instructions for the swipe actions were presented by a quick tutorial shown after users dissolved a thought for the first time (Figure 6). In particular, the above described swiping actions were chosen to avoid augmenting the interactive practice with other elements, such as buttons, to go to the next thought or back to the "Thoughts List" screen, which could distract users from the mindfulness practice.

Finally, to ensure that the interactive practice was identical for both versions of the app, we disabled the back button (available on Android devices) in the "Practice" screen.

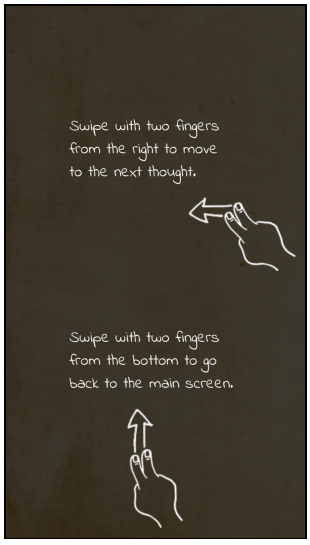


Figure 6: Swipe actions' tutorial in the "Practice" screen.

3.3. Measures

3.3.1. Demographics and usage data

A short initial questionnaire included into the app (see Figure 8) was used to collect participants' age and gender, and to identify naive meditators. To this purpose, 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. We considered as naive meditators those participants who answered (i) negatively both questions, or (ii) affirmatively only the first one. On the contrary, participants who answered affirmatively both questions were considered experienced meditators.

During the study period, AEON logged the number of practice sessions (i.e., when the users entered the "Practice" screen), the amount of time participants spent in the practice sessions, and the number of different thoughts they practiced on. In particular, to support the logging of the number of different thoughts while guaranteeing users' privacy, the app generated an anonymous alphanumeric code to identify each thought and sent to the server only that alphanumeric code (not the text of the thought). The app collected also some device characteristics, i.e. the operating system, the language that participants set in the device and the screen resolution. Finally, the app assigned a unique and anonymous alphanumeric code to each participant, generating it from the device identifier.

All data was saved on the mobile device during the study and sent to a secure server when an Internet connection was available.

At the end of the study, the data collected by the app was used to derive the values of the following variables for each participant:

- total practice time: total amount of time (in seconds) the participant spent in practice sessions;

- daily practice times: practice time during each day of the study. If a practice session spanned two days, the practice time was associated to the day in which the session started;
- distribution of practice sessions throughout the day: how the total number of practice sessions in a day is distributed (in percentage) on each of the single hours. If a practice session spanned two hours, the session was associated to the hour in which the participant started practicing;
- total days of practice: total number of days in which the participant practiced distancing from thoughts during the study period;
- total number of thoughts: total number of different thoughts on which the participant practiced distancing from thoughts during the study period.

3.3.2. Decentering

Decentering was measured with the 11-item Decentering Subscale of the Experience Questionnaire (DEQ) (Fresco et al., 2007), which was included into the app (see Figure 9). The subscale includes items such as "I am better able to accept myself as I am" or "I am not so easily carried away by my thoughts and feelings" - the full list of items is available in (Fresco et al., 2007). Items are rated on a 5-point scale ("never", "rarely", "sometimes", "often", "all the time") where "never" corresponds to 1 and "all the time" to 5. Ratings are summed to obtain an overall score that can range from 11 to 55. We measured internal reliability with Cronbach's alpha, α=.86 (START), .88 (2WEEKS), .93 (4WEEKS).

3.3.3. Qualitative feedback

The optional *qualitative questionnaire* presented at the end of the study contained six open-ended questions that asked participants about their experience with the app (see Table 1). The questionnaire was included into the app and participants could write their answers in the text area that was available below each question (see Figure 10).

N.	Question
1	What did you think while you were using the app?
2	How did you feel while you were using the app?
3	Did you notice anything new in your days or in yourself during the period of the study?
4	Did you relate to your worries or think about them differently during this period?
5	Now that you are familiar with the app, what do you think about it?
6	Is there anything that you would change or improve in the app?

Table 1: Questions of the qualitative questionnaire.

3.4. Method and Procedure

The study was based on a within subjects design with the assessment point (START, 2WEEKS and 4WEEKS) as independent variable.

We released AEON on Google Play the 21st of February 2014 and on Apple's App Store on the 11th of March, and participants with devices running at least Android 4.0.3 or iOS 7 could download it for free. On both app stores, the app was listed under the "Health & Fitness" category with the title "AEON Mindfulness app". In this way, participants could find it both by browsing the app category or by searching for apps using "mindfulness" as keyword.

English was the language used by the app menus and tutorial, but participants were able to enter their thoughts for the interactive practice in their preferred language. To encourage participants in using the app and answering the mindfulness questionnaire during the study period, we defined an incentives mechanism, following the general suggestions of previous studies that employed a research in the large paradigm, e.g. (Ferreira et al., 2012; Henze et al., 2011a; Miluzzo et al., 2010). In the following, we describe the whole experimental procedure, while the incentives are described in more detail at the end of this section. When launched for the first time, the app informed participants that by using it they would participate in a study. Purpose of the study, data collected

and anonymization measures were briefly explained. Additional information on the app and the terms and conditions of use were available to participants through two optional screens. Participants were then asked to use the app for a period of four weeks. As an incentive, the app informed participants that at the end of the study it was going to: (i) remain free to use, and (ii) unlock new "cool" features (see Figure 7).

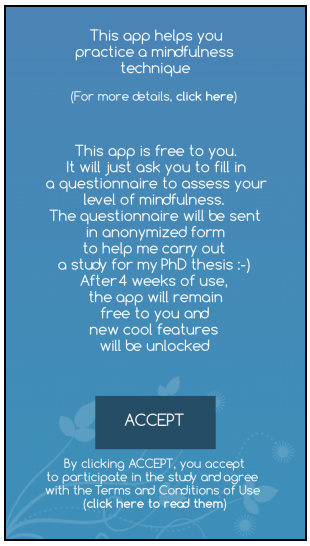
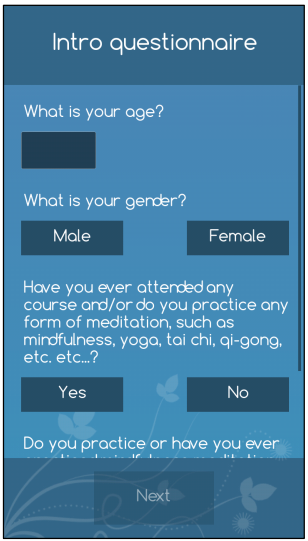
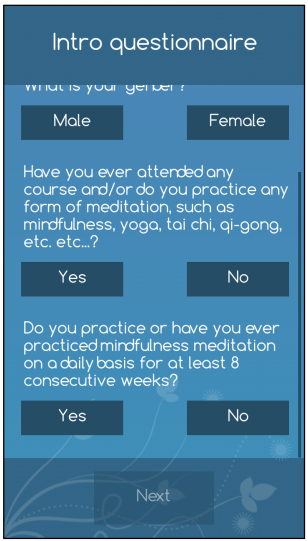


Figure 7: Screen shown by the app after its first launch.

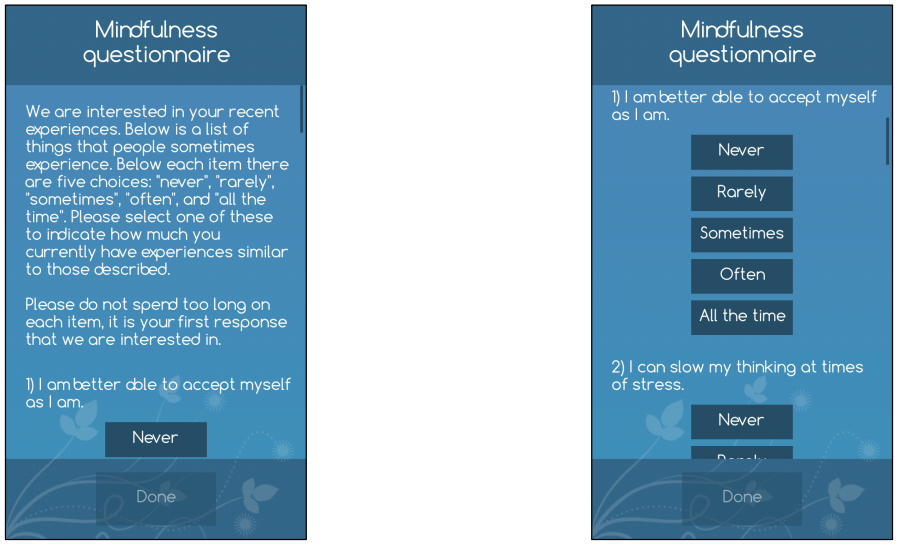
When participants gave their consent to participate in the study, the app asked them to fill (i) the initial short questionnaire depicted in Figure 8 and (ii) the mindfulness questionnaire (see Figure 9).





(a) (b)

Figure 8: Initial questionnaire: demographic questions (a); questions to identify naive and experienced meditators (b).



(a) (b)

Figure 9: Mindfulness questionnaire: instructions (a); the first two items (b).

The app exploited the notification system of the smartphone to ask participants to fill out again the mindfulness questionnaire two and four weeks after they filled it the first time. Each time, participants were told that by answering the questionnaire they were going to receive new app features at the end of the study.

After receiving the notification, participants could answer the questionnaire within three days. This was done to give participants the opportunity to answer the questionnaire at a convenient time when they were not in a rush and, at the same time, to ensure that they answered within the same limited

number of days. If they did not answer within three days, they were excluded from the study. In this case, the app stopped collecting data, remained free to use but did not unlock new features.

After completing the third mindfulness questionnaire at the end of the study, participants received a proposal from the app to fill out the optional qualitative questionnaire (see Figure 10) and were informed that an extra feature was going be unlocked if they answered also that questionnaire. To further motivate participants to answer the questionnaire, the app did not disclose what the extra feature was: they had to answer the questionnaire to discover it.

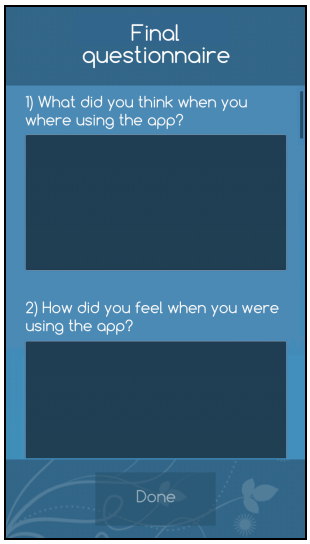


Figure 10: Qualitative questionnaire.

Finally, the app thanked participants for their participation in the study and illustrated them the new features that were unlocked, i.e. the possibility to choose among a set of different backgrounds for the "Practice" screen and the possibility to see a line graph of their three measurements of mindfulness taken during the study. Participants who answered the qualitative questionnaire unlocked also an extra feature (water sound effects during the interactive practice, that could be turned on or off).

4. Results

4.1. Demographics and usage data

Table 2 shows the number of users who completed each of the following steps with the app between the 21st of February (11th of March for the iOS version) and the 8th of October 2014: (i) download, i.e. downloading and installing of the app, (ii) accept conditions, i.e. clicking on the "Accept" button in the initial screen (Figure 7), (iii) initial questionnaire, i.e. completion of the questionnaire in Figure 8, (iv) mindfulness START, i.e. completion of the mindfulness questionnaire (Figure 9) at the beginning of the study, (v) mindfulness 2WEEKS, i.e. completion of the mindfulness questionnaire after two weeks, (vi) mindfulness 4WEEKS, i.e. completion of the mindfulness questionnaire after four weeks, and (vii) qualitative questionnaire, i.e. completion of the optional qualitative questionnaire (Figure 10). For each step, the table indicates on how many Android and iOS devices it was completed. From step (iii) on, it provides also the number of naive meditators (NM) and experienced meditators (EM). Finally, from step (iv) on, it also highlights on how many devices the interactive practice was used (Practice used) and on how many it was never used during the study (Practice never used).

Completion of step	**Total devices**	**Practice used**	**Practice never used**
(i) Download	3979 (2791 Android, 1188 iOS)[a]		
(ii) Accept conditions	2997 (2132 Android, 865 iOS)		
(iii) Initial questionnaire	2891 (2065 Android, 826 iOS; 2549 NM, 342 EM)		
(iv) Mindfulness START	2817 (2009 Android, 808 iOS; 2485 NM,	1540 (1127 Android, 413 iOS; 1374 NM,	1277 (882 Android, 395 iOS; 1111 NM, 166

	332 EM)	166 EM)	EM)
(v) Mindfulness 2WEEKS	386 (255 Android, 131 iOS; 326 NM, 60 EM)	348 (231 Android, 117 iOS; 295 NM, 53 EM)	38 (24 Android, 14 iOS; 31 NM, 7 EM)
(vi) Mindfulness 4WEEKS	147 (96 Android, 51 iOS; 128 NM, 19 EM)	136 (89 Android, 47 iOS; 120 NM, 16 EM)	11 (7 Android, 4 iOS; 8 NM, 3 EM)
(vii) Qualitative questionnaire	66 (46 Android, 20 iOS; 54 NM, 12 EM)	62 (43 Android, 19 iOS; 52 NM, 10 EM)	4 (3 Android, 1 iOS; 2 NM, 2 EM)

[a] The count of iOS devices can be lower than the actual number of devices in which the app has been installed. Indeed, from iTunes Connect we could only get the number of installs by user and not the number of devices on which the same user installed the app.

Table 2: number of participants for each step of the study.

The sample of our study was thus formed by the 136 participants who answered all three mindfulness questionnaires and practiced distancing from thoughts with the app. Based on participants' self-reported data, there were 39 male and 97 female respondent in the sample, and there were 120 naive meditators and 16 experienced meditators. Figure 11 shows the distribution of participants' self-reported age (M=37.85, SD=11.40).

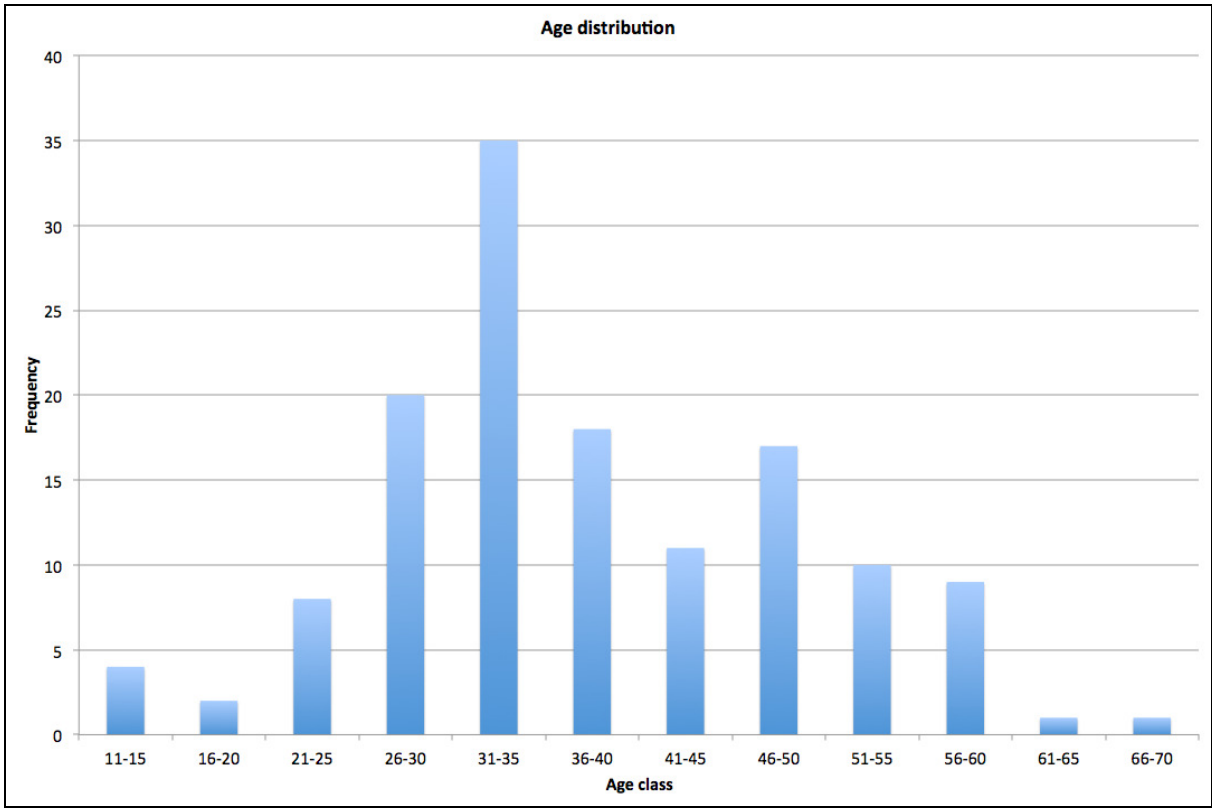


Figure 11: Distribution of participants' self-reported age.

Table 3 reports data about participants' device language. The most common language was English (69.1% of devices), followed by German (6.6%) and Swedish (5.1%).

Language	**Frequency**	**Percentage**
Arabic	1	0.7%
Chinese	1	0.7%
Czech	1	0.7%
Danish	2	1.5%
Dutch	6	4.4%
English	94	69.1%
French	2	1.5%

German	9	6.6%
Hungarian	1	0.7%
Italian	4	2.9%
Portuguese	2	1.5%
Russian	1	0.7%
Slovenian	1	0.7%
Spanish	2	1.5%
Swedish	7	5.1%
Unknown*	2	1.5%

* We collected device language with a function available in the Unity development environment (Unity Technologies, 2005). Such function can recognize 42 languages (Unity Technology, 2015).

Table 3: Participants' device languages and their frequency.

Figure 12 illustrated data about participants' device resolution. The most common resolution was 1080x1920 (19.1% of devices), followed by 720x1280 (13.2% of devices) and 480x800 (12.5% of devices).

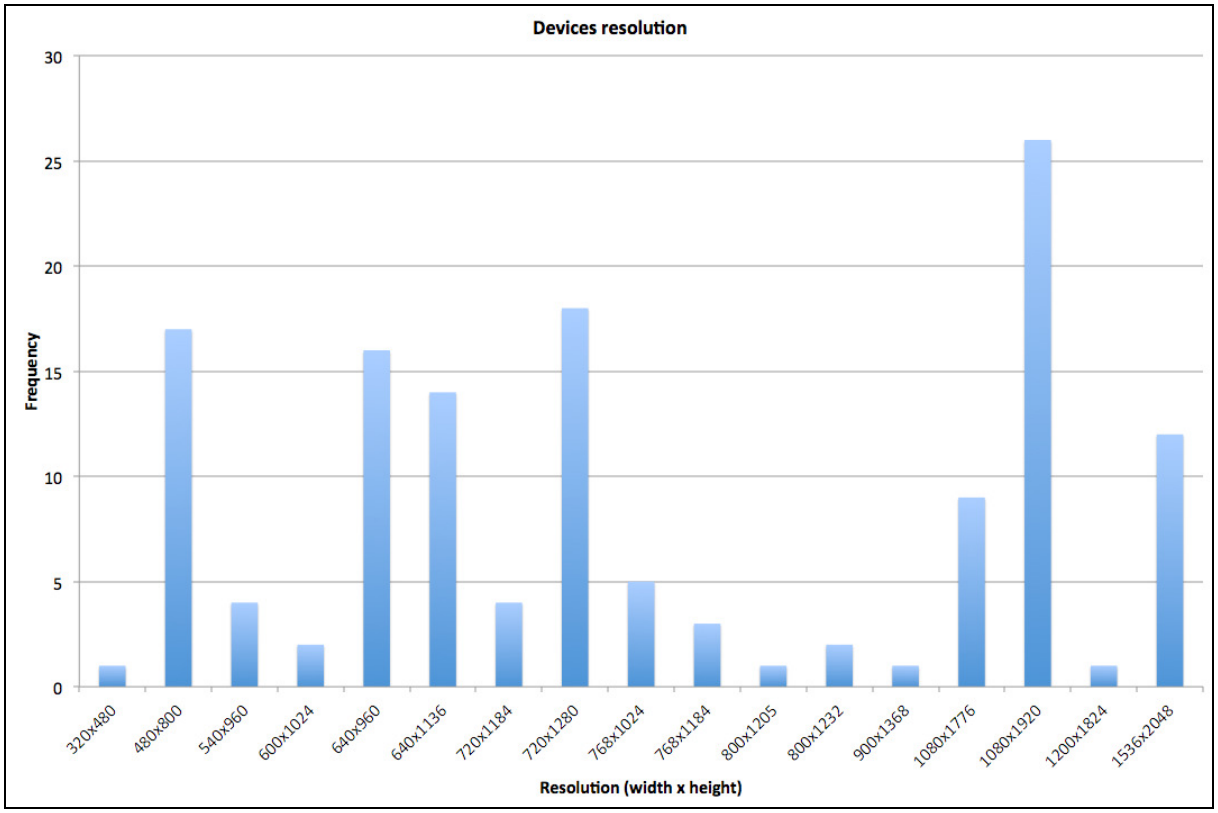


Figure 12: Participants' device resolution.

Figure 13 shows when the user practiced during the day, considering the practice sessions of all participants. The highest percentages of sessions occurred during evening hours (10.2% of sessions start during 21:00-21:59, while 10.8% start during 22:00-22:59) and 44.9% of sessions start during 18:00 to 00:59.

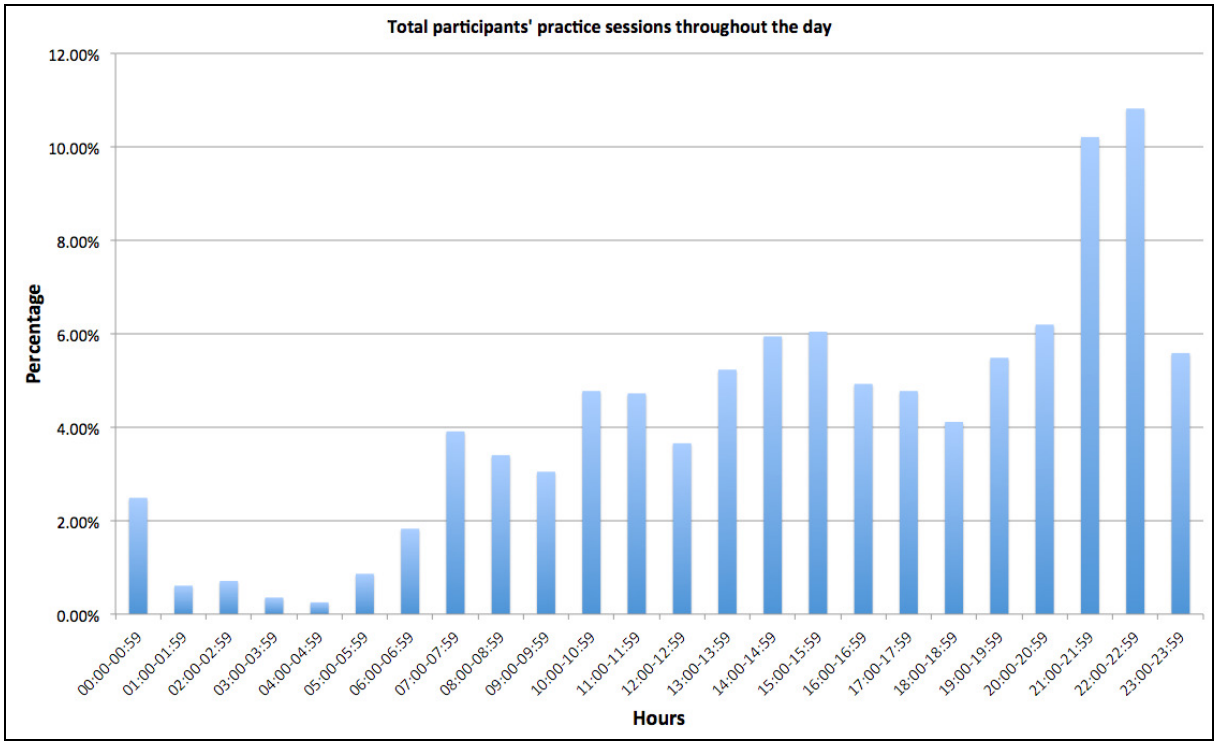


Figure 13: Percentage of practice sessions throughout the day, considering all participants.

Figure 14 shows the number of participants who practiced (*active participants*) for each day of the four weeks of the study. The number of active participants shows a quick drop after the first 4 days, displays a peak on the 15th day, and then drops again to low values until the end of the study. The mean of active participants' practice time during each day of the study ranged from 77.14 to 278.08 s (M=163.92, SD=53.68).

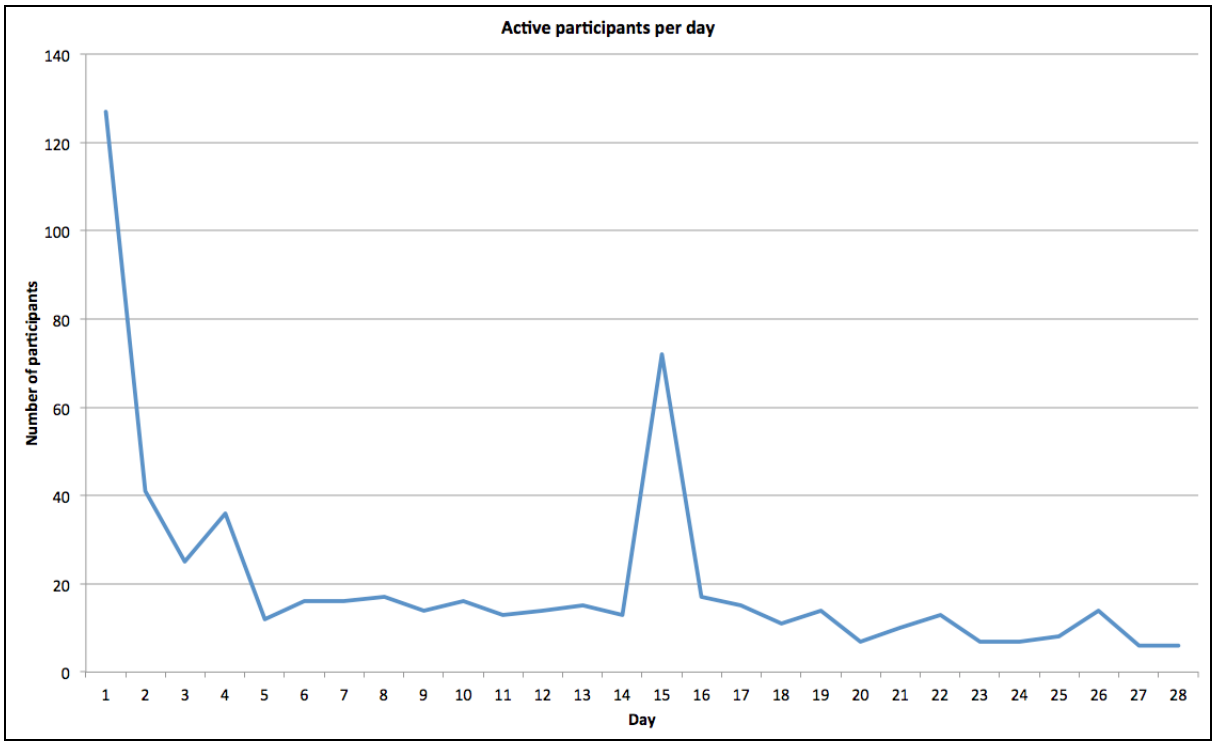


Figure 14: Active participants per day.

Figure 15 shows for how many days participants practiced with the app through a frequency distribution. Participants who used the application for most of the days are rare: the distribution reaches the highest values between 1 and 6 days of practice.

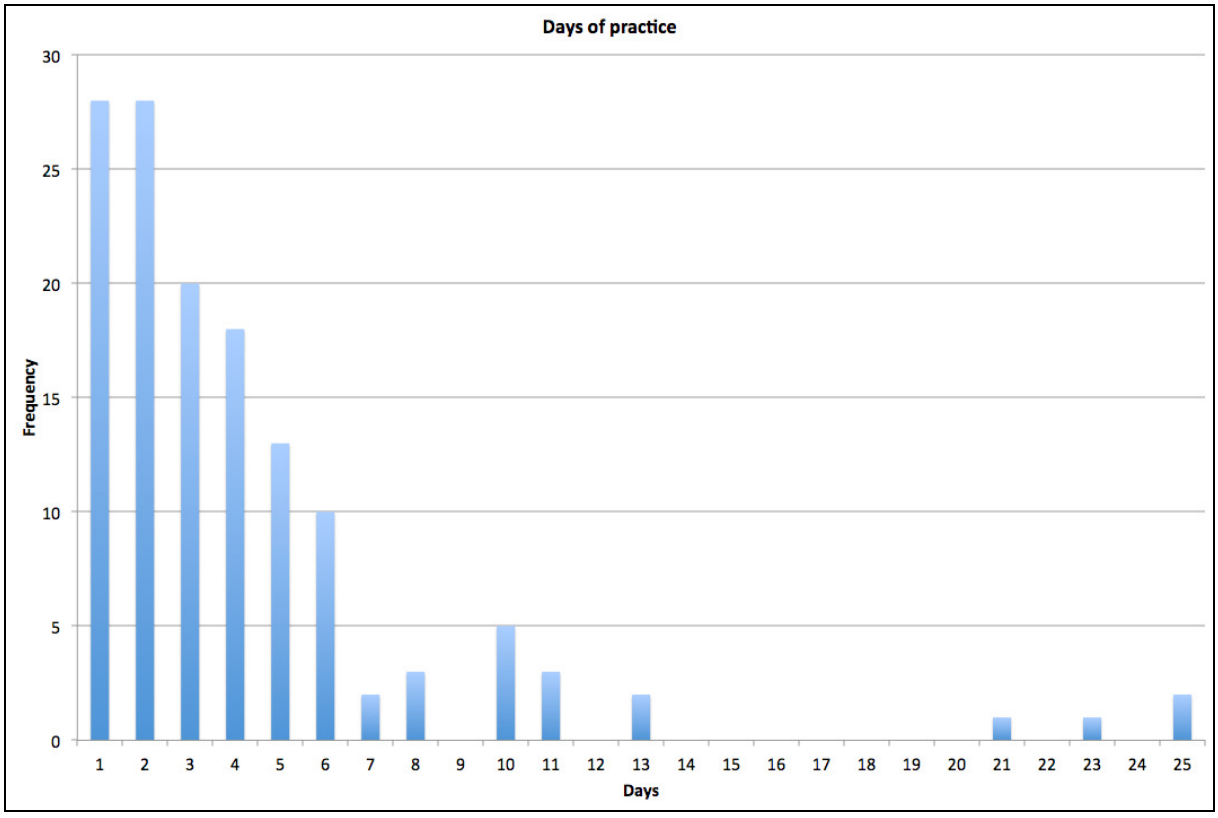


Figure 15: Frequency distribution of participants' days of practice.

Table 4 shows participants' total number of thoughts. The most frequent case is the 1-5 range.

Number of thoughts	Number of participants	Percentage
1-5	97	71.3%
6-10	21	15.4%
11-15	6	4.4%
16-20	4	2.9%
21-25	2	1.5%
26-30	2	1.5%
31-35	2	1.5%
41-45	1	0.7%
96-100	1	0.7%

Table 4: Total number of thoughts and their frequency.

4.2. Decentering

Figure 16 shows the mean level of decentering of naive and experienced meditators on the three assessment points. The scores were analyzed with a two-way mixed design ANOVA with Greenhouse-Geisser correction. The within-subject variable was assessment point (START, 2WEEKS, 4 WEEKS) and the between-subject variable was experience with meditation (naive meditator, experienced meditator). The analysis revealed a significant main effect for both experience with meditation ($F(1,134)=9.10$, $p<.01$, $\eta^2_G=.05$), with experienced meditators achieving higher levels of decentering than naive ones, and for assessment point ($F(2,268)=12.80$, $p<.001$, $\eta^2_G=.02$), and the interaction did not attain significance ($F(2, 268)=1.64$, $p=.20$). The main effect of assessment point was then investigated by carrying out *t*-test pairwise comparisons with Bonferroni correction. For naive meditators, the post-hoc analysis revealed a significant difference ($p<.001$) between START ($M=31.14$, $SD=5.98$) and 2WEEKS ($M=33.94$, $SD=6.26$), and a significant difference ($p<.001$) between START and 4WEEKS ($M=35.67$, $SD=7.23$): the level of decentering of naive meditators was higher after two as well as four weeks with respect to the beginning of the study. A significant difference ($p<.01$) was also found between 2WEEKS and 4WEEKS: the level of decentering of naive meditators was higher at the end of the study with respect to the 2WEEKS assessment. For experienced meditators, the post-hoc analysis found instead no significant differences in any pair of conditions.

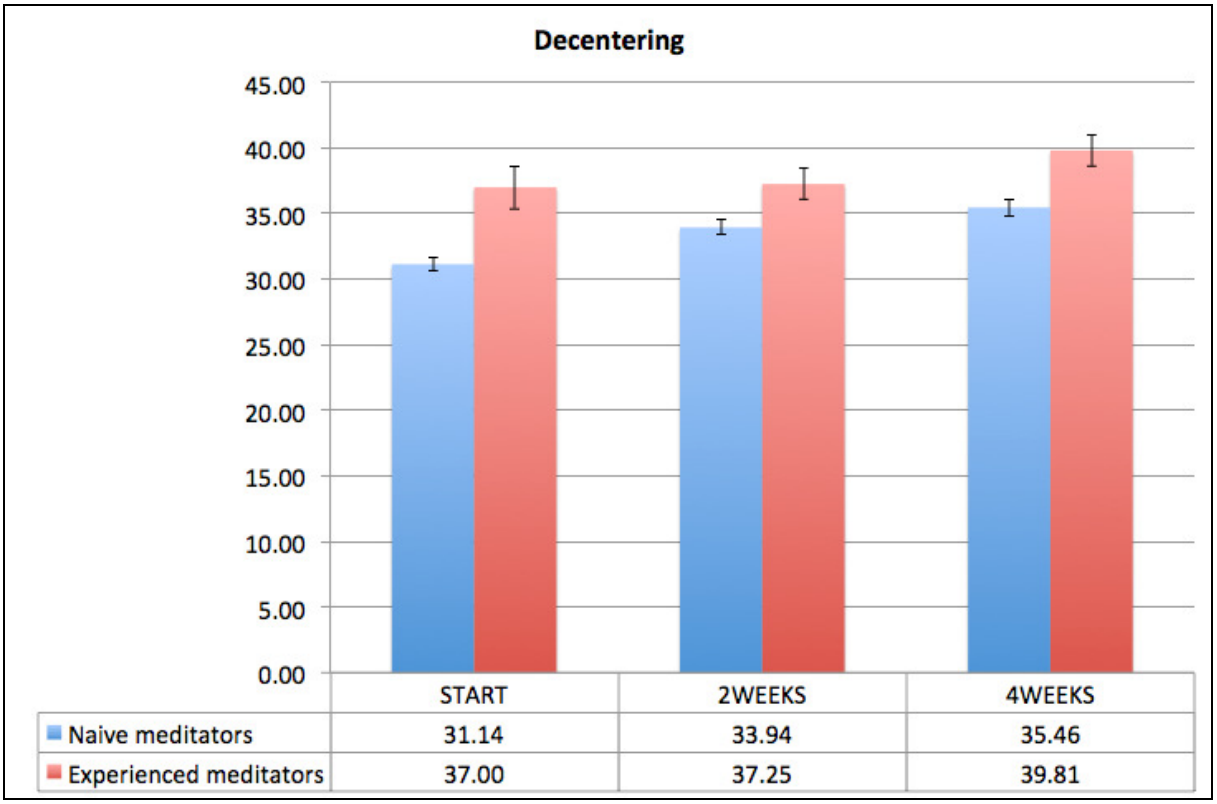


Figure 16: Mean level of decentering (capped bars indicate ±1SE).

The level of decentering increased from START to 2WEEKS for 61.8% of participants (64.2% of naive meditators, 43.8% of experienced meditators), from START to 4WEEKS for 70.6% of participants (71.7% of naive meditators, 62.5% of experienced meditators), and from 2WEEKS to 4WEEKS for 58.8% of participants (57.5% of naive meditators, 68.8% of experienced meditators).

We tested if the changes in the level of decentering correlated with days of practice, practice time and practice sessions, finding no significant correlations.

4.3. Qualitative feedback

Among the 136 participants who practiced distancing from thoughts with the app, 62 answered also the optional qualitative questionnaire. The qualitative questionnaires from three participants had to

be discarded, because two of them contained only random characters, while the third contained Swedish sentences. Considering the remaining 59 participants (50 naive meditators, 9 experienced meditators), we employed thematic analysis (Braun and Clarke, 2006) for each question to identify common themes, and group together similar answers. In the following, we summarize such categorization for each question.

4.3.1. First question

Almost half of the participants (47.5%) who answered the qualitative questionnaire indicated that, when using the app, they thought it was helpful. In particular, 28.8% of participants thought that the app was useful to distance themselves from their thoughts or worries or see them as external objects. Interestingly, one participant remarked that the app helped him realize that he was not his thoughts.

A group of participants (20.3%) highlighted that they liked the app and enjoyed using it. Another group (13.6%) mentioned instead confusion about how to use the app properly or skepticism about its usefulness.

Finally, 11.9% of the respondents said that they focused on their thoughts or worries when using the app, 6.8% said that they did not think about anything special, and one said he tried not to think at all.

4.3.2. Second question

The usage of AEON elicited positive feelings in the majority of participants (84.7%) who answered the qualitative questionnaire, with relaxation and peacefulness as the most mentioned positive feelings (49.2%), followed by a sense of well-being (23.7%).

A few respondents (5.1%) indicated that they did not experience any particular feeling when using the app, while 6.8% of participants reported also in this question that they were confused about how

to use the app or skeptical about its effectiveness. Finally, for 5.1% of respondents, using AEON to face their thoughts sometimes elicited negative feelings such as sadness.

4.3.3. Third question

The majority (76.3%) of participants who answered the qualitative questionnaire mentioned that they experienced something new during the period of the study. In particular, a group of respondents (15.3%) said that they were more mindful or aware of themselves; another group (23.7%) reported that they were better able to handle or distance themselves from their thoughts, including negative ones; and one participant said both things. Other participants referred to a sense of calmness (10.2%) or well-being (8.5%). However, 13.6% of respondents were not sure whether such new feelings were due to the use of AEON or external factors.

Finally, 23.7% of respondents said that they did not experience anything new during the period of the study. Three of these participants provided an explanation, i.e. they barely used the app.

4.3.4. Fourth question

The majority (81.4%) of participants who answered the qualitative questionnaire revealed that during the period of the study they related to their thoughts, worries or feelings differently. In particular, they stated that the app was helpful for (i) seeing their worries as more external objects (25.4%), (ii) not reacting in response to their thoughts (10.2%), and (iii) distancing from their thoughts (8.5%). For 18.6% of respondents, these different perspectives toward their thoughts, worries or feelings were experienced only slightly or only sometimes.

Finally, 16.9% of respondents did not relate to their thoughts, worries or feelings differently during the study period.

4.3.5. Fifth question

The majority (66.1%) of participants provided positive opinions about the app. In particular, 40.7% of respondents said they liked the app and 28.8% said it was useful. Other respondents (8.5%) explicitly mentioned they were going to keep using the app in the future.

The negative opinions (11.9% of respondents) mentioned instead that the app was not easy or clear to use, or that it was too simple to be useful.

4.3.6. Sixth question

Participants who answered the qualitative questionnaire provided some suggestions for improvement. The most frequent one, provided by 11.9% of respondents, is the possibility to receive more instructions about how to practice distancing from thoughts in a proper way or advice on the thoughts to enter into the app, such as a list of common thoughts that people might have. Other suggestions were to extend the app with more interactive practices to support other mindfulness exercises in addition to distancing from thoughts (given by 10.2% of respondents); to offer background music or ambient sounds (5.1% of respondents); receive reminders to use the app (6.8% of respondents) or usage statistics (5.1% of respondents).

5. Discussion

5.1. Demographics and usage data

The data collected by the app reveal that 2997 out of the 3979 users who downloaded the app accepted to take part into the study. This loss of potential participants (24.7%) could be explained by the fact that users are not accustomed to participate in a study by downloading and using research apps (Ferreira et al., 2012) and, in our case, they had no option to opt-out from the study but quitting the app after reading the "Accept" screen. The fact that these participants downloaded and run the app suggests that they were interested in trying it. However, when informed that trying the app required to participate in a study and that their questionnaire data was going to be sent to the researchers, they changed their mind. Another reason for this initial loss of participants could be

that users encountered technical difficulties when installing and/or launching the app the first time. This could have let them to uninstall the app or not use it anymore.

The percentage of users who accepted the conditions (75.3%) is in line with a previous study that employed research in the large and adopted the same mechanism to ask for user consent (Henze et al., 2011a), obtaining an acceptance rate of 81.3%. Other studies report varying percentages; acceptance was 87.6% in (Pielot et al., 2011), while it was 25.8% in (McMillan et al., 2010). The low acceptance rate of (McMillan et al., 2010) could be due to the fact that their app collected also users' location data, suggesting that the more potential participants feel researchers are able to access their personal data, the more they are likely to change their mind about trying the app.

Most users who accepted the conditions of the study answered also the initial questionnaire and the first mindfulness questionnaire. The few users from whom we did not receive such questionnaires (106 for the initial questionnaire, and 74 for the first mindfulness questionnaire) could have become concerned about disclosing such personal data or not interested in assessing their level of mindfulness, finding it tedious to complete the corresponding 11-items questionnaire.

Focusing our attention on the 2997 participants who accepted the conditions to take part in the study, there are four things interesting to note. First, 41.3% of them answered the first mindfulness questionnaire, but never used the interactive practice and did not answer the second mindfulness questionnaire. Such users could have wondered whether their entered thoughts were transmitted to the researchers (the app did not say explicitly that the entered thoughts were not sent), changed their mind soon after answering the first mindfulness questionnaire, or expected a different content from the app.

Second, only 12.9% answered the mindfulness questionnaire after two weeks, and only 4.9% also answered the same questionnaire after four weeks. Although this percentage is small, it is in line with previous research in the large conducted over a 4-weeks period (Sahami Shirazi et al., 2011), see Section 2.2, in which only 5.0% of participants answered the questionnaire at the end of the study. Evidence of the fact that research apps are used only for a short period of time, and thus

longer studies see large dropout percentages, emerges also from other studies that employed research in the large, e.g. (Ferreira et al., 2012; Henze et al., 2011a; Miluzzo et al., 2010). As suggested by Miluzzo et al. (2010), this could be due to the fact that users are not accustomed to use research apps and need to perceive they are receiving clear benefits from using them, otherwise they use such apps rarely or for a short period of time. Moreover, according to recent market research (Consumer Health Information Corporation, 2011), 26% of health apps in on-line stores are downloaded and used only once, and 74% of health app users drop out by the 10th app use.
In our specific case, those who practiced with the app but dropped out might have expected to obtain immediate benefits in their everyday life. Unfortunately, mindfulness and decentering require time and regular practice to be developed and enhanced (Kabat-Zinn, 2003, 1990).
Third, restricting attention to participants who answered the second and third mindfulness questionnaire, respectively 38 (3.1%) and 11 (0.9%) of those participants never practiced with the app. Such participants could have been willing to practice but never found the time to do it. Alternatively, they could have been caught up in the general tendency of people to escape or avoid contact with their internal experience, such as thoughts or worries (Kabat-Zinn, 2005, 1990). This could have led them to procrastinate the practice of distancing from thoughts, and once they reached the end of the study, they could have been only curious to see the new app features we promised to unlock.
Finally, only 2.2% of participants who accepted the conditions to take part in the study answered also the qualitative questionnaire. This result confirms the fact that with research in the large it could be difficult to obtain qualitative feedback from users (Ferreira et al., 2012; Henze et al., 2011a). On a positive side, most qualitative questionnaires we received from participants who practiced with the app (i.e., 59 out of 62) were carefully answered and useful to the research.
The previously cited considerations on the brief use of health and research apps are confirmed by the usage data collected in our study. Indeed, the majority of participants used the interactive practice for a total number of days that ranged from 1 to 6 (see Figure 15), and the number of active

participants per day shows a quick drop after the first 4 days (see Figure 14). The sudden peak in the number of active participants toward the 15th day of the study is likely due to the notification on the 14th day with which the app asked participants to answer the second mindfulness questionnaire, which could have attracted attention towards the app, prompting them to use it. This suggests that notifications might contribute to make the app more used by some participants, as remarked also by some respondents to the qualitative questionnaire.

The analysis of when participants' practiced during the day shows that a high number of sessions (44.9%) took place during evening hours, from 18:00 to 00:59 (see Figure 13). According to mindfulness teachers, e.g. (Gunaratana, 2002; Kabat-Zinn, 1990), a good time to meditate is during moments of relative peace and quiet, as it requires a sustained attention. Thus, although the app gave no instructions about when to use it, many participants could have naturally found that the evening was a peaceful and quiet moment for them to practice distancing from thoughts with the app. Taken together with participants' desire of having reminders to practice that emerged from the qualitative feedback, this result suggests that many users could take advantage from the possibility of setting notifications for the evening as useful reminders to practice mindfulness. This feature can also lead users to use more a mindfulness app and benefit more from it.

Finally, the data collected by the app highlights that AEON was used by participants on devices with 16 different languages (Table 3) and with 17 different screen resolutions (Figure 12). Although one cannot know for sure that the language participants set in their smartphone is their mother language, taken together these results can have enhanced the external and ecological validity of the study (Cramer et al., 2010; Henze and Pielot, 2013). Indeed, results can be more easily generalized to users from different cultural contexts and a variety of mobile devices. Moreover, instead of an artificial lab setting, the app was used in more naturalistic contexts.

Despite such considerations, a limitation of the present study is that participants could be predisposed towards technology, thus constituting a biased sample. However, this kind of users is the actual target of the AEON app, and the research in the large approach we employed in this study allowed us to evaluate the effectiveness of AEON with a larger and more heterogeneous sample of participants than our previous evaluation (Chittaro and Vianello, 2014).

5.2. Decentering

The analysis of mindfulness questionnaire data reveals that participants' level of decentering increased during the study, and that the level of decentering was higher for experienced meditators than for naive meditators.

The difference between naive and experienced meditators is quite predictable: experienced meditators are likely to have already cultivated a good level of decentering before using the app. Indeed, as outlined by Shapiro et al. (2006), if an objective shift in perspective toward the internal and external experience normally occurs in individuals' development and growth across the lifespan, a regular mindfulness practice continues and accelerates this shift, thus resulting in higher levels of decentering. Our result is also consistent with a previous study that compared individuals with different meditation experience using the same questionnaire that we employed in our evaluation, i.e. (Soler et al., 2014). In particular, according to Soler et al. (2014) such questionnaire is sensitive to frequency and lifetime practice of meditation. This suggests that the questionnaire is suitable for comparing and distinguish samples with and without meditation experience.

The analysis of decentering over time in our study showed that for naive meditators the level of decentering significantly increased after two and four weeks of app use with respect to the beginning of the study, and also between two and four weeks. Considering the whole period of study, the level of decentering of naive meditators increased by 4.32 (see Figure 16). Clinical studies that measured changes in the level of decentering during a 7- or 8-week mindfulness

intervention with the same questionnaire we employed in our evaluation, e.g. (Carmody et al., 2010; Hoge et al., 2015), revealed differences (between the beginning and the end of the study) which were larger (8.62 and 8.0, respectively) than ours. However, since in our study participants practiced for a much shorter period of time, we consider our result to be consistent.

A possible explanation of this result is the fact that AEON provides users with an external visualization of their thoughts and of their disappearing. Such visualization could have helped naive meditators develop the ability to see their thoughts as external and temporary objects rather than inherent aspects of the self or as reflections of reality. This perspective on the internal experience, also referred to as *reperceiving* or *metacognitive awareness,* is fundamental to cultivate a decentering state (Shapiro et al., 2006; Teasdale et al., 2002; Wells, 2005).

For experienced meditators, the post-hoc analysis did not reveal any statistically significant differences in level of decentering across the three assessment points. With their previous practice of mindfulness techniques, experienced meditators could have already developed the ability of distancing from thoughts. Moreover, if their previous practice was regular, they could also have developed mindfulness at the trait level (Carmody and Baer, 2008), i.e. the capacity of being mindful in their everyday life (Thompson and Waltz, 2007). As any trait-like quality, trait mindfulness tends to be stable over time (Brown et al., 2007).

However, it is interesting to note that the trend in the level of decentering over time shown in Figure 16 is positive also for experienced meditators. Therefore, the pessimistic scenario of a detrimental effect on experienced meditators that we had considered as a possibility in Section 3 did not occur.

Overall, these results suggest that the use of AEON can help naive meditators increase their level of decentering and that it might be useful also for experienced ones. Evidence on the effectiveness of the app emerges also from the answers provided by respondents to the qualitative questionnaire. Indeed, some participants commented that when using the app they focused on their thoughts or

worries. This suggests that the use of the app can help people focus on their internal experience, which is the first step to achieve decentering (Shapiro et al., 2006).

Moreover, the qualitative feedback reveals also that most participants related to their thoughts differently by using AEON. In particular, some of them explicitly remarked that the app helped them distance themselves from their thoughts or feelings, including the negative ones. Some participants highlighted also that the app was useful to see their worries as external objects, while others said that AEON helped them not to react in response to their thoughts. For some participants, the app was also useful to be more mindful or aware of their thoughts or in general. Overall, these considerations suggest that the app helped users achieve a detached stance toward their thoughts and feelings, which includes an increased awareness of them and the ability to let them go instead of reacting or grasping on them. Interestingly, this stance is a desired outcome of decentering (Fresco et al., 2007; Safran and Segal, 1996; Wells, 2005). Thus, participants' qualitative feedback supports the quantitative results we obtained from the questionnaires and provides additional evidence on the effectiveness of the app.

In addition, considering that the majority of participants did not practice with the app very frequently, the obtained results might suggest that also a short use of the app can be beneficial to users. Even practicing for a few sessions could have been sufficient for evoking in participants a reflection on the transitory nature of their thoughts. However, it is not known if the effect lasts for more than 4 weeks. Thus, future evaluations should (i) introduce a follow-up assessment point as done in some clinical studies of mindfulness interventions, e.g. (Bieling et al., 2012), and (ii) extend the evaluation period to 8 weeks as the length of the mindfulness programs employed in those decentering studies, e.g. (Bieling et al., 2012; Carmody et al., 2010; Hoge et al., 2015). This would offer the possibility to investigate whether the effects of the app on people last after a period of usage. Moreover, we cannot exclude that other factors, different from the interactive practice, contributed to the obtained result. In particular, we should consider that the version of AEON in the study did not provide users only with the interactive practice (as the original AEON did), but

included also the mindfulness questionnaire they had to answer three times during the 4 weeks to assess the decentering variable. Since the act of responding to a mindfulness questionnaire itself may exert a positive influence on the development of mindfulness (Bergomi et al., 2013), one could hypothesize that the questionnaire items might too have encouraged in participants a reflection on the nature of their thoughts and contributed to change their perspective on them.

To explore this consideration, we analyzed data of the 11 participants (8 naive and 3 experienced meditators) that answered the questionnaire three times, but had to be excluded from the study because they never practiced. Although the small number of participants in the two groups does not allow us to carry out the statistical analyses performed in the study, the trend for these participants looks positive (see Figure 17). This suggests that the possible role of the questionnaire is worth investigating further, for example by assigning some users to a version of the app that only allows them to answer the mindfulness questionnaire during the first 4 weeks and makes the interactive practice available only at the end of the fourth week. By comparing the answers to the mindfulness questionnaires of this group with those of participants who practiced with the app could allow us to better investigate the effectiveness of the interactive practice. Moreover, we are also considering adding a third condition in our future studies, i.e. a non-interactive version of the app that offers a visualization of entered thoughts that disappear automatically. Overall, this could allow us to evaluate separately the role of the external visualization of thoughts, the user interaction with them, and the mindfulness questionnaire in improving mindfulness. This study setting would also allow us to replicate the organization of those studies of clinical mindfulness interventions, see e.g. (Keng et al., 2011) for a review, where one group of participants that followed a mindfulness course is compared to one or more groups of participants who only answered the mindfulness(s) questionnaire(s) and/or underwent another psychological treatment during the period of the study.

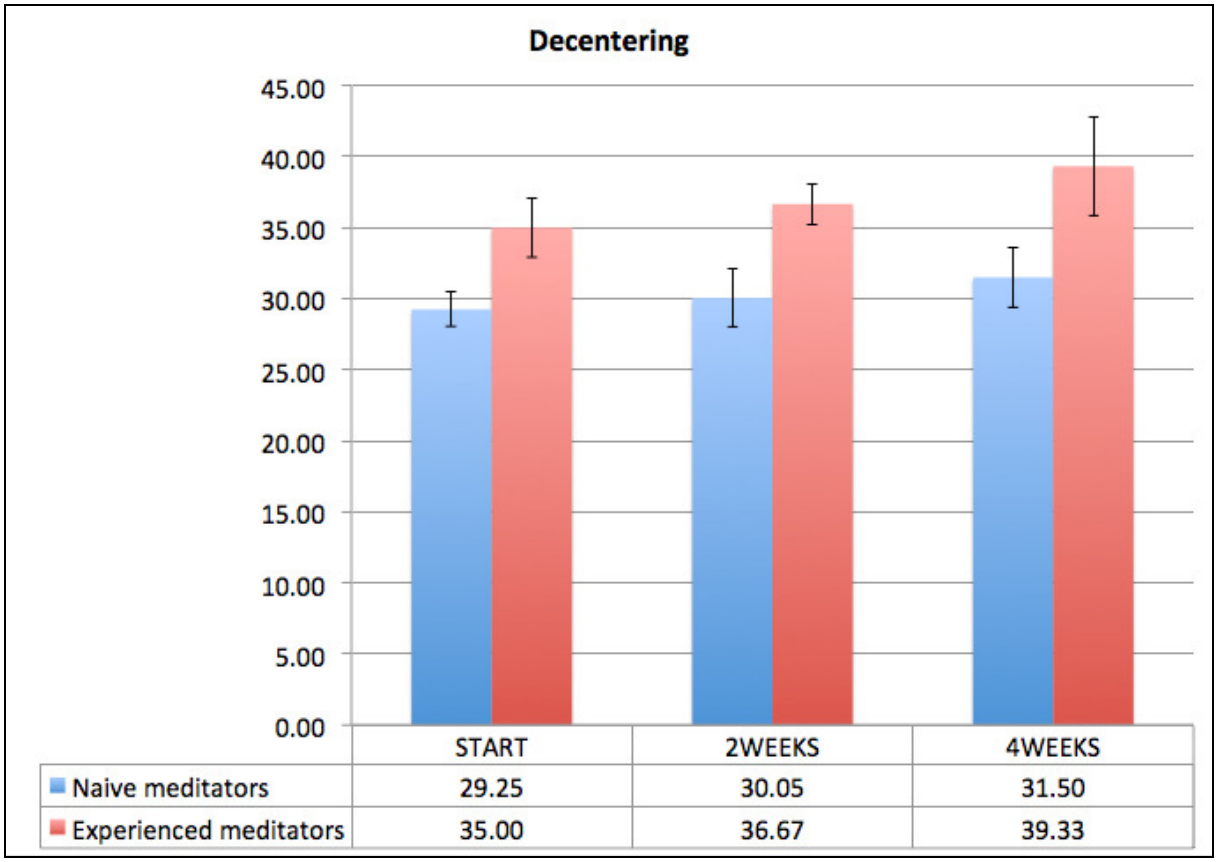


Figure 17: Mean level of decentering of the 11 (8 naive, 3 experienced) excluded participants (capped bars indicate ±1SE).

Another limitation of the current study, shared with other research in the large studies, is the lack of control on how participants use the app, which can possibly threaten internal validity of the study. However, according to Henze and Pielot (2013) the larger the sample of the study, the more individual differences and contextual factors could be factored out.

5.3. Qualitative feedback

In addition to the effectiveness of the app (see previous Section), the feedback provided by participants reveal that using the app elicited positive feelings in the majority of them, with relaxation and well-being as the most commonly reported. Other than the effects of mindfulness practice, which can promote positive emotional states (Brown and Ryan, 2003), a possible factor

that could have contributed to this result is the fact that passive or active interactions with nature or natural elements on a computer, e.g. looking at images of nature on a computer screen or exploring a natural 3D environment, can have a restorative effect on people, including stress reduction, relaxation and an overall restoration in energy and well-being, see e.g. (Bates and Marquit, 2011; Berman et al., 2008; Valtchanov et al., 2010). In our case, the interactive practice lets users directly interact with a simulated natural element and see the effect of their actions on it. Another factor that could have contributed to this result is that participants directly acted on the visualization of their thoughts and made them virtually disappear, which could have provided a relieving effect, as remarked by a few participants.

These considerations could also explain the fact that a high number of participants found the app beautiful. Moreover, in addition to the positive feelings elicited in participants, also the visual stimuli offered by the water simulation might have made participants like the app, since it could have been perceived as esthetically pleasant. Overall, these results suggest that turning the practice of mindfulness into an interactive exercise that involves a natural element can offer users a pleasant and enjoyable experience. These factors can help people approach mindfulness as well as motivate them to practice it more frequently.

6. Conclusions and future work

In the present study, we investigated the effects of using a mobile mindfulness app (AEON) in everyday contexts during a 4-week period. People could participate in the study by downloading AEON from on-line app stores and by answering a mindfulness questionnaire three times: at the first launch of the app and after two and four weeks, respectively. Finally, they could answer an optional open-ended qualitative questionnaire at the end of the study.

The obtained results show that using the app can help naive meditators increase their level of decentering over time. They reveal also that the app was perceived as useful and beautiful by participants, and its usage elicited positive feelings.

To the best of our knowledge, this is the first quantitative study that evaluates a mobile mindfulness app when used by people in their everyday contexts and over a prolonged period of time. In this way, the present study can have a greater external and ecological validity compared to the evaluation of interactive mindfulness practices carried out so far.

Results also confirm a limitation of using research in the large for carrying out longitudinal studies. Indeed, only a small percentage of the initial participants reached the end of the study. Thus, future work should consider other ways of keeping participants engaged during all the study period. For example, rewards can be distributed along the period instead of giving them all at the end as we did in this paper. In addition, notifications can be used to remind users to practice (the peak we obtained on the 15th day seems to suggest that notifications could affect some users).

The use of notification and distributed rewarding mechanisms could make it easier to retain participants in a future, longer study. For example, studies of meditation-oriented approaches (such as MBSR and MBCT) that go beyond short-term effects tend to last between one to three months, although they are relatively rare (Tang et al., 2015). In our case, considering the fact that people tend to use mobile apps little and for a short period of time (Consumer Health Information Corporation, 2011), extending too much the period of evaluation seems to be an unfeasible option to keep participants engaged until the end. As a possible solution, we could consider a study period of 8 weeks as the length of the mindfulness programs employed in other decentering studies, e.g. (Bieling et al., 2012; Carmody et al., 2010; Hoge et al., 2015).

In future studies, we will also employ a control group and a non-interactive version of the app, as we discussed in Section 5. Moreover, we will extend the investigation of the possible effects of the app to the broader context of supporting physical and psychological health, in line with traditional mindfulness interventions in clinical settings (Keng et al., 2011). As a specific example, we have started collaborating with sexologists to employ AEON as an adjunct in the treatment of men's premature ejaculation and women's vaginal anorgasmia. A positive role that AEON might play in

such therapeutic interventions is that of helping patients distance themselves from the distressful recurring thoughts that typically arise in such cases.

Finally, we are also considering the possibility to use voice input for entering thoughts, a feature that has started to be explored in the field of Cognitive Behavioral Therapy (Jain and Kala, 2014). However, one should consider that while voice input can make it easier for people to enter their thoughts, it restricts the usage of the app only to contexts in which users are alone. Indeed, it can be socially uncomfortable (and in some cases even odd) to speak loudly one's worries in presence of other people.

Reference

Ahtinen, A., Mattila, E., Välkkynen, P., Kaipainen, K., Vanhala, T., Ermes, M., Sairanen, E., Myllymäki, T., Lappalainen, R., 2013. Mobile mental wellness training for stress management: Feasibility and design implications based on a one-month field study. JMIR mHealth uHealth 1, e11. doi:10.2196/mhealth.2596

Baer, R.A., 2003. Mindfulness training as a clinical intervention: A conceptual and empirical review. Clin. Psychol. Sci. Pract. 10, 125–143. doi:10.1093/clipsy/bpg015

Bates, S.C., Marquit, J., 2011. Space psychology: Natural elements in habitation design. Pers. Ubiquitous Comput. 15, 519–523. doi:10.1007/s00779-010-0316-6

Bergomi, C., Tschacher, W., Kupper, Z., 2013. The assessment of mindfulness with self-report measures: Existing scales and open issues. Mindfulness 4, 191–202. doi:10.1007/s12671-012-0110-9

Berman, M.G., Jonides, J., Kaplan, S., 2008. The cognitive benefits of interacting with nature. Psychol. Sci. 19, 1207–1212. doi:10.1111/j.1467-9280.2008.02225.x

Bieling, P.J., Hawley, L.L., Bloch, R.T., Corcoran, K.M., Levitan, R.D., Young, L.T., MacQueen, G.M., Segal, Z.V., 2012. Treatment specific changes in decentering following mindfulness-based cognitive therapy versus antidepressant medication or placebo for prevention of depressive relapse. J. Consult. Clin. Psychol. 80, 365–372. doi:10.1037/a0027483.Treatment

Bless, J.J., Westerhausen, R., Arciuli, J., Kompus, K., Gudmundsen, M., Hugdahl, K., 2013. "Right on all occasions?" - On the feasibility of laterality research using a smartphone dichotic listening application. Front. Psychol. 4. doi:10.3389/fpsyg.2013.00042

Blunck, H., Bouvin, N.O., Franke, T., Grønbæk, K., Kjaergaard, M.B., Lukowicz, P., Wüstenberg, M., 2013. On heterogeneity in mobile sensing applications aiming at representative data collection, in: Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication (UbiComp '13). ACM Press, pp. 1087–1098.

Boggs, J.M., Beck, A., Felder, J.N., Dimidjian, S., Metcalf, C.A., Segal, Z.V., 2014. Web-based intervention in mindfulness meditation for reducing residual depressive symptoms and relapse prophylaxis: A qualitative study. J. Med. Internet Res. 16, e87. doi:10.2196/jmir.3129

Böhmer, M., Hecht, B., Schöning, J., Krüger, A., Bauer, G., 2011. Falling asleep with angry birds, facebook and kindle: A large scale study on mobile application usage, in: Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '11). ACM Press, pp. 47–56.

Böhmer, M., Krüger, A., 2014. A case study of research through the app store: Leveraging the system UI as a playing field for improving the design of smartphone launchers. Int. J. Mob. Hum. Comput. Interact. 6, 32–45.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–110.

Brown, K.W., Ryan, R.M., 2003. The benefits of being present: Mindfulness and its role in psychological well-being. J. Pers. Soc. Psychol. 84, 822–848. doi:10.1037/0022-3514.84.4.822

Brown, K.W., Ryan, R.M., Creswell, J.D., 2007. Mindfulness: Theoretical foundations and evidence for its salutary effects. Psychol. Inq. 18, 211–237.

Budde, A., Michahelles, F., 2010. Product Empire—Serious play with barcodes, in: Proceedings of Internet of Things (IOT). IEEE, pp. 1–7.

Buddharaju, P., Fujiki, Y., Pavlidis, I., Akleman, E., 2010. A novel way to conduct human studies and do some good, in: CHI'10 Extended Abstracts on Human Factors in Computing Systems. ACM Press, pp. 4699–4702. doi:10.1145/1753846.1754216

Carissoli, C., Villani, D., Riva, G., 2015. Does a meditation protocol supported by a mobile application help people reduce stress? Suggestions from a controlled pragmatic trial. Cyberpsychology, Behav. Soc. Netw. 18, 46–53. doi:10.1089/cyber.2014.0062

Carmody, J., Baer, R.A, 2008. Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. J. Behav. Med. 31, 23–33. doi:10.1007/s10865-007-9130-7

Carmody, J., Baer, R.A., Lykins, E.L.B., Olendzki, N., 2010. An empirical study of the mechanisms of mindfulness in a mindfulness-based stress reduction program. J. Clin. Psychol. 65, 613–626. doi:10.1002/jclp.20579

Chiesa, A., Malinowski, P., 2011. Mindfulness-based approaches: Are they all the same? J. Clin. Psychol. 67, 404–424. doi:10.1002/jclp.20776

Chittaro, L., Vianello, A., 2014. Computer-supported mindfulness: Evaluation of a mobile thought distancing application on naive meditators. Int. J. Hum. Comput. Stud. 72, 337–348. doi: 10.1016/j.ijhcs.2013.11.001

Consumer Health Information Corporation, 2011. Motivating patients to use smartphone health apps [WWW Document]. URL http://www.prweb. com/releases/2011/04/prweb5268884.htm.

Coulton, P., Bamford, W., 2011. Experimenting through mobile "apps" and "app stores." Int. J. Mob. Hum. Comput. Interact. 3, 55–70.

Cramer, H., Rost, M., Belloni, N., Bentley, F., Chincholle, D., 2010. Research in the large. using app stores, markets, and other wide distribution channels in Ubicomp research, in: Proceedings of the 12th ACM International Conference Adjunct Papers on Ubiquitous Computing-Adjunct. ACM Press, pp. 511–514. doi:10.1145/1864431.1864501

Do, T.M.T., Blom, J., Gatica-Perez, D., 2011. Smartphone usage in the wild: A large-scale analysis of applications and context, in: Proceedings of the 13th International Conference on Multimodal Interfaces (ICMI '11). ACM Press, pp. 353–360.

Dufau, S., Duñabeitia, J.A., Moret-Tatay, C., McGonigal, A., Peeters, D., Alario, F.-X., Balota, D. A, Brysbaert, M., Carreiras, M., Ferrand, L., Ktori, M., Perea, M., Rastle, K., Sasburg, O., Yap, M.J., Ziegler, J.C., Grainger, J., 2011. Smart phone, smart science: How the use of

smartphones can revolutionize research in cognitive science. PLoS One 6, e24974. doi:10.1371/journal.pone.0024974

Ferreira, D., Dey, A.K., Kostakos, V., 2011. Understanding human-smartphone concerns: A study of battery life, in: Proceedings of the 9th International Conference on Pervasive Computing (Pervasive '11). Springer Berlin Heidelberg, pp. 19–33.

Ferreira, D., Kostakos, V., Dey, A.K., 2012. Lessons learned from large-scale user studies: Using Android market as a source of data. Int. J. Mob. Hum. Comput. Interact. 4, 28–43.

Fresco, D.M., Moore, M.T., van Dulmen, M.H.M., Segal, Z.V, Ma, S.H., Teasdale, J.D., Williams, J.M.G., 2007. Initial psychometric properties of the experiences questionnaire: Validation of a self-report measure of decentering. Behav. Ther. 38, 234–246. doi:10.1016/j.beth.2006.08.003

Girardello, A., Michahelles, F., 2010. AppAware: Which mobile applications are hot?, in: Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '10). ACM Press, pp. 431–434.

Glück, T.M., Maercker, A., 2011. A randomized controlled pilot study of a brief web-based mindfulness training. BMC Psychiatry 11, 175. doi:10.1186/1471-244X-11-175

Gunaratana, H., 2002. Mindfulness in plain english. Wisdom Publications, Boston.

Henze, N., Boll, S., 2010. Push the study to the app store: Evaluating off-screen visualizations for maps in the Android market, in: Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services (Mobile HCI '10). ACM Press, pp. 373–374.

Henze, N., Pielot, M., 2013. App stores: External validity for mobile HCI. interactions 20, 33–38.

Henze, N., Pielot, M., Poppinga, B., Schinke, T., Boll, S., 2011a. My app is an experiment: Experience from user studies in mobile app stores. Int. J. Mob. Hum. Comput. Interact. 3, 71–91.

Henze, N., Rukzio, E., Boll, S., 2011b. 100,000,000 taps: Analysis and improvement of touch performance in the large, in: Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '11). ACM Press, pp. 133–142.

Henze, N., Sahami Shirazi, A., Schmidt, A., Pielot, M., Michahelles, F., 2013. Empirical research through ubiquitous data collection. Computer 46, 74–76.

Hoge, E.A., Bui, E., Goetter, E., Robinaugh, D.J., Ojserkis, R.A., Fresco, D.M., Simon, N.M., 2015. Change in decentering mediates improvement in anxiety in mindfulness-based stress reduction for generalized anxiety disorder. Cognit. Ther. Res. 39, 228–235. doi:10.1007/s10608-014-9646-4

Jain, D., Kala, M.H., 2014. Wearable audio journal and mobile application to capture automatic thoughts in patients undergoing cognitive behavioral therapy, in: Proceedings of the Companion Publication of the 19th International Conference on Intelligent User Interfaces (IUI Companion '14). ACM Press, pp. 85–88.

Kabat-Zinn, J., 2005. Coming to our senses: Healing ourselves and the world through mindfulness. Hyperion, New York.

Kabat-Zinn, J., 2003. Mindfulness-based interventions in context: Past, present, and future. Clin. Psychol. Sci. Pract. 10, 144–156. doi:10.1093/clipsy/bpg016

Kabat-Zinn, J., 1990. Full catastrophe living: Using the wisdom of your body and mind to face stress, pain, and illness. Delta, New York.

Karpischek, S., Michahelles, F., Fleisch, E., 2011. My2Cents: Enabling research on consumer-product interaction. Pers. Ubiquitous Comput. 16, 613–622. doi:10.1007/s00779-011-0426-9

Keng, S.L., Smoski, M.J., Robins, C.J., 2011. Effects of mindfulness on psychological health: A review of empirical studies. Clin. Psychol. Rev. 31, 1041–1056. doi:10.1016/j.cpr.2011.04.006

Killingsworth, M.A., Gilbert, D.T., 2010. A wandering mind is an unhappy mind. Science 330, 932–932. doi:10.1126/science.1192439

Kranz, M., Murmann, L., Michahelles, F., 2013. Research in the large: Challenges for large-scale mobile application research - A Case study about NFC adoption using gamification via an app store. Int. J. Mob. Human-Computer Interact. 5, 45–61.

Kristjánsdóttir, Ó.B., Fors, E.A., Eide, E., Finset, A., van Dulmen, S., Wigers, S.H., Eide, H., 2011. Written online situational feedback via mobile phone to support self-management of chronic widespread pain: A usability study of a Web-based intervention. BMC Musculoskelet. Disord. 12, 51. doi:10.1186/1471-2474-12-51

Krusche, A., Cyhlarova, E., King, S., Williams, J.M.G., 2012. Mindfulness online: A preliminary evaluation of the feasibility of a web-based mindfulness course and the impact on stress. BMJ Open 2, e000803. doi:10.1136/bmjopen-2011-000803

Krusche, A., Cyhlarova, E., Williams, J.M.G., 2013. Mindfulness online: An evaluation of the feasibility of a web-based mindfulness course for stress, anxiety and depression. BMJ Open 3, e003498. doi:10.1136/bmjopen-2013-003498

Lappalainen, R., Sairanen, E., Järvelä, E., Rantala, S., Korpela, R., Puttonen, S., Kujala, U.M., Myllymäki, T., Peuhkuri, K., Mattila, E., Kaipainen, K., Ahtinen, A., Karhunen, L., Pihlajamäki, J., Järnefelt, H., Laitinen, J., Kutinlahti, E., Saarelma, O., Ermes, M., Kolehmainen, M., 2014. The effectiveness and applicability of different lifestyle interventions for enhancing wellbeing: The study design for a randomized controlled trial for persons with metabolic syndrome risk factors and psychological distress. BMC Public Health 14, 310. doi:10.1186/1471-2458-14-310

Lau, M.A., Bishop, S.R., Segal, Z.V., Buis, T., Anderson, N.D., Carlson, L., Shapiro, S., Carmody, J., Abbey, S., Devins, G., 2006. The Toronto mindfulness scale: Development and validation. J. Clin. Psychol. 62, 1445–1467. doi:10.1002/jclp.20326

Lim, D., Condon, P., DeSteno, D., 2015. Mindfulness and compassion: An examination of mechanism and scalability. PLoS One 10, e0118221. doi:10.1371/journal.pone.0118221

Ly, K.H., Asplund, K., Andersson, G., 2014. Stress management for middle managers via an acceptance and commitment-based smartphone application: A randomized controlled trial. Internet Interv. 1, 95–101. doi:10.1016/j.invent.2014.06.003

McMillan, D., Morrison, A., Brown, O., Hall, M., Chalmers, M., 2010. Further into the wild: Running worldwide trials of mobile systems, in: Proceedings of the 8th International Conference on Pervasive Computing (Pervasive '10). Springer Berlin Heidelberg, pp. 210–227.

McMillan, D., Morrison, A., Chalmers, M., 2013. Categorised ethical guidelines for large scale mobile HCI, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). ACM Press, pp. 1853–1862. doi:10.1145/2470654.2466245

Miller, G., 2012. The smartphone psychology manifesto. Perspect. Psychol. Sci. 7, 221–237. doi:10.1177/1745691612441215

Miluzzo, E., Lane, N.D., Lu, H., Campbell, A.T., 2010. Research in the app store era: Experiences from the cenceme app deployment on the iPhone, in: First Workshop on Research in the Large at UbiComp. ACM Press.

Moore, A., Malinowski, P., 2009. Meditation, mindfulness and cognitive flexibility. Conscious. Cogn. 18, 176–186. doi:10.1016/j.concog.2008.12.008

Morris, M.E., Kathawala, Q., Leen, T.K., Gorenstein, E.E., Guilak, F., Labhard, M., Deleeuw, W., 2010. Mobile therapy: Case study evaluations of a cell phone application for emotional self-awareness. J. Med. Internet Res. 12, e10. doi:10.2196/jmir.1371

Nes, A.A.G., van Dulmen, S., Eide, E., Finset, A., Kristjánsdóttir, O.B., Steen, I.S., Eide, H., 2012. The development and feasibility of a web-based intervention with diaries and situational feedback via smartphone to support self-management in patients with diabetes type 2. Diabetes Res. Clin. Pract. 97, 385–393. doi:10.1016/j.diabres.2012.04.019

Pielot, M., Henze, N., Boll, S., 2011. Experiments in app stores-how to ask users for their consent, in: CHI '11 Workshop on Ethics, Logs and Videotape. ACM Press, pp. 1–4.

Plaza, I., Demarzo, M.M.P., Herrera-Mercadal, P., García-Campayo, J., 2013. Mindfulness-based mobile applications: Literature review and analysis of current features. JMIR mHealth uHealth 1, e24. doi:10.2196/mhealth.2733

Poppinga, B., Cramer, H., Böhmer, M., Morrison, A., Bentley, F., Henze, N., Rost, M., Michahelles, F., 2012. Research in the Large 3.0: App stores, wide distribution, and big data in MobileHCI research, in: Proceedings of the 14th International Conference on Human-Computer Interaction with Mobile Devices and Services Companion (MobileHCI '12). ACM Press, pp. 241–244.

Querstret, D., Cropley, M., 2013. Assessing treatments used to reduce rumination and/or worry: A systematic review. Clin. Psychol. Rev. 33, 996–1009. doi:10.1016/j.cpr.2013.08.004

Runyan, J.D., Steenbergh, T.A., Bainbridge, C., Daugherty, D.A., Oke, L., Fry, B.N., 2013. A smartphone ecological momentary assessment/intervention "app" for collecting real-time data and promoting self-awareness. PLoS One 8, e71325. doi:10.1371/journal.pone.0071325

Safran, J., Segal, Z.V., 1996. Interpersonal process in cognitive therapy. Jason Aronson Inc., New York.

Sahami Shirazi, A., Rohs, M., Schleicher, R., Kratz, S., Müller, A., Schmidt, A., 2011. Real-time nonverbal opinion sharing through mobile phones during sports events, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11). ACM Press, pp. 307–310. doi:10.1145/1978942.1978985

Segal, Z.V., Williams, J.M.G., Teasdale, J.D., 2002. Mindfulness-based cognitive therapy for depression: A new approach to preventing relapse, Psychotherapy Research. Guilford Press, New York. doi:10.1093/ptr/kpg004

Shapiro, S.L., Carlson, L.E., Astin, J.A., Freedman, B., 2006. Mechanisms of mindfulness. J. Clin. Psychol. 62, 373–386.

Shaw, C., Gromala, D., Seay, A.F., 2007. The Meditation Chamber: Enacting autonomic senses, in: Proc. of ENACTIVE/07. ACROE Press, pp. 405–408.

Soler, J., Cebolla, A., Feliu-Soler, A., Demarzo, M.M.P., Pascual, J.C., Baños, R., García-Campayo, J., 2014. Relationship between meditative practice and self-reported mindfulness: The MINDSENS composite index. PLoS One 9. doi:10.1371/journal.pone.0086622

Tang, Y.Y., Hölzel, B.K., Posner, M.I., 2015. The neuroscience of mindfulness meditation. Nat. Rev. Neurosci. 16, 213–225. doi:10.1038/nrn3916

Teasdale, J.D., Moore, R.G., Hayhurst, H., Pope, M., Williams, S., Segal, Z.V., 2002. Metacognitive awareness and prevention of relapse in depression: Empirical evidence. J. Consult. Clin. Psychol. 70, 275–287. doi:10.1037//0022-006X.70.2.275

Thieme, A., Wallace, J., Johnson, P., McCarthy, J., Lindley, S., Wright, P., Olivier, P., Meyer, T.D., 2013. Design to promote mindfulness practice and sense of self for vulnerable women in secure hospital services, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). ACM Press, pp. 2647–2656. doi:10.1145/2470654.2481366

Thompson, B.L., Waltz, J., 2007. Everyday mindfulness and mindfulness meditation: Overlapping constructs or not? Pers. Individ. Dif. 43, 1875–1885. doi:10.1016/j.paid.2007.06.017

Thompson, N.J., Walker, E.R., Obolensky, N., Winning, A., Barmon, C., Diiorio, C., Compton, M.T., 2010. Distance delivery of mindfulness-based cognitive therapy for depression: Project UPLIFT. Epilepsy Behav. 19, 247–254. doi:10.1016/j.yebeh.2010.07.031

Unity Technologies, 2005. Unity3D (Version 4.3) [Software]. URL http://unity3d.com

Unity Technology, 2015. Unity - Scripting API: SystemLanguage [WWW Document]. URL http://docs.unity3d.com/ScriptReference/SystemLanguage.html

Valtchanov, D., Barton, K.R., Ellard, C., 2010. Restorative effects of virtual nature settings. Cyberpsychology, Behav. Soc. Netw. 13, 503–512.

Vidyarthi, J., Riecke, B.E., 2014. Interactively mediating experiences of mindfulness meditation. Int. J. Hum. Comput. Stud. 72, 674–688. doi:10.1016/j.ijhcs.2014.01.006

Vidyarthi, J., Riecke, B.E., Gromala, D., 2012. Sonic Cradle: Designing for an immersive experience of meditation by connecting respiration to music, in: Proceedings of the Designing Interactive Systems Conference (DIS '12). ACM Press, pp. 408–417.

von Watzdorf, S., Michahelles, F., 2010. Accuracy of positioning data on smartphones, in: Proceedings of the 3rd International Workshop on Location and the Web (LocWeb '10). ACM Press, pp. 1–4. doi:10.1145/1899662.1899664

Wang, G., 2009. Designing smule's iphone ocarina, in: International Conference on New Interfaces for Musical Expression (NIME '09). pp. 303–307.

Wells, A., 2005. Detached mindfulness in cognitive therapy: A metacognitive analysis and ten techniques. J. Ration. Cogn. Ther. 23, 337–355. doi:10.1007/s10942-005-0018-6

Yang, P.C., Chang, C.C., Chen, Y.L., Chiang, J.H., Hung, G.C.L., 2014. Portable assessment of emotional status and support system. Lect. Notes Comput. Sci. 8423, 175–183.

Yu, M.C., Wu, H., Lee, M.S., Hung, Y.P., 2012. Multimedia-assisted breathwalk-aware system. IEEE Trans. Biomed. Eng. 59, 3276–3282. doi:10.1109/TBME.2012.2208747

Zhai, S., Kristensson, P.O., Gong, P., Greiner, M., Peng, S.A., Liu, L.M., Dunnigan, A., 2009. Shapewriter on the iphone: from the laboratory to the real world, in: CHI'09 Extended Abstracts on Human Factors in Computing Systems. ACM Press, pp. 2667–2670.