

DESIGN AND EVALUATION OF SMARTPHONE-BASED TRAINING FOR MINDFULNESS AND OPENNESS TO EXPERIENCE

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ABSTRACT

In this study a modified version of an app for training mindfulness and the mindfulness factor openness to experience, is presented. This study also extends the utility of an existing app, Positive Activity Jackpot. The Positive Activity Jackpot app uses gamified micro-tasks, by developing and integrating mindfulness-specific tasks. An evaluation of the app's subjective and objective efficacy is reported from the findings in the following two studies: firstly, an expert review and secondly, a between subjects experiment. The newly created/modified app was rated by experts as a suitable tool for inducing the state mindfulness in the first study and demonstrated a significant training effect for state mindfulness in the second study, but failed to reach significance for the openness to experience measure. In conclusion, micro-tasks using mindfulness apps may fit current busy schedules, as well as engaging users through playful audio-visual feedback. The validity of the openness to experience sub-scale in this study, as well as the lack of appropriate state mindfulness instruments for evaluating digital mindfulness apps, were identified as main limitations.

KEYWORDS

Gamification, Mobile App, mHealth, Mindfulness, Meditation, Openness to Experience

1. INTRODUCTION

After the invention of PCs and brain imaging, smartphones are believed to transform psychology research profoundly (Miller, 2012). The great spread of smartphones along with its technological capabilities makes it a promising tool and platform for researchers. At the same time, there is a growing interest and application of mindfulness within medicine and other areas (Black, 2014). Practising mindfulness as attention and emotion regulation training has been shown to improve psychological wellbeing, especially by alleviating stress, anxiety, depression and other mood disorders (Khoury, Sharma, Rush, & Fournier, 2015). Naturally, the interest in smartphone-based mindfulness interventions as a convenient method to deliver these benefits is growing as well.

A literature and software review of smartphone-based mindfulness interventions by Plaza, Demarzo, Herrera-Mercadal, and García-Campayo (2013) found 50 mindfulness-based mobile applications (apps) out of >1000 hits related to mindfulness and meditation on the Google Play store and concluded that there is "a complete lack of evidence to support the usefulness of those apps" (Plaza et al., 2013, p.13). Another review by Mani, Kavanagh, Hides, and Stoyanov (2015), that focused on iPhone apps, identified 23 mindfulness apps that were mostly guided-meditation apps only (thus limited in interactivity) and of poor quality. Interactivity is the key element to build experiential knowledge, which fosters the cultivation of mindfulness (Sliwinski, Katsikitis, & Jones, 2015). In terms of quality, the aspects of engagement and aesthetics and information were particularly low, which translates to a lower intention and motivation to use the apps and practise mindfulness. Although mindfulness re-search is growing rapidly, with the benefits of the practice being more and more confirmed (Sedlmeier et al., 2012), the current state of art for mobile-based mindfulness interventions is lacking innovation and research.

Before developing mindfulness technology and evaluating its efficacy, however, the issue that must be addressed is that there appears to be no consensus in the scientific community about the concept of mindfulness itself. There is a great number of questionnaires that claim to measure mindfulness, with great

conceptual differences (Bergomi, Tschacher, & Kupper, 2013a). One of the most recent operationalisations of mindfulness is the Comprehensive Inventory of Mindfulness Experiences (CHIME) by Bergomi et al. (2014), which was developed to unify other available questionnaires and provide a comprehensive measure of mindfulness. Nine aspects of mindfulness were identified that are covered by previous operationalisations of mindfulness (2013b; 2014). Those aspects were factor analysed and reduced to eight factors, forming the final structure of mindfulness and resulting measurement instrument.

This current study aims to present an accessible and interactive method to train one mindfulness factor, that is openness to experience, which to date has not been addressed by scientific in the context of mindfulness training. The factor expresses a non-avoidant (confrontational) attitude towards experiences that are characterised by openness and curiosity (Bergomi et al., 2013b, 2014). People scoring high on this dimension try to perceive all the richness of stimuli in their environment and do not suppress their emotions or distract themselves but deliberately direct their attention to all of them (including pain and other negative experiences). As such, openness to experience is a crucial aspect of mindfulness for the process of emotional regulation, by bringing experiences into attention to be addressed by the self-regulatory processes of mindfulness meditation (Chambers, Gullone, & Allen, 2009).

The outcome of this study is to present a smartphone-based app for improving mindfulness and openness to experience, which can be used anywhere, by anyone. In the following, the design of the mobile app is described, including the proposed custom modifications. In two evaluation studies the suitability of this app is tested in the context of improving mindfulness. Finally, relevant implications are discussed, along with recommendations for future studies.

2. DESIGN

To improve the mindfulness factor openness to experience, the existing Android app Positive Activity Jackpot (National Center for Telehealth and Technology; T2, 2014) was chosen, which is available for free on the Google Play Store. It is designed like a slot machine, where players press a lever, which spins a wheel of fortune, representing various activities. During the spin, an intriguing sound is played, together with pulsing vibrations. The resulting activity can be chosen to be performed, or an-other spin can be made. After selecting an activity, the app provides the opportunity to invite friends and to schedule the activity in the phone's personal calendar.

In its original form, this app features 375 activities (e.g. “watch TV”, “go to a muse-um”, “buy clothes”), which are not suitable for this study, because they provide a distraction of inner experiences, particularly internal discomfort. For this reason, custom activities were developed (see Table 1) and integrated in this app. The activities were designed based on existing validated questionnaires and theory about openness to experience (Bergomi et al., 2014; Cardaciotto, Herbert, Forman, Moitra, & Farrow, 2008; McCrae, Costa, & Martin, 2005; Walach, Buchheld, Butenmüller, Kleinknecht, & Schmidt, 2006). The beneficial key mechanic of this app is encouraging users to perform novel tasks in a playful (gamified) way. By using the custom developed activities, it is targeted at improving the mindfulness aspects openness to experience.

2.1 Activities

The openness to experience is a subject of investigation in personality psychology and is measured by established instruments. Although there are a few questionnaires that claim to measure a construct called openness to experience (e.g. Big Five, HEXACO), only one questionnaire was found that measures it as intended in this study within the context of mindfulness, namely the NEO-Personality Inventory-3 (NEO-PI-3; McCrae, Costa, & Martin, 2005), in particular its sub-scale openness to inner feelings and emotions. Available items from validated questionnaires are taken as theoretical basis to develop activities that increase openness to experience, as well as items from other mindfulness questionnaires, which were used to develop this CHIME factor (Bergomi et al., 2014), namely the Freiburg Mindfulness Inventory (FMI; Walach et al., 2006) and the Philadelphia Mindfulness Scale (PHLMS; Cardaciotto et al., 2008).

Based on these items, activities were developed to improve the mindfulness factor openness to experience (see Table 1). The central theme of all available items was identified as non-avoidance of feelings and sensations, especially negative ones, which was used as the theoretical design guideline for constructing the

activities. To achieve an increased non-avoidance to inner experiences, activities were developed that focus attention on this particular aspect. To sustain engagement, a variety of activities targeting different parts of body and mind were chosen. For practical reasons, some the activities make use of physical resources (paper, pen, stop watch), however, digitalizing all activities is possible (e.g. by implementing a drawing and countdown function in the app).

Table 1. Openness to experience activities

| # | Activity description |
|----|-------------------------------------------------------------------------------------------------------------------------------------|
| 1 | On a piece of paper, describe your current feeling(s) with as many adjectives as possible. |
| 2 | On a piece of paper, draw your current feeling(s). |
| 3 | Sit still for 1 minute and concentrate on what you feel (use the stop watch). |
| 4 | Choose a random part of your body. Focus on it for 1 minute and observe curiously what you feel (use the stop watch). |
| 5 | Touch the paper sheet. Explore it slowly and observe what you feel. |
| 6 | Touch the pen. Explore it slowly and observe what you feel. |
| 7 | Close your eyes for 1 minute and investigate what you currently feel (use the stop watch). |
| 8 | On a piece of paper, describe what you currently smell. |
| 9 | On a piece of paper, write down what you are currently aware of (e.g. sounds, smells, tactile sensations, etc.). |
| 10 | For 1 minute, focus on the feeling of air on your skin (use the stop watch). |
| 11 | Focus on something that is difficult in your life. Curiously observe the sensations in your body for 1 minute (use the stop watch). |
| 12 | On a piece of paper, draw a tree with your non-dominant hand. Observe how you feel. |
| 13 | Sing something! Curiously observe how you feel during and after. |
| 14 | Balance on one leg, while curiously observing how you feel. |

3. EVALUATION

To evaluate this app and its activities, two studies were conducted. In stage 1, domain experts were consulted to evaluate the feasibility of this app for improving openness to experience. Stage 2 tested the app's efficacy experimentally.

3.1 Stage 1: Expert review

The first stage aims to validate the subjective efficacy of the modified version of the Positive Activity Jackpot for improving the mindfulness factor openness to experience. Following ethics approval (S/15/762), seven domain experts (3 males, 4 females) with a median age of 44 years (range 23-52 years) participated in this experiment. All experts had prior meditation experience (active meditators for at least three years; median 11 years), and prior game experience (including experience in academic game studies). Participation was voluntary and not incentivized. To gather feedback from the experts and their opinion on the fit of openness to experience to the proposed app, an offline survey was created, which was distributed via email. A demographic sheet asked for the experts' gender, age, and prior gaming and meditation experience. The evaluation sheet provided some basic information about the study's purpose along with instructions to score and answer each question honestly. A detailed definition of openness to experience was presented, followed by a description of the proposed app, with a link to the game on the app store. On a 7-point scale (anchor points: not feasible at all, neutral, very feasible), participants were asked "In your expert opinion, how feasible is it that this game can improve openness to experience?". After scoring the feasibility of the game for openness to experience, participants were asked to explain their judgement. The Positive Activity Jackpot app was scored for its fit with openness to experience with a mean of 5.6 (SD: 0.9, range 5-7), which supports its choice as a mindfulness game for training openness to experience. Two participants were excluded from analysis, as they did not give a definite score, stating to have no opinion.

3.2 Stage 2: Experimental evaluation

The aim of the second stage is to evaluate the modified version of the Positive Activity app for its efficacy based on empirical user testing.

3.2.1 Participants

For this stage, a total of 20 participants from a convenience sample were used, who were recruited via social networks, radio advertisement, posters, flyers and face-to-face promotion on the campus of the University of the Sunshine Coast, Queensland, Australia. Participants had no prior meditation experience and sufficient gaming experience to be familiar with touch controls. Interest in mindfulness was used as a selection criterion to minimise a priori differences in disposition, which is a methodological concern for one-shot studies (Sedlmeier et al., 2012). One participant was excluded from analysis due to prior meditation experience. The remaining participants were 12 males and 7 females with a median age of 26 (range 19-44). Participation was incentivized with a \$20 voucher for a large retailer. The study was completed with ethics approval from the University of the Sunshine Coast (S/15/788).

3.2.2 Design

A between subjects factorial design was applied, where each participant interacted with the app. Mindfulness was measured before and after a 20 minute intervention and at follow-up. In a pre- and post-test and one-week follow-up, the State Mindfulness Scale (SMS; Tanay & Bernstein, 2013) measured the participant's state mindfulness and immediate effect of the app (instructing the participant to focus on the past 15 minutes). To measure the effect on the individual mindfulness aspect as hypothesized, CHIME (Bergomi et al., 2014) was administered in pre-test and one-week follow-up (instructing the participant to focus on the past two weeks).

3.2.3 Measurement

The SMS with its two factors, State Mindfulness of Mind and State Mindfulness of Body, both taking traditional Buddhist scholarship as a conceptual foundation. The 21 questionnaire items were generated based on the feedback from mindfulness researchers and instructors. Participants rate their agreement with each statement on 5-point Likert scale. Example items are "When my mood changes, I notice it right away" and "I see my mistakes and difficulties without judging myself". The CHIME scale measures eight individual mindfulness factors with 37 items to which participants answer on a 6-point Likert scale.

To investigate the reliability of the measurement instruments, we conducted reliability analyses on the current sample, which revealed a Cronbach's $\alpha=.94$ for the SMS total and a Cronbach's $\alpha=.84$ for the CHIME total. Both SMS sub-scales had also good to excellent reliability (Mind, $\alpha=.92$; Body, $\alpha=.86$). The CHIME sub-scale for openness to experience demonstrated a poor reliability of $\alpha=.49$. A further analysis of the openness to experience sub-scale showed that deleting any individual item would not increase the reliability above .53. No gender effects were found for the openness to experience sub-scale. Game experience had no effect on scale reliability.

3.2.4 Procedure

Participants were greeted and presented with a research project information sheet explaining the purpose and procedure of the experiment, as well as a consent form before the start of the experiment. Then, a pre-test questionnaire was administered, which included CHIME, SMS, and a self-assessment about mindfulness and game experience, as well as demographics. For the time of the intervention the participant was left alone, with the instruction to keep on playing until the experimenter comes back. Participants were instructed to perform the chosen activity immediately or to pull the lever again to draw another activity if so desired. The play session was stopped by the experimenter (entering the room) after exactly 20 minutes, after which the SMS was applied as a post-test questionnaire. Seven days later, participants were contacted by email to complete the follow-up questionnaire, which included CHIME and SMS. After completion of the study, the incentive was sent out.

3.2.5 Analysis

Descriptive statistics were used to explore individual differences between participants. Reliability statistics were conducted for all scales and sub-scales used. Experimental data obtained from mindfulness questionnaires (pre-test, post-test, follow-up) were analysed by means of repeated measure ANOVA. Post-hoc tests were applied to highlight where differences occur. Two participants did not finish the follow-up questionnaire, which was treated as missing data. One participant did the follow-up one day later than instructed (after eight days instead of seven), one participant completed it five days later, and one participant was 12 days late. The follow-up time was coded as a variable and tested for interactions.

3.2.6 Results

Repeated measures ANOVAs were applied to test the effects of time on mindfulness. The modified Positive Activity Jackpot had a statistically significant effect on state mindfulness, as measured by the SMS total scores, ANOVA, $F(2, 32) = 16.8, p < .01$. This effect was pre-sent for both SMS sub-scales, Mind, $F(2, 32) = 17.9, p < .01$, and Body, $F(2, 32) = 13, p < .01$. No interaction effects for gender, age, follow-up time, and group, were revealed for any of the conducted tests. As shown in Figure 1, SMS scores increase significantly from pre- to post-test, $F(1, 18) = 34.8, p < .01$., and then drop again at follow-up, while still being higher compared to the pre-test, though not significant.

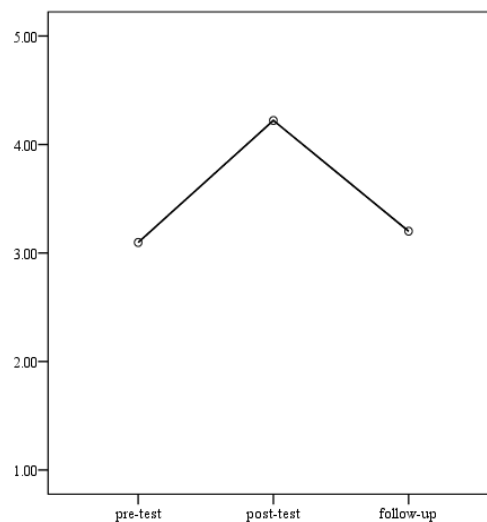


Figure 1. SMS total scores across all points in time for the modified version of the Positive Activity Jackpot app

No significant increase of trait mindfulness, as scored by the CHIME total and the CHIME openness to experience sub-scale, was observed between pre-test and the one-week follow-up. No interaction effects for gender, age, follow-up time, and group, were revealed for any of the conducted tests. Correlating the total scores of SMS and CHIME at both, pre-test and follow-up, revealed significant correlations in both cases (.585 and .487) at the .01 level and .05 level respectively. Correlations between individual factors of SMS and CHIME are shown in Table 2.

Table 2. Correlation matrix between CHIME and SMS total scores and individual factors at pre-test

| | CHIME | Openness | SMS | Mind | Body |
|----------|--------|----------|--------|-------|------|
| CHIME | - | - | - | - | - |
| Openness | .264 | - | - | - | - |
| SMS | .585** | -.206 | - | - | - |
| Mind | .653** | -.013 | .927** | - | - |
| Body | .453 | -.351 | .943** | .75** | - |

Note. ** $p \leq .01$.

At the end of the experiments, after the debriefing, participants shared their feedback about their experience unprompted. Besides the variety of tasks, participants liked the gong sound (programmed by the stop watch), which “was very helpful to let go”. Two participants found the sound of pulling the lever (quickly alternating high pitched tones) annoying. From all activities, the tree-drawing task was liked the most, whereas the least liked (and most skipped) activities were standing on one leg, and singing, because they triggered embarrassment and because they were perceived as unsuitable for public environments.

4. DISCUSSION

The aim of this study was twofold: firstly, to modify an existing smartphone app so as to in-corporate a mindfulness factor within it, namely openness to experience; and secondly, to evaluate its efficacy in achieving a state of mindfulness for the participants engaged with the game. Stage 1 investigated the subjective suitability of a modified version of Positive Activity Jackpot app for improving the mindfulness factor openness to experience. Domain experts stated their agreement that this gamified app has the potential of training mindfulness in the context of openness to experience. Stage 2, tested empirically the efficacy of the app on a state and trait mindfulness scale, including the specific factor openness to experience. The app showed a significant effect on state mindfulness, as measured by the SMS, confirming its efficacy for training mindfulness. This was furthermore supported by positive comments about its subjective efficacy in form of participants’ informal feedback at the end of the study. Some participants even resisted ceasing the game when the experimenter came in to conclude the play session. The Positive Activity Jackpot allows for quick play sessions on the go that can be easily integrated into the daily routines of its users. The use of short micro-tasks is especially suitable for the context of modern busy lives, which was identified as a core concern of mindfulness app users (Laurie & Blandford, 2016).

A study by Vacca and Hoadley (2016), describes the design and evaluation of a mindfulness app which also features micro-tasks, though with a focus on self-reflection and non-reactivity. Activities included several tracking exercises such as noticing one’s mood, thoughts, as well as recent experiences of compassion and gratitude. After each activity, the user is redirected to a screen with the instruction to not react. The app’s general design and functionality is similar to our modified version of the Positive Activity Jackpot, which makes the implications by Vacca and Hoadley (2016) applicable to our app. The author’s found that a daily commitment by the user (prompted by the app) of a maximum of three activities in-creased engagement, which was further promoted by check-ins in the form of notifications (Vacca & Hoadley, 2016).

This app’s custom activities for openness to experience were not effective in improving their target mindfulness factor. Besides the methodological challenges of measuring their efficacy (see Limitations), it is unclear if the chosen activities are feasible for training open-ness to experience. No other study to date focused on approaches to improve openness to experience, which might be attributed to its common definition of being a personality trait (McCrae, Costa, & Martin, 2005), which cannot be trained. The app’s positive effects on state mind-fulness, however, confirm its positive influence on mindfulness. Yet, it is unclear how a non-digital application of these activities would compare against this digitalized approach.

In the case of the mindfulness app AEON, a non-digital control group, where participants had to imagine the same task revealed to be equally effective for improving the mindfulness skill of thought-distancing (Chittaro & Vianello, 2014), therefore it may be that drawing these activities on paper cards will yield similar benefits. While mindfulness meditation is some-times perceived as a daunting task (Lomas, Cartwright, Edginton, & Ridge, 2014), the advantage of this digital app is that it provides a more motivating method through its gamification elements, that might strengthen the daily mindfulness practice and achieve more stable benefits.

A valuable addition to the existing app mechanics would be presenting more information about mindfulness to educate the user, integrating more context-dependent tasks, providing progress feedback and rewards for spotting and enduring experiential states, as well as using digital timers and drawing tools to replace the physical aids that were used in this study. To keep users motivated and engaged (i.e. to use the app daily to maintain bene-fits), social features are recommended that make them part of a community. In addition to that, opportunities to collect in-game rewards by doing daily challenges can increase the long-term engagement with the game. As a general design implication for apps that aim to improve openness to experience, it is recommended to gamify activities that stimulate inner exploration. The use of gambling

elements such as a wheel of fortune or a slot machine mechanic, intriguing sound effects and tactile stimuli (vibrations) enhance the motivation and engagement in use.

Finally, mindfulness is intended to be practised regularly and continuously. For this study, the app was used only once for 20 minutes, which already revealed significant effects on a state level. This supports the regular use of this app by users to improve mindfulness and associated health benefits. Although training effects for state mindfulness were demonstrated, as a stand-alone app it does not do justice to the whole concept of mindfulness, which includes at least seven other factors (Bergomi et al., 2014). It is not meant to be a substitute for meditation, but rather an additional support tool and a way of getting people into a routine for practising mindfulness.

For evaluating digital health apps and serious games, objective physiological measures (e.g. galvanic skin response, heart rate variability) are recommended, which can be correlated with the participant's subjective experience. Biometrics can continuously measure during use of the app and allow pinpointing of relevant events and their effects to further investigate effective mechanisms of action. This would be especially helpful to assess the distinct influence between the general app design such as its user interface and its content (in this case the activities). Within apps for mindfulness, new opportunities of the technology can be exploited to develop alternative methods of measurement that are less dependent on self-assessment (like questionnaires) and more reliable. For example, the user's behaviour within an app or digital game can be tracked and classified in mindful and mindless behaviour to assess the user's state.

5. LIMITATIONS

No significant effects were found for openness to experience, as measured by the CHIME. This may have resulted due to measurements for openness to experience being undertaken only at pre-test and follow-up. The impact of the app on openness to experience could not be measured directly after the intervention, because CHIME is a trait questionnaire, which addresses the last 2 weeks (contrary to the SMS, which refers to the last 15 minutes). To minimise history effects, the break between intervention and measurement was shortened to one week only, however this may have been still too long to track any benefits. On the other hand, addressing the participant's experience of the last two weeks, while only one week passed, may have decreased the instruments sensitivity.

Furthermore, the poor reliability of the CHIME sub-scale for openness to experience undermines the correct measurement of the app's efficacy. It is unclear what accounts for the poor reliability, investigating CHIME and its relationship with individual factors revealed that its total score does not correlate significantly with openness to experience, which demonstrates a weakness of the scale in this study. Openness to experience correlates negatively with the SMS (total and all sub-scales) in this study, which underlines the methodological weakness of this CHIME factor.

Both questionnaires, SMS and CHIME were found to correlate significantly. This shows that CHIME results might have been in support of the app's efficacy if the instrument had been also administered at the post-test level. However, the variance between the correlations of SMS and CHIME scores from pre-test to follow-up highlights the conceptual differences between both instruments. The principle challenge is to measure individual mindfulness factors, as defined by CHIME, on a state level.

Future studies on mindfulness-based interventions need to find a way to assess all mindfulness factors directly after an intervention. For the context of apps, it would provide additional value to add measurement points in-between the intervention. Especially short questionnaires would be suitable as process measures, in this case one item on a visual-analog scale per CHIME factor would be feasible. However, any item should be consistent with the overall design of the app. Being an integral part of the app, this method would provide the least detrimental effect on engagement (not breaking the "magic circle") and may overcome some of the biases associated with self-report questionnaire (e.g. Hawthorne effect).

6. CONCLUSION

Mindfulness apps have become popular, however, they offer little or no interactivity. In this study, we tested a modified version of the Positive Activity Jackpot, which has potential for engaging users by incorporating gamification in the form of slot machine mechanics. Based on existing validated scales for openness to experience, we have created activities to be used by the app. Two studies validated the app for its subjective and objective efficacy, confirming its feasibility for the context of training mindfulness plus delivering a general positive experience. This study and the associated modified Positive Activity Jackpot app presents an original contribution to the landscape of mindfulness apps and mobile interventions. The value of such an app lies in the flexibility and cost-efficacy of self-administered mindfulness treatment to improve health and wellbeing. Moreover, the activities of the app can be conveniently adjusted to fit the training need.

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