

Mindful Scroll: An Infinite Scroll Abstract Colouring App for Mindfulness

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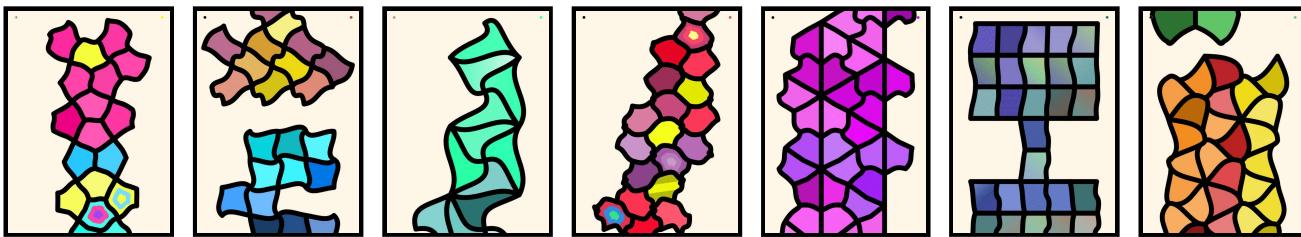


Figure 1: Example patterns revealed while using Mindful Scroll

ABSTRACT

We design and evaluate Mindful Scroll, a mobile application for mindfulness that encourages a slow and deliberate approach to colouring. The app renders an infinite scroll of generated geometric tilings that reveal pseudo-random colour palettes and fill effects when coloured using a finger or pen. A five-day study ($N=28$) evaluated the efficacy of the app in reducing anxiety and enhancing mindfulness. The results indicate that the app is capable of promoting a greater sense of mindfulness over time and produced similar results across several measures compared to traditional structured colouring and existing mindfulness-based mobile applications. All participants expressed a desire to use the app again, with a majority stating they felt more mindful after the study.

CCS CONCEPTS

- Human-centered computing → Interaction tech.

KEYWORDS

colouring, mindfulness, mobile applications, well-being

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1 INTRODUCTION

Mobile devices have an unparalleled capacity to captivate and retain attention. Social media apps such as TikTok and Instagram have been deliberately engineered to maximize user engagement and screen time. However, excessive usage has been linked to increased anxiety, depression, and a decline in overall well-being [62]. Mindfulness, an ancient Buddhist practice, often characterized as a judgement-free awareness of the present moment [10, 34], has been shown to improve mental well-being, physical health, and peace of mind [10, 28, 65]. The majority of mindfulness-based mobile applications (MBMAs) focus on guided meditation, where the user listens to audio recordings of an instructor to meditate. However, meditation is just one of the many ways to practice mindfulness, and may not be suitable for everyone.

Mandala colouring has been shown to reduce anxiety and promote mindfulness [6, 11, 19, 64]. Despite the popularity of adult colouring books [18] and the convenience of mobile apps, little work has been done to evaluate digital colouring as a mindfulness practice. Additionally, existing apps for structured colouring lack a central focus on mindfulness, and often fail to provide an experience akin to traditional colouring [20].

Pause¹ is a popular MBMA using slow, continuous finger movement to help focus on the present moment. It was originally a research project [13] and it was formally compared to Headspace², an MBMA for guided meditation [50]. The results found similar improvements in mood and general well-being. However, Pause intentionally uses a minimal design and several participants expressed a desire for increased feedback and interaction [13]. We take inspiration from adult colouring books to create a more engaging user experience that still follows the core principles of mindfulness.

We present Mindful Scroll, a mobile colouring app for mindfulness that leverages infinite scrolling, a feature commonly associated with social media, to cultivate an uninterrupted state of flow and

¹<https://www.pauseable.com/>

²<https://www.headspace.com/>

relaxation. As users scroll, the app continuously generates pseudo-random geometric tilings (i.e., a set of shapes), with distinct colour palettes and fill styles that are revealed by colouring. To encourage a slow and purposeful approach to colouring, stroke widths adjust according to the speed at which users colour, with thinner strokes corresponding to faster speeds. When a shape is almost completely filled in, the app reveals a colour or pattern. This pseudo-random auto-fill mechanism, along with several other subtle effects, introduces a level of discovery and surprise to keep users focused and engaged as they uncover different patterns (Fig. 1).

We conducted a five-day study to evaluate the impact of the app on mindfulness. The study adopts much of the design used to evaluate Pause [50], using attention, overall well-being, mood, and happiness as measures of mindfulness. Two additional metrics, state mindfulness and state anxiety, were introduced to enable a relative meta-comparison with traditional colouring. Our results indicate that Mindful Scroll has the capacity to cultivate mindfulness, and based on the pattern of results in the original Pause study, it appears to enhance mood and happiness to a greater extent. All participants expressed that they would use the app again and 71% of participants reported an increased sense of mindfulness after the study. A simple version of our app that resembles Pause was used to investigate how different levels of engagement influence the practice of mindfulness. Qualitative results highlight the value of enhancing engagement through visual methods, specifically in the context of MBMAs.

Our work makes two contributions: (1) a novel approach using abstract digital colouring for mindfulness; and (2) an evaluation of the app as an MBMA, while drawing comparisons to an existing MBMA.

2 BACKGROUND AND RELATED WORK

In this section, we provide background on the concept of mindfulness, as well as related work on traditional colouring and existing technologies for mindfulness.

2.1 Mindfulness

Mindfulness has two distinct interpretations in literature. One originates from Buddhism and other cultural traditions, referring to the development of a non-judgemental awareness, particularly through the practice of meditation [10, 34]. The other, emerging from Western scientific literature, is a state of consciousness that extends beyond specific practices. In this paper, we refer to the Western interpretation of mindfulness, distinguishing between state mindfulness—a temporary awareness induced through mindfulness practices, and trait mindfulness—an enduring quality cultivated over time through consistent practice.

Several studies have demonstrated the benefits of mindfulness in terms of both psychological and physical well-being [27, 36, 54]. Mindfulness can be cultivated through a variety of techniques, including meditation, Yoga and Tai Chi. These practices involve maintaining an awareness of the present moment or a particular focal point, such as the slow and deliberate movements in Yoga. They foster a general attitude of acceptance by enabling practitioners to observe their inner thoughts and emotions without judgement. Given the inherent challenge of practising mindfulness [34], practitioners often use a specific point of focus—such as the sound of their

breath—to redirect their attention, rather than attempting to sustain a broader awareness of the present moment [57]. Mindfulness has been shown to improve attention [12, 32], support emotional regulation [4, 24], and reduce symptoms of anxiety and depression [27]. To evaluate whether our app is an effective tool for practising mindfulness, our study design attempts to measure some of these key benefits.

2.2 Colouring

Traditional drawing has been established as an effective tool for improving quality of life. A comprehensive review of prior research on art and healing revealed that drawing enhances cognitive function, mood, and overall well-being [56]. Drawing also has strong connections to mindfulness, particularly techniques that require careful observation and attention to detail [26].

In the past decade, adult colouring books have gained considerable popularity, coinciding with a growing interest in mindfulness [29]. They were the fastest-growing genre among adult books in 2015 and continue to be a popular category today [18]. Marketed as an effective tool for relaxation and stress relief, colouring books provide a simple and engaging way to practice mindfulness. They minimize the pressures often associated with free colouring by providing guidance and requiring less aesthetic curation. Mandala designs are frequently the subject of colouring books due to their intricate and repetitive patterns. They also hold significance among various spiritual traditions, serving as a focal point for meditation [33]. Several works have demonstrated that colouring geometric patterns like mandalas reduces state anxiety and enhances mindfulness [6, 11, 19, 64]. Given the geometric nature of tilings, we seek to determine whether our approach to digital colouring can yield similar benefits.

Mantzios et al. [46] determined that both traditional and app-based mandala colouring are effective in reducing anxiety and improving state mindfulness. However, they use a minimal digital colouring interface where each shape is filled with a single swipe motion, and only the impact of a single colouring session was examined. With our app, users colour in a manner similar to traditional colouring, and we evaluate app usage over multiple days, providing a more comprehensive understanding of digital colouring and its relation to trait mindfulness.

2.3 Mindfulness and HCI

Roquet and Sas [21] conducted an auto-ethnographic review of the 14 highest-rated mobile apps for mandala colouring. Half of them used a tap-to-fill approach (the approach used by the other half was not specified), and all featured a zoom function, simplifying the process of colouring the intricate parts of a mandala. They identified controlled movement and the intricate geometry of mandalas as primary elements contributing to the benefits of mandala colouring, but concluded that apps for mandala colouring, at the time of their evaluation, do not capture the full essence of mandala colouring for wellness. Anima [17] is a system that uses a tablet for mandala drawing, a separate tablet for colour selection, and an EEG headband to monitor brain activity. Based on the detected mindfulness states, the colour options are adjusted to provide feedback and promote observation. While the study focused on the system design, we

evaluate our app's ability to cultivate mindfulness through both quantitative and qualitative methods, and our system approach uses no specialized hardware.

The majority of commercial technologies for mindfulness offer guided meditation as their main feature [15, 42, 45, 50]. Yet, many people prefer more interactive or physically active forms of mindfulness [35], and meditation often requires a quiet and private setting. Niksirat et al. [50] created a framework for the design of interactive MBMAs, where technology is used to detect user attention and provide feedback. As a case study application, they created Pause [13], a mobile app that encourages Tai Chi inspired, slow and controlled finger movements. The app has since been commercialized, but it still uses the minimal audiovisual feedback from the research prototype that is thought to more effectively guide users into a meditative state. When the user moves at a slow speed, a circle expands around their finger, filling the display; but any pauses or rapid movements attenuates sounds and shrinks the circle. In an initial evaluation [13], despite an overall positive response, several participants expressed a desire for Pause to respond more expressively to different movements. The simplicity of the app is deliberate to encourage users to close their eyes and meditate. However, people who struggle to meditate may need more stimulation to stay focused and engaged. Striking the right balance is crucial, as too many interactive elements could make it difficult to achieve a relaxed and meditative state. We aim to gain a better understanding of this delicate equilibrium by evaluating two versions of the app designed to provide different levels of engagement.

Pause is the only well-established mindfulness app designed for slow finger movement instead of guided meditation. We rely on the Pause research as a foundation for our study design and draw on those academic findings to contextualize our app within the broader context of previous work.

3 DESIGN GUIDELINES

Informed by related work, we established five design guidelines for our mindfulness-based colouring app.

3.0.1 Slow Movement. Physical exercises such as Yoga and Tai Chi cultivate a state of relaxation through slow and purposeful body movements. The gradual pace establishes a consistent focal point for practitioners and cultivates a heightened awareness of the body and mind [34]. Despite their numerous benefits, these practices typically require a dedicated space, limiting their convenience. Practices that involve smaller-scale movements, such as the Pause app [50], have demonstrated comparable effectiveness in facilitating relaxation and mindfulness, while also enabling a greater focus on the mind rather than the body. Inspired by Pause, we present a unique approach to colouring that focuses on the physical motion of drawing, emphasizing a slow and deliberate process through subtle feedback.

3.0.2 Limited Autonomy. Adult colouring books include a set of preexisting designs, reducing the need for creative decision making. We take this concept a step further by liberating users from the task of selecting colours and shapes. The app uses automatically generated colours and shapes in a pseudo-random manner. This

introduces an element of surprise that keeps the experience interesting and novel. Rather than manually selecting a design or a set of colours, users can simply open the app and begin colouring. This approach also fosters a sense of acceptance akin to mindfulness [34], as users are prompted to embrace the shapes and colours as they appear. Despite the reduced sense of control, the app still allows for some level of freedom and creative expression. Users have the ability to choose which shapes to fill, and the manner in which the shapes are manually filled. For example, they can completely fill every other shape, or leave some shapes only partly filled. The app does not provide any explicit guidance on how users should colour, other than subtle feedback to encourage them to colour slowly.

3.0.3 Convenience. Since consistency is key to cultivating mindfulness [34], we set out to create a mindfulness practice that prioritizes ease and accessibility. MBMAs have a broader reach compared to other technologies for mindfulness and they can be used in a variety of different settings. Our app is a responsive web application tailored to mobile devices. We exclude the need for any supporting accessories, ensuring that the process of starting and completing a session with the app is quick and convenient. Also, unlike other colouring apps, users can simply open the app and start colouring, without the need to choose a design or a set of colours. While the app is equipped with built-in audio, it remains fully functional without the audio component. This stands in contrast to the majority of MBMAs that mainly offer audio-based guided meditations.

3.0.4 Engagement. Existing MBMAs tend to be minimal and simple by design since their purpose is to help users meditate. Many individuals struggle to achieve and maintain a state of focus when practising mindfulness; however, they could flourish with practices that offer a clear focal point and increased engagement [34]. While the Pause app provides slow finger movement as a focal point, it offers minimal audiovisual feedback. To enhance user engagement, we introduce colouring as a complementary element to slow finger movement, and incorporate additional effects such as pseudo-random fill effects. The unpredictable nature of the app cultivates a sense of surprise and exploration, allowing users to continually discover new facets of the app over time. As one of the three heuristics for enjoyable user interfaces [44], curiosity is recognized in game and user interface design for its ability to enhance engagement. We use curiosity as the basis for many design decisions as it prompts a more implicit form of engagement, preserving the app's primary goal of promoting relaxation and mindfulness.

3.0.5 Focus on the Present. With regular colouring, there is often an underlying pressure associated with the final outcome [11]. However, a fundamental aspect of mindfulness practice involves nurturing a present-moment awareness [34]. To align with this ethos, we purposefully designed the app to evoke a sense of transience, where drawings gradually disappear over time and strokes are sometimes covered by certain fill types. This redirects attention towards the act of colouring itself, minimizing concerns about the eventual outcome. Additionally, in contrast to Pause, which displays textual prompts such as "slow down" or "keep moving", we refrain from providing any explicit guidance. Instead, we use subtle audiovisual feedback to help users focus more on their thoughts and emotions.

4 MINDFULNESS-BASED COLOURING APP

In this section, we provide a detailed description of the app and its core characteristics, including a simple and enhanced version.

4.1 Core Characteristics

Each stroke only leaves a trail of colour within the shape where it originated. To ensure a satisfying colouring experience, colouring outside the lines is not shown, accommodating difference in precision between fingers and physical drawing tools. A small circle on the top right displays the current colour (Fig. 2), which is especially useful in the enhanced version of the app where the colour changes when the user lifts their finger.

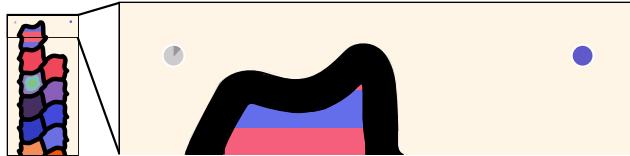


Figure 2: Close-up of the user interface: The left circle indicates the elapsed time during a colouring session, the right circle displays the current colour.

4.2 Soundscape

An ambient soundscape is used to help encourage a mindful approach to colouring. To avoid sounding repetitive over time, the audio is intentionally minimal and devoid of any prominent melody or rhythm. The design of the soundscape was informed by a prior study [23], indicating that music without harmony or melody is more effective at supporting meditation and resulted in higher perceived states of mindfulness. Music with low tonal complexity, minimal melody and harmony, and a steady beat reduces activity in the brain regions associated with mind-wandering and rumination [3, 55]. We selected our soundscape from a library of music for mindfulness based on these principles. Our track resembles gentle waves and soothing white noise, creating a serene atmosphere that accommodates users who struggle with silence or are easily distracted by environmental noise. The subtle and unpredictable nature of a soundscape encourages focus and enhances the colouring experience, without the need for the active engagement often required by listening to a favourite playlist.

4.3 Speed-Responsive Feedback

Visual and audio feedback subtly encourages users to colour at a slow pace by responding to the filtered speed of each touch gesture. For visual feedback, the width of the stroke decreases when the user colours too fast, and increases when the user colours slowly (Fig. 3). This naturally helps the user to slow down the movement of their finger as it takes more time and effort to fill in the shapes when the strokes are thinner. The changes in line width are subtle and reset for every new stroke, to give users the freedom to colour at the pace they find most comfortable, and to prevent them from feeling discouraged or restricted. For audio feedback, we employ a similar approach to Pause, where the volume of the soundscape increases when the user moves slowly and decreases when the user draws too quickly or outside the lines.

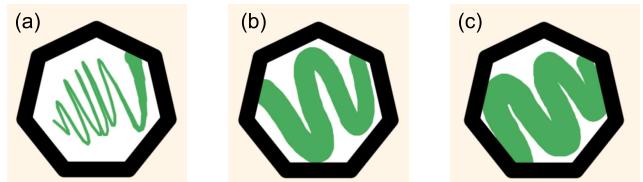


Figure 3: Stroke width changes as a function of colouring speed: (a) fast; (b) slow; (c) very slow.

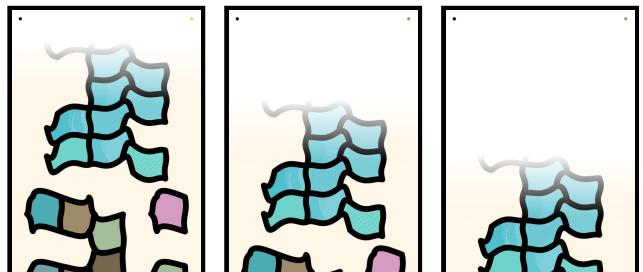


Figure 4: Consecutive screenshots of user scrolling up to see a previous tiling. When the top of the current tiling reaches the display top, the previous tiling fades to white.

4.4 Infinite Scroll

To enhance engagement and encourage prolonged use, we incorporate infinite scrolling, found in popular social media apps like TikTok and Instagram. This feature automatically generates new shapes as the user scrolls up, providing a smooth and uninterrupted colouring experience. The user can scroll with one finger on any part of the display not occupied by a shape or with two fingers anywhere. When the user colours on the bottom fifth of the display, the shapes automatically scroll up slowly and continuously. This eliminates the need for manual scrolling, offering a smooth and more continuous colouring experience. If desired, the auto-scroll can be stopped by touching any part of the display that is not a shape, or performing a manual scroll gesture.

To simulate an endless scrolling experience, when the user scrolls beyond a certain threshold, the app initiates a refresh process—it redraws a portion of the existing tiles and strokes, while simultaneously adding a new set of tilings underneath. To prevent a detectable slowdown, we pre-render new tilings on a buffer canvas and break down the refresh process into smaller steps, handling larger tasks asynchronously when possible. This ensures that the refresh happens in the background, even when the user is actively drawing or scrolling.

4.5 Transience

When the user scrolls up, the previous drawings are partially revealed to look as though they gradually disappear. This is inspired by Buddha boards [63], where paint strokes slowly evaporate over time. The decision to make drawings ephemeral is intended to promote a heightened awareness of the present moment and encourage mindfulness. By not emphasizing the final product, users can fully immerse themselves in the act of colouring and the movement of their finger. Also, the app omits features like undo, erase, save, and print to further reinforce this focus on the present moment. Users

can effortlessly scroll down to the next shape or set of shapes if dissatisfied with the current display, leaving it in the past—a practice that harmonizes with the non-reactive aspect of mindfulness. Additionally, scrolling down embodies the act of letting go, empowering users to release feelings and emotions in the same way they would while drawing.

4.6 Time

For the purpose of the study, we added a small timer at the top left of the display to indicate the amount of time remaining during a colouring session (Fig. 2). When 10 minutes has elapsed, the timer turns a slightly darker shade of grey, offering a gentle signal to users without disrupting their flow. This allows users to continue their session even after the set time, offering the freedom to preserve their meditative state for as long as they desire. We wanted time to be inconspicuous unless intentionally sought out by the user. In contrast, Pause displays a message on the screen once the set time has elapsed and ends the session once the user lifts their finger. Similarly, guided meditations end once the audio or video track is complete, regardless of the user's willingness or desire to continue.

4.7 Simple Version

We created two versions of the app: SIMPLE with similar interaction levels to Pause, and ENHANCED with more effects and variation. In SIMPLE, shapes are randomly chosen from a set of 14, including squares, circles, and triangles (Fig. 5). The different shapes are approximately the same size and the size of each kind of shape is fixed. Each shape is associated with a unique colour, randomly generated at the beginning of each new session. The limited selection of shapes is meant to create a more minimal experience in comparison to ENHANCED.

4.8 Enhanced Version

The enhanced version of the app uses complex shapes to increase engagement, as visually complex figures elicit increased levels of attention and curiosity [8, 58]. The app randomly generates a tiling from the 81 isohedral tilings, each containing a single shape repeated with no gaps [37]. We use tactile³, an open-source JavaScript library to generate the tilings. We modified the code to introduce a parquet deformation effect [38], where the tiles transform from top to bottom while retaining their general shape. Additionally, we incorporated pseudo-random variations in the width and overall profile of each tiling (Fig. 1), which are more pronounced on larger displays, such as tablets.

4.8.1 Colour. Each tiling is randomly assigned its own unique colour palette of four distinct colours. We used an open-source API⁴ to extract over 1000 popular colour palettes from Color Hunt⁵. When the user is not actively colouring, the current colour gradually shifts to a lighter or darker shade. This is done by altering the luminance of the colour while holding the hue and saturation constant. After six seconds, the colour shifts to another colour from the current colour palette. The colour does not change when the user is actively colouring. These variations in colour are designed

to increase engagement and enable more creative expression, allowing users to fill shapes with multiple colours and see overlapping strokes. This stands in contrast to SIMPLE, where the task is centred around filling each shape with a single constant colour.

4.8.2 Auto-Fill. When a tile is more than 90% filled, the app automatically fills the rest of the tile. As the user colours, the outline of the current tile expands and contracts to subtly indicate when the 90% fill threshold is passed. They have the option to continue their stroke or lift their finger or stylus and observe how the system completes the tile.

We implemented a variety of fill, stroke, and dot types to add an element of surprise to the colouring process, with the objective to increase user engagement. The attributes of each tile are determined by distinct sets of weights, unique to each tiling. For instance, every tiling has its own unique set of fill types (e.g., solid and stripes) with corresponding weights that determine how often each fill type occurs (e.g., .8 for solid and .2 for stripes). This approach instills a level of predictability and familiarity, allowing users to somewhat discern the underlying rules of each tiling as they colour. It also enhances visual appeal by preventing an assortment of fill types within the same group of tiles. Although predictability and surprise are contradictory concepts, we seek to explore and understand their balance. A lack of predictability may lead to chaos and confusion, whereas excessive predictability may cause disinterest; the objective is to find a middle ground to inform the design of more effective mindfulness experiences.

The auto-fills are often simple solid fills that use existing colours within each tile, such as the first or last colour used, the most or least used colour within the tile, or a mean hue. In less frequent cases, the final colour is the inverse or complement of one of the aforementioned choices. The fill colour may also gradually fade in from one side of the tile as opposed to an immediate auto-fill. Pattern fills include stripes at varying angles, linear and radial gradients, and nested outlines, where the shape outline is repeated multiple times at decreasing scales (Fig. 7). Each pattern uses two to five colours, and colour sets are determined by the number of colours in each tile and their degree of similarity. There are also post-fill effects when one or more filters are applied after a tile is filled. These include a Gaussian blur, and varying degrees of dithering and pixelation.

4.8.3 Additional Variations. While the app primarily uses the same stroke style as SIMPLE, it introduces three additional stroke types: blurred, transparent, and dotted (Fig. 8). The stroke styles have matching dot types, activated when the user taps within a shape instead of dragging. For example, the transparent stroke always has a transparent dot. The regular stroke has two additional decorative dot types, resembling a flower and a clover. Pseudo-random rules establish connections between stroke types and auto-fill; for example, tiles coloured with the blurred stroke are more likely to use the blurred fill effect.

Animation adds an additional dimension of variety. In rare cases, a watercolour effect is used to fill a tile, slowly extending the colour through a radial gradient to the neighboring tiles. A similar gradient effect can be explicitly created within an individual tile if the user holds their finger or stylus steady for more than 1.5 seconds.

³<https://github.com/isohedral/tactile-js>

⁴<https://github.com/SrgGroot/colorhuntapi>

⁵<https://colorhunt.co/>

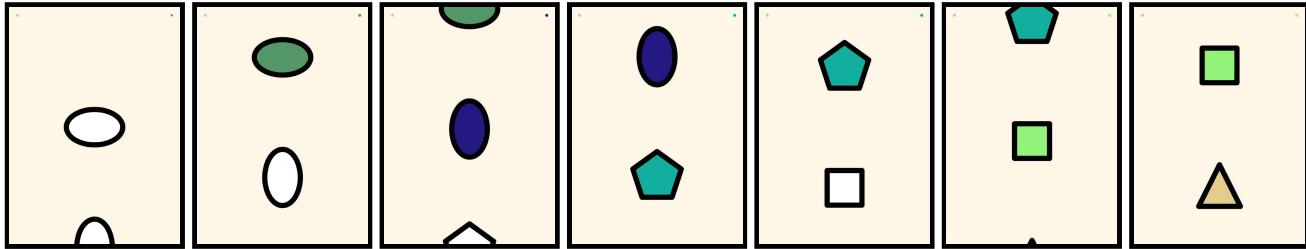


Figure 5: Example 3 minute time-lapse of simple version where the user fills each shape completely before moving to the next.

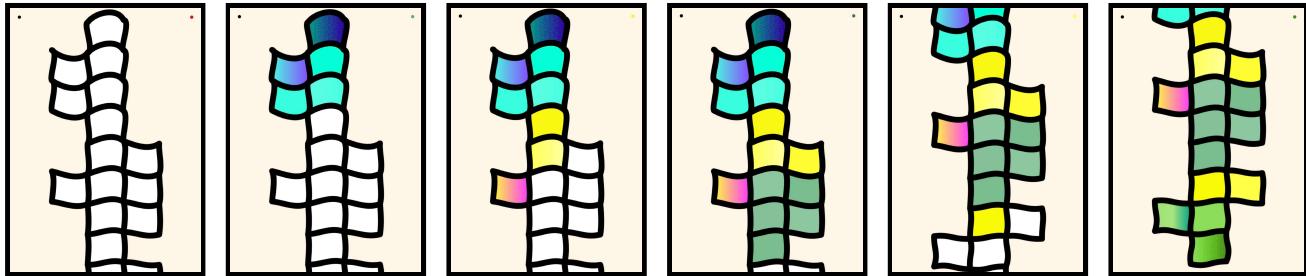


Figure 6: Example 3 minute time-lapse of enhanced version where the tiling is filled completely. The tiles are coloured from top to bottom and the gradient fill type occurs throughout. The dither post-fill effect is used after the gradient on the top and bottom tiles.

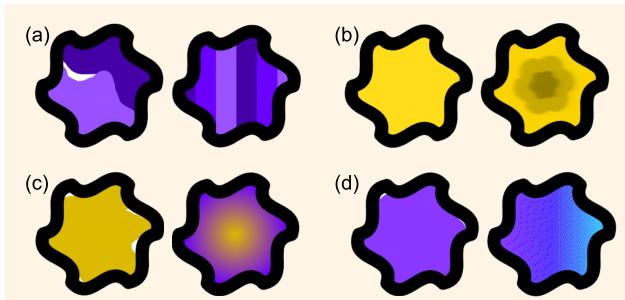


Figure 7: Before and after examples of the auto-fill effect: (a) vertical stripes using the two input colours and an intermediate colour; (b) nested outline with the blurred post-fill effect; (c) radial gradient using the input colour and another colour from the current colour palette; (d) horizontal gradient with the dither post-fill effect. The first shape for each example depicts the state immediately before the auto-fill, where at least 90% of the shape is filled.

Although there are a multitude of variations, the different effects are revealed in a slow and subtle way. For example, it is rare for a single tiling to include more than one pattern type or stroke style. In addition to making the app more engaging, the various fill effects also lessen control over the outcome of colouring. Recall, mindfulness involves responding to thoughts and emotions without judgement. Users can practice this aspect of mindfulness when they encounter a fill that is not what they had expected or when their original strokes are no longer visible. The aim is to observe and move forward without getting caught up in preferences. It is about letting go of expectations and embracing the present moment.

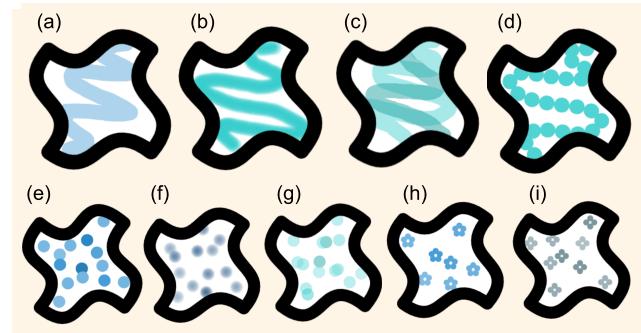


Figure 8: Stroke types (a-d): (a) regular; (b) blurred; (c) transparent; (d) dotted. Please note, (c) contains two strokes rather than one to show the transparent effect. Dot types (e-i): (e) regular; (f) blurred; (g) transparent; (h) flower; (i) clover.

5 EXPERIMENT

The goal of this experiment is to determine whether our approach to digital colouring fosters mindfulness and well-being at a level comparable to other MBMAs. We also seek to understand how the level of engagement within an MBMA shapes the user experience and the cultivation of mindfulness. We conducted a five-day study that is a near replication of the study comparing Pause to Headspace [50]. Participants were randomly assigned to either the simple or the enhanced version of the app and to a phone or tablet device (Fig. 9). Each participant used the app for ten minutes each day. To measure their mindfulness levels, participants completed questionnaires before the initial session and after the final session. Additionally, a semi-structured interview was conducted after the experiment to gather qualitative feedback.

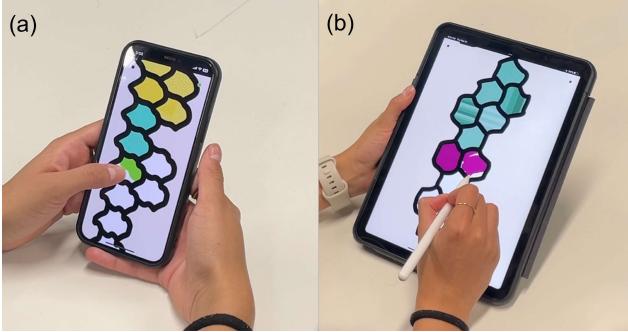


Figure 9: Device conditions: (a) phone with touch; (b) tablet with stylus.

We use a five day period because previous work established three to five days as an adequate time frame for enhancing mindfulness [50, 60, 66]. Consistent with these studies, we administer the questionnaires before the initial session and immediately after the final session to measure mindfulness levels. In the Pause study, participants used the app for 20 minutes each day, with a five-minute break in between, though the reason for this structure is not provided. Since 10 minutes of daily mindfulness practice was found to be equally as effective as 20 minutes [7], we asked participants to use the app for a minimum of 10 minutes a day to minimize the time commitment required. This also aligns with the majority of MBMAs that recommend practicing mindfulness for approximately 10 minutes a day [51]. Furthermore, the Pause study had participants complete the questionnaires and an attention test a day before using the app. We had participants complete these questionnaires on the same day as the first session.

5.1 Participants

We recruited 28 participants, all of whom completed the entire five-day experiment once with either a phone or tablet device. Due to scheduling issues, one participant used the app for 6 days and another for 7 before completing the post-training questionnaires and interview. The average age was 24.6 years (min: 19, max: 35); 15 were female, and 13 were male, 23 participants were right-handed and 5 were left-handed. Participants were recruited using email and social media, and received \$50 for completing the experiment. 18 participants used the app on a phone and 10 used it on a tablet with a stylus. We received Research Ethics Board approval from the University of Waterloo, and informed consent was obtained from each participant.

When asked to describe how often they practised mindfulness in the past 12 months, the responses were diverse: one participant said never; 13 mentioned only a few instances per year; three practised less than once a month; four said around once or twice a month; and six practised at least once a week; none reported practising every day. Among the 28 participants, 18 had previously used a MBMA, and 15 had used traditional art media to practice mindfulness. Regarding their experience with technology for mindfulness, several mentioned having experience with guided meditation apps. See Appendix A.2 for detailed participant demographics.

5.2 Apparatus

Participants used the app on either their personal phone or tablet with stylus. They were told to use the app with the same device for the entire study. Their interactions, including the position, speed, and frequency of touch or stylus input, were logged to a file, and screenshots of the app were captured every 10 seconds. On the first day, participants were shown how to add the app to their home screen for ease of access and to ensure it runs in full-screen mode. They were informed to click on the timer anytime after the 10 minute mark to access the daily questionnaire. For each session, participants were advised to find a comfortable location with few distractions and to turn off all device notifications. Moreover, participants had the option to mute the app's audio if they preferred.

5.3 Procedure

The participant came to our lab on first day. We asked about their experience with mindfulness and technology, they completed an attention network test (ANT), then answered five questionnaires to assess state mindfulness, state anxiety, general well-being, mood, and happiness. Then they were shown how to add the app to their home screen, and given a brief tutorial to explain basic usage, such as how to colour and scroll, and what the timer and the colour preview indicate. They were not told how the app worked or about any of the hidden features. Then the participant used the app for 10 minutes in a quiet room and completed the daily questionnaire. Then they completed the questionnaires on state mindfulness and state anxiety once again, concluding the first day of the study. For the next three days, the participant used the app sometime during the day for at least 10 minutes, and completed the daily questionnaire immediately after. On the fifth day, they returned to the lab to complete their fifth session, complete the attention test again, then the same questionnaires on well-being, mood, and happiness. Finally, they took part in a 30 minute semi-structured interview (see Appendix A.1 for interview question guide).

5.4 Design

This is a mixed design with three primary independent variables: TRAINING is within subjects with 2 levels (UNTRAINED for pre-app usage, TRAINED for post-app usage); APP is between subjects with 2 levels (SIMPLE, ENHANCED); and DEVICE is between subjects with 2 levels (PHONE, TABLET). Participants were randomly assigned to APP and DEVICE groups.

5.5 Measures

We used attention, well-being, mood, and happiness as measures of mindfulness, and justify these measures by referencing mindfulness practices shown to improve each area. We included questionnaires on state mindfulness and state anxiety, which we frequently encountered in our review of existing research on colouring [11, 19, 39, 46]. This not only allowed us to gain insights into the effects of our app following a single session but also facilitated a meaningful comparison with traditional colouring. We also introduced a daily questionnaire to gain further insights into the user experience over the course of the experiment.

5.5.1 Attention. Mindfulness practice is linked to improved attention as it involves regulating attention and resisting distractions. The ANT is a widely used tool in psychology to measure attention. Participants are presented with a set of arrows in quick succession and must indicate their orientation (right or left) by pressing the appropriate keys. The test identifies three components of attention: alerting (sustaining attention), orienting (directing attention), and executive (resolving conflicts between multiple potential responses). It has been used in previous studies on mindfulness [2, 50] which found a positive correlation between mindfulness practice and improved executive attention.

5.5.2 Well-Being. The Psychological General Well-Being Index (PGWBI) [22] is a 22-item questionnaire that measures well-being. Participants rate statements like "How have you been feeling in general during the past month?" on a 6-point numeric scale. This questionnaire has been used in studies to demonstrate the effectiveness of various mindfulness-based interventions [1, 14, 49, 50].

5.5.3 Mood. The Profile of Mood States (POMS) [48] is a 65-item questionnaire that uses a 5-point numeric scale. It lists a series of adjectives or phrases such as "friendly" and "tense", and participants rate each from 0 (not at all) to 5 (extremely), based on how they were feeling in the past week. The results can be categorized to six dimensions: tension, depression, anger, fatigue, confusion, and vigour. Total Mood Disturbance (TMD) captures overall mood by combining the scores of all subscales, except vigour which is subtracted. POMS has been used in existing work that found a positive impact of mindfulness training on mood [25, 53], including one study [61] on the effects of a short-term (20 minute) meditation technique applied over a span of five days.

5.5.4 Happiness. The Subjective Happiness Scale (SHS) [43] is a 4-item questionnaire where participants respond both in absolute terms (e.g., "In general, I consider myself...") and in relation to others (e.g., "Compared to most of my peers, I consider myself..."). Each question uses a 7-point numeric scale where 1 is "not very happy" and 7 is "very happy." We include this questionnaire due to the established connection between mindfulness and happiness in previous research [16, 50], supported by evidence showing that mindfulness increases positive affect and reduces negative affect [9, 52].

5.5.5 State Mindfulness. The State Mindfulness Scale (SMS) [59] is a 21-item questionnaire, utilizing a 5-point numeric scale ranging from 1 (not at all) to 5 (very well) for responses. The items evaluate the extent to which participants experienced a state of mindfulness within the past 10 minutes. The questions can be divided into two sub-scales: the mind scale includes statements like "I noticed pleasant and unpleasant thoughts," while the body scale has statements such as "I clearly physically felt what was going on in my body."

5.5.6 State Anxiety. The State Anxiety Inventory (SAI) [47] is a 20-item questionnaire, where each item is rated on a 4-point numeric scale ranging from 1 (not at all) to 4 (very much so). It is commonly administered alongside the SMS to explore the temporary effects of various mindfulness practices. Participants respond to statements such as "I feel calm" based on how they feel in the present moment. We include this questionnaire as traditional mindfulness practices are known to provide relaxation and reduce anxiety [34].

5.5.7 Daily Questionnaire. The questionnaire consists of five Likert-type questions that ask participants to reflect on their app experience that day. The questions focus on how engaging the app was and how it made participants feel (Fig. 13). There is also a section for participants to describe their overall experience in more detail.

6 QUANTITATIVE RESULTS

For each questionnaire, an ANOVA was used unless the data was not normally distributed, in which case the test was Friedman with post hoc pairwise Wilcoxon-signed rank. Normality was tested with Shapiro-Wilk. When the assumption of sphericity was violated, degrees of freedom were corrected using Greenhouse-Geisser ($\epsilon < 0.75$) or Huynh-Feldt ($\epsilon \geq 0.75$). For each measure, trials were aggregated by participant and factors being analysed. Effect size was measured by generalized eta square, with values near 0 indicating minimal influence and values near 1 indicating a substantial influence on the measured effect [5]. There was no significant difference between phone and tablet users on any measures, so we present results for both devices collectively. We also test for the effect of TRAINING separately for SIMPLE and ENHANCED given the focus of our study. We include general meta comparisons to Pause and Headspace [50], as well as traditional colouring [11, 19, 39, 46] to help situate our results relative to those previous works.

6.0.1 Attention. With consistent practice, the app has the potential to enhance attention. Lower executive attention scores in the ANT indicate reduced impact from distractors and an enhanced ability to sustain focus. Executive attention scores were positively affected by the app ($F_{1,24} = 18.62, p < .00002, \eta^2_G = .074$), with the mean score changing from 75.4 ($SD = 27.2$) when UNTRAINED to 63.0 ($SD = 25.8$) when TRAINED. There is no main effect on response time, alerting, or orienting. The mean accuracy, representing the average number of correct responses to each target, declined over the course of the study. There was a main effect of TRAINING on Mean Accuracy ($\chi^2_F(27) = 44.93, p < .017$), with UNTRAINED ($M = .98, SD = .01$) exhibiting higher performance compared to TRAINED ($M = .98, SD = .02$). While this suggests a decrease in performance due to the app, the difference in means is relatively minor. Pause and Headspace demonstrated similar results, with executive attention being the only component affected by training. However, users of Pause also had a significant decrease in response time.

6.0.2 Well-Being. Participants felt an improvement in overall well-being after using the app for five days. There was a main effect of TRAINING on quality of life ($F_{1,24} = 4.53, p < .043, \eta^2_G = .025$). With higher scores indicating higher levels of perceived wellness, the mean of TRAINING increased from 2.88 ($SD = .68$) to 3.05 ($SD = .53$). This aligns with findings from previous works, such as Pause and Headspace, showing the comparable effectiveness of our approach.

6.0.3 Mood. The app improves mood, with ENHANCED having a greater effect than SIMPLE (Fig. 10). There are main ANOVA effects for TRAINING on TMD, tension, depression, anger, fatigue, and confusion (ANOVA results in Table 1). The ENHANCED group had a significant decrease in TMD, tension, depression, anger, fatigue, and confusion, while the SIMPLE group only had an effect on TMD, tension, depression, and anger. In all cases, the score improved between 1.4 to 11.0 after using the app (indicated by a decrease for

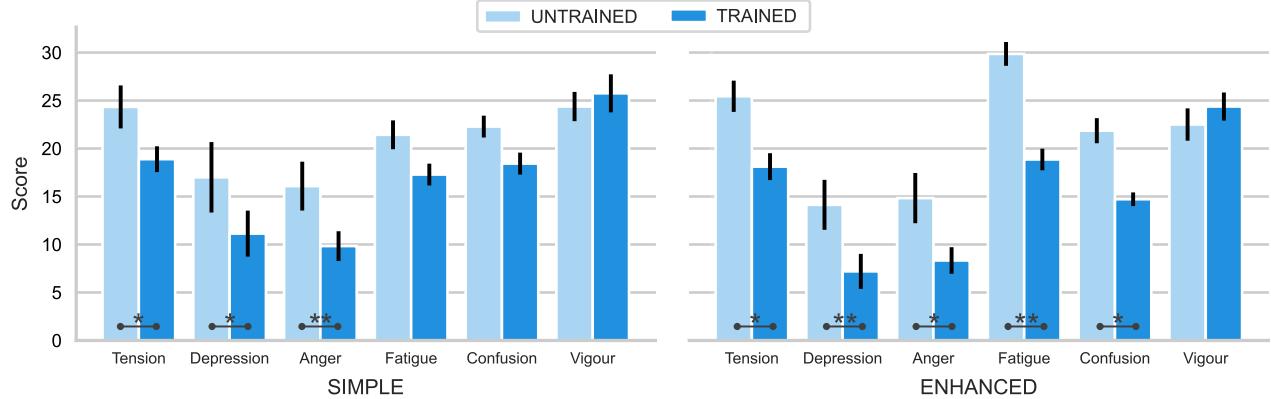


Figure 10: Scores from the POMS by TRAINING for each APP. Lower values indicate less mood disturbance in dimensions except for vigour which is the inverse. (In all graphs, error bars are SEM and significant differences shown as horizontal bars.)

all subscales except *Vigour*), with the greatest decrease from 29.9 to 18.9 for *Fatigue* with ENHANCED. For comparison, SIMPLE and Pause had a positive impact on only three of the six subscales (TMD was not reported for Pause). The results indicate that ENHANCED is more effective at improving mood than both SIMPLE and Pause.

6.0.4 Happiness. Users of ENHANCED felt happier at the end of the study. There was a significant effect of TRAINING for ENHANCED ($F_{1,12} = 5.27, p < .041, \eta^2_G = .019$), as happiness before training ($M = 4.13, SD = 1.48$) was lower than happiness after ($M = 4.48, SD = 1.40$). There was no significant effect on happiness for SIMPLE. Interestingly, Pause had no significant effect on happiness.

6.0.5 State Mindfulness (SMS). The app had no effect on state mindfulness when the SMS was administered before and after the first session (Fig. 11). However, in our analysis of the mind and body subscales, the app elicited an enhanced state of cognitive mindfulness (Fig. 12). There was a main effect of TRAINING on the mind subscale ($F_{1,12} = 7.28, p < .019, \eta^2_G = .12$), but there was no main effect of TRAINING on the body subscale. This suggests the app is only capable of evoking a temporary state of mindfulness in relation to the mind, not the body.

6.0.6 State Anxiety (SAI). Participants felt considerably less anxious after using the app for the first time (Fig. 11). There was a main effect of TRAINING ($F_{1,24} = 26.97, p < .000025, \eta^2_G = .16$) and for only ENHANCED ($F_{1,12} = 25.64, p < .0002, \eta^2_G = .27$) and only SIMPLE ($F_{1,12} = 6.1, p < .030, \eta^2_G = .074$). With higher scores indicating a higher level of state anxiety, both versions of the app reduced stress and anxiety among participants. For ENHANCED, the mean score was 43.2 ($SD = 9.89$), which decreased to 32.9 ($SD = 7.94$) after the first session. For SIMPLE, the initial score was 40.5 ($SD = 14.14$), which decreased to 35 ($SD = 10.48$) after the first session.

6.0.7 Daily Questionnaire. Participants had a positive daily experience with the app (Fig. 13): 83.2% reported feeling engaged, 74.8% felt that time passed quickly, and 82.5% found it easy to focus ("agree" or "strongly agree" selected). Additionally, a majority (79.2%) felt relaxed while using the app, with 79.0% feeling more relaxed after each session. There was no significant difference in

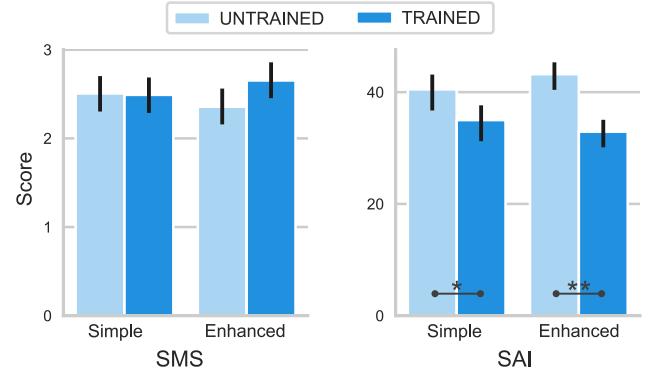


Figure 11: Scores for the State Mindfulness Scale (SMS) and State Anxiety Inventory (SAI) by TRAINING for each APP. For SMS, lower values correspond to lower levels of state mindfulness. For SAI, lower values correspond to lower levels of state anxiety.

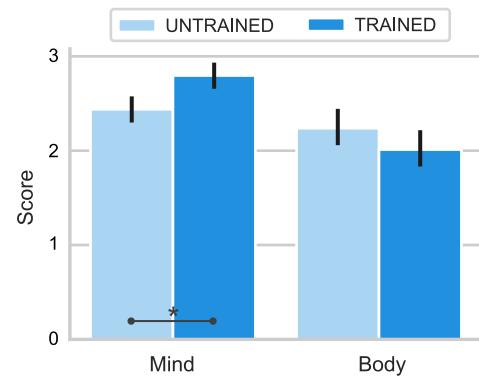
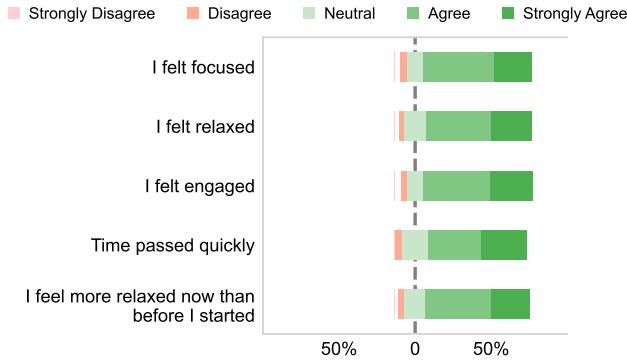


Figure 12: Scores for the SMS mind and body subscales by TRAINING. Lower values correspond to lower levels of state mindfulness in the mind or body.

the responses between SIMPLE and ENHANCED, or over the course of the experiment.

Table 1: ANOVA analysis for Mood measures.

Measure	TRAINING			TRAINING FOR SIMPLE			TRAINING FOR ENHANCED		
	$F_{1,24}$	$p <$	η^2_G	$F_{1,12}$	$p <$	η^2_G	$F_{1,12}$	$p <$	η^2_G
<i>TMD</i>	17.80	.0003 ***	.18	7.70	.0168 *	.15	10.14	.0079 **	.21
<i>Tension</i>	10.62	.0033 **	.10	5.17	.0422 *	.08	5.45	.0376 *	.11
<i>Depression</i>	16.49	.0004 ***	.14	6.80	.0229 *	.13	10.18	.0078 **	.16
<i>Anger</i>	16.66	.0006 ***	.11	11.35	.0056 **	.15	5.16	.0423 *	.08
<i>Fatigue</i>	13.08	.0014 **	.13	2.38	.1488 ns	.05	12.19	.0044 **	.22
<i>Confusion</i>	7.88	.0098 **	.09	1.90	.1934 ns	.05	6.52	.0253 *	.13
<i>Vigour</i>	1.60	.22 ns	.02	.65	.4345 ns	.01	.95	.3492 ns	.03

**Figure 13: Daily questionnaire responses.**

7 SEMI-STRUCTURED INTERVIEW RESULTS

We discuss qualitative feedback from the semi-structured interviews analyzed using affinity diagramming [30, 31, 41], a bottom-up, inductive approach. We extracted pertinent comments from the interviews, generated 20 codes to capture the main message of each comment, and then grouped codes into categories using a diagramming tool. Through an iterative process, we identified ten high-level themes based on both the volume of comments within each category and their relevance to mindfulness. See Appendix A.3 for a list of all individual codes. We refer to participants based on whether they used the simple version (S) or the enhanced version (E), for example S3 and E20.

7.1 Cultivation of Mindfulness

Several participants were able to effectively practice mindfulness while using the app. They said they could think more clearly and observe their thoughts with less judgment: “*While colouring, I was thinking about things, but I wouldn’t dwell on a single thought for too long. I would notice them come and go*” [S3] and, “*Any thoughts that came up felt irrelevant for some reason. I would make note of them and let them pass, which left me with a clear mind*” [E20]. Many expressed that the app was engaging enough to prevent overthinking or rumination, while also enabling them to think freely and thoroughly process their feelings and emotions. Participants less practised in mindfulness tended to use their time on the app for active thinking, such as problem solving or planning. While this deviates somewhat from traditional mindfulness practice, it highlights the app’s versatility in meeting diverse user needs.

Overall, 20 of the 28 participants felt more mindful after using the app for five days (71.4%), with several expressing an increased sense

of relaxation and mental clarity. While a couple of participants were cautious about attributing any changes in well-being to the app, some acknowledged the possibility that over a longer period of time, more significant benefits could emerge. Numerous participants described experiencing less stress and reactivity, which is one of the core principles of mindfulness: “*I feel less bothered by trivial things, like I have more control over my thoughts*” [E4], and; “*I realized that a lot of thoughts that come to mind aren’t worth stressing over*” [E20]. Participants also felt an increased sense of awareness: “*I definitely started to notice things in my surroundings more than I typically do*” [E1], and “*It made me realize how I struggle to let go of things as they happen*” [E28].

The experiment prompted many participants to look for other ways to incorporate mindfulness into their routines, with some mentioning tangible steps they took such as going for a walk, making a nice meal, or taking a day off from work. These actions demonstrate how, through regular use of the app, participants began to recognize the value of consistent mindfulness practice. E19 even expressed, “*I have to be ready to relax when I use Headspace. The app made me feel ready after only a couple days.*” This illustrates how the app can be used as a bridge to other mindfulness practices, such as traditional meditation, that require some pre-existing level of focus and relaxation.

7.2 Variation

Unaware of an alternative app, several users of the simple version expressed a desire for more variety: “*I would use the app again if there were more features. It may be too dull to use on a regular basis*” [S5]. Participants valued the unpredictability of the simple version and looked forward to uncovering what the next colour or shape would be. However, they felt that the lack of variation made it difficult to focus, particularly when colours and shapes would repeat in succession. Some began to experience a sense of monotony over the course of the experiment: “*It started to feel a bit similar, like every day I was doing the same thing*” [S3]. In contrast, the enhanced version received acclaim for its diverse set of effects: “*I was surprised by how many features it had. It felt good to find new and interesting things with the app*” [E7]. Our study shows how variety can be used within the context of mindfulness to sustain user focus and engagement.

7.3 Forms of Feedback

There was a positive response to the different types of feedback and their subtlety. The majority of participants were able to determine

the connection between speed and the thickness of strokes by the end of the first session. However, E2, S8, S22, S25, and E28 thought the changes in line width were random or controlled by pressure. This attests to the subtlety of the feature, and illustrates how some individuals took more of an inquisitive approach to the experience than others. The changes in line width were successful in guiding participants to move at a slower pace: *"The slow movement felt intuitive. The slower I went, the easier it would be to colour in a block"* [E1]. Being such a subtle form of feedback, participants could naturally adopt a slower pace without needing to make a conscious effort or disrupt their train of thought. Several participants noticed their thought patterns adapt to the speed at which they coloured, with many experiencing increased relaxation and a heightened awareness of their thoughts while colouring slowly. Collectively, these observations demonstrate the efficacy of the visual cues in encouraging slow movement and a state of mindfulness.

Participants were divided on the audio aspect of the app: some did not understand why the volume was changing, whereas others found it helpful as a reminder to slow down. When asked about the audio, E20 noted, *"The music was more like background noise, I was more focused on the actual colouring aspect than the audio."* Since colouring is such a visually immersive activity, participants may have paid less attention to the audio aspect of the app. A couple participants did not use the audio for practical reasons, such as forgetting to turn up their volume or not having headphones readily available. This highlights the minor inconveniences of initiating audio-based mindfulness activities. Coupled with fact that many participants chose to use the app without audio, it is evident there is a niche for MBMAs that extends beyond guided meditation and other audio-based practices.

Unlike the majority of MBMAs, the app does not offer any form of verbal feedback. Three participants valued the absence of spoken or written feedback: *"With guided meditation, there's someone else talking to me, so I have less self-awareness...I could notice when words were in my head. The words came from me and they weren't a reaction to something I read or heard"* [E24]. Verbal cues can introduce distractions and disrupt the natural flow of thoughts [40].

7.4 Relaxation

Despite requiring some level of active engagement, all but one of the participants felt relaxed when using the app (96.4%). Participants felt that relaxation came easily, unlike other mindfulness practices that require a conscious effort to clear the mind and relax. S23 preferred the app to Headspace, stating, *"It can be anxiety-inducing when you're trying to focus and meditate but it's not working. It seems too purposeful...With this app, it takes your mind off of whatever is causing you stress and it feels more natural to meditate."* The act of colouring helped people naturally ease into a state of focus and relaxation. A participant with ADHD found solace in the app's continuous interaction, expressing, *"I'm really restless a lot of the time, so having a sort of outlet to put my energy into helped me to relax and just be in my head"* [E11]. By providing a simple means of distraction, participants were able to relax more easily.

7.5 Focus

With traditional meditation, focus can be difficult to maintain, especially when there is no distinct focal point. The app provides colouring as a focal point, and the majority of participants found it easy to direct and maintain their attention towards it. The variety of effects in the enhanced version instilled a sense of curiosity and exploration among participants, enhancing their ability to concentrate: *"I would use it for more than ten minutes because I wanted to continue to discover new shapes, colours, and features"* [E6]. While a couple users of the simple version found it difficult to concentrate, others found even the small variation of shapes and colours was enough to maintain engagement. This shows the degree to which attention spans can vary, emphasizing the need for MBMAs to accommodate these differences. Developers, however, should be cautious when tailoring MBMAs for those with shorter attention spans, ensuring that there remains a level of resistance for users to enhance their attentional skills.

7.6 Sense of Achievement

Participants enjoyed the process of colouring and filling in the shapes. They felt that the colouring was an easy and simple way to feel a sense of accomplishment: *"You are able to complete so many things in succession. It's like popping bubble wrap and it feels good"* [S21]. Users of the enhanced version felt a similar sense of achievement when the tiles would fill automatically, with E18 even associating the effect with a *"hit of dopamine."* E18 shared their previous experience with Pause: *"I feel like it's missing something. The session ends and I feel nothing."* MBMAs typically refrain from providing explicit forms of reward, choosing instead to rely on the inherent fulfillment of mindfulness practice. Structured colouring naturally cultivates a sense of accomplishment, without compromising the relaxing nature of the practice.

7.7 Present-Moment Awareness

Since infinite scrolling fosters a sense of continuous progression, a few participants were unaware that the drawings were gradually disappearing. Participants who noticed responded positively: *"I feel like I am constantly thinking about the future, and I hardly focus on the present. I interpreted it as a metaphor to focus on the present moment"* [S4]. The feature induced a greater sense of relaxation, as users could focus more on the process of colouring than on an eventual outcome.

7.8 Acceptance

Participants expressed an understanding and, in some cases, an appreciation for the constraints that the app imposed. Several recognized that more freedom would compromise their ability to relax and practice mindfulness: *"I would have liked the ability to make more choices, but with that would come less of a capacity to be mindful. The lack of control forced me to go with the flow and stay attentive"* [S1]. The app facilitates a more relaxing and immersive experience by alleviating the cognitive load associated with increased autonomy. Additionally, with more control, users can feel a greater sense of pressure over the final outcome, which shifts their focus towards the future rather than the present.

The limitations imposed by the app prompted participants to cultivate the skill of acceptance. Over time, many became more receptive to the experience: “*At first, I was upset that I couldn’t pick the colours. Then I realized it took the decisions out of my hands and I could just enjoy the act of painting*” [E25]. Similar to the practice of mindfulness, where thoughts and emotions are accepted without judgement, participants released judgement and embraced the process of colouring with constraints. E28 expressed a shift in their approach to making art: “*I noticed I was trying different mediums and being a lot more carefree with the way I was drawing...I was letting myself have more creative freedom and letting go of some of the rules in my head*.” This not only showcases the app’s ability to influence creative processes but also attests to its potential in cultivating an awareness that extends beyond the app.

7.9 Boredom

Boredom allows for free thinking and an increased awareness of the mind and body; however, people often seek ways to escape it when it arises. This is evident by the way users of the simple version experimented with different drawing styles: “*I tried to come up with different ways to colour, as a way to be creative, like colouring in half of a shape, only using dots, and leaving some shapes empty*.” [S24]. Users of the enhanced version tried to make connections between their colouring techniques and the resulting effects generated by the app. One participant noted, “*I tried to look for connections, like if specific colours caused certain effects. I liked experimenting to see if the different features were input related*” [E7]. Participants experienced some sense of boredom when using the app, which caused them to look for constructive ways to enhance engagement.

A participant well-versed in guided meditation recognized how the app facilitated different aspects of mindfulness: “*When a shape would change, it was like letting go of a thought. I had to keep scrolling and try not to let it bother me*” [E24]. The app provides a visual approach to practising acceptance, which offers a more direct experience compared to one solely based in thoughts and emotions.

7.10 Potential for On-going Use

All participants said they would use the app or a more refined version of it again. Two participants even continued to use the app post-study. Consistency is an essential part of cultivating mindfulness, and its challenge makes this result even more noteworthy. Participants mainly said they would use the app before bed, after work, during times of stress, and when transitioning between tasks. Their reasons for repeated use were more diverse, but ultimately revolved around the benefits of mindfulness and the convenience of it being a mobile app.

8 DISCUSSION

Overall, we found that our app enhanced mindfulness. It improved attention and well-being, and had positive effects on mood and happiness. Participants reported reduced anxiety and stress after their first session, underscoring the app’s capacity to promote relaxation. However, some participants did not understand the changes in line width and thus never adopted a slow approach to drawing. Providing more explicit guidance at the outset, rather than relying on

minimal instructions to promote curiosity, could have enabled participants to experience the app’s intended benefits more effectively. We received positive feedback on the app’s diverse visual effects, its subtle visual and audio feedback, and the absence of verbal cues. Participants experienced an enhanced sense of mindfulness when using the app, highlighting clear thinking and the ability to observe thoughts without judgment.

No app can target mindfulness directly; ultimately it must present some proximal task believed to promote mindfulness as a side effect. Below, we reflect on two outcomes of our decision to focus on abstract colouring: (1) the effect of interface engagement on trait mindfulness; and (2) the ability of colouring to promote state mindfulness.

8.0.1 An Engaging Design for Trait Mindfulness. Our app helps to cultivate a greater sense of mindfulness over time. The majority of participants reported an increase in trait mindfulness, noting reduced stress, improved control over thoughts, and heightened awareness of their surroundings. Across several measures, our enhanced version was more adept at increasing mindfulness than our simple version. It was the only app that made participants feel happier over time, and it also had more of a positive impact on mood. We attribute the success of our enhanced app to its more engaging design. It may have simply been more enjoyable to use, causing participants to experience an elevated sense of well-being over time. This could also explain why all participants expressed their willingness to use the app again, as less engaging apps may lack the appeal for repeated use. With its diverse set of effects, users may have found it easier to concentrate on the app, which could have facilitated focusing on the present moment and maintaining a state of mindfulness. Even with its increased stimulation, the app remained equally effective in reducing anxiety and improving attention. It strikes a balance between simplicity and engagement, one that we believe is lacking in the current market of MBMAs.

8.0.2 Achieving State Mindfulness in Physical Colouring. Our results support digital colouring as an effective mindfulness practice with a similar impact to traditional structured colouring. Although no direct comparison was made, our app showed similar results to existing works [11, 19, 39, 46] that evaluated traditional colouring using the same measures. After a single 10-minute session, our app improved state mindfulness in relation to the mind and reduced anxiety. However, state mindfulness overall seemed unaffected, potentially due to the app’s initial learning curve. Users unfamiliar with the app may find mindfulness more challenging, leading to subtler immediate benefits compared to more familiar activities like colouring. Furthermore, traditional colouring, with its visceral feedback, may have a greater impact on state mindfulness by engaging more of the body and cultivating a heightened sense of body awareness. The app’s ability to foster state mindfulness is also apparent through qualitative feedback. Participants reported heightened mindfulness, reduced anxiety, and improved mental clarity. The app’s engagement prevented overthinking and rumination, enabling users to process their emotions more effectively. The act of colouring induced relaxation by relieving the pressures associated with traditional mindfulness practices, where maintaining self-directed focus is often expected.

8.1 Limitations

Mindfulness is important but highly subjective, so evaluation is challenging. One potential limitation is the study's duration, which, despite being informed by prior research, may not fully capture the potential effects of the app over time. Conducting a longer study would provide more reliable insights, but even our five-day study required significant logistics. Also, administering questionnaires 30 minutes after the final session meant responses were more directly influenced by emotions elicited by the app. Waiting for a few hours or until the next day could elicit responses that are more representative of a participant's baseline level of mindfulness. By conducting a near replication of the Pause study, our results are closely tied to that specific work, reducing their broader applicability. Another limitation is the use of self-reported measures, which naturally introduce inherent biases. We are interested in using more objective measures in the future, such as EEG, to provide a more comprehensive assessment of the app and its impact on users.

Finally, there is no single mindfulness tool that will work for everyone, so there is value in exploring a range of options.

8.2 Future Work

Future work could examine ways of making digital colouring more akin to traditional methods, such as through haptic feedback and sound effects. A comparative analysis using a paper-based version of the app could provide greater insight into how our app compares to traditional methods for enhancing mindfulness. Future iterations could adjust the frequency of various features and effects based on user input, drawing from apps like TikTok which generate content based on user behaviour over time. Finally, this work introduces a promising research direction for enhancing engagement in mindfulness practices. Future investigations could explore other ways of digitally augmenting engagement across various forms of mindfulness practice. A critical aspect for future work is defining the threshold at which engagement may impede the mindfulness experience. Investigating the balance between fostering engagement and preserving the contemplative nature of mindfulness is crucial for developing effective digital tools in this domain.

9 CONCLUSION

Our work presented a novel approach to digital colouring and established its efficacy in cultivating mindfulness. Participants felt that they could focus and relax more easily due to the continuous feedback and interaction provided by our app. They also expressed how the slow movement of the app promoted a state of relaxation and mental clarity. The app's positive reception highlights the value of MBMAs that facilitate mindfulness practices beyond traditional meditation. We hope our work can serve as a source of inspiration for the development of MBMAs that provide engaging and visually immersive user experiences, establishing a promising avenue for future research on adopting features from social media to enhance mindfulness technologies.

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A APPENDIX

A.1 Interview Guideline

This is the guide used for our discussions during semi-structured interviews. We used these questions as a foundation for the interview, expanding and refining these topics as necessary.

- What is your overall impression of the app after using it for 5 days?
- What aspects of the system did you find frustrating or confusing?
- What aspects of the system did you find particularly useful or enjoyable?
- Is there anything specific that you would improve or change about the app?
- Do you feel more mindful? Why or why not?
- Would you use the app again? Why or why not? If yes, how could you see yourself using it in the future?

A.2 Participant Demographics

Characteristic	Number	Percent
Declared gender		
Woman	15	53.6
Man	13	46.4
Handedness		
Left Handed	5	17.9
Right Handed	23	82.1
Use of computer technology		
2–3 hours per day	1	3.6
4–5 hours per day	5	17.9
6–7 hours per day	5	17.9
More than 8 hours per day	17	60.7
Familiarity with computer technology		
Moderately familiar	4	14.3
Very familiar	11	39.3
Extremely familiar	13	46.4
Frequency of meditation in the past 12 months		
Never	1	3.6
Rarely (a few times)	17	60.7
Occasionally (less than once a month)	2	7.1
Monthly	3	10.7
Weekly	4	14.3
Daily	1	3.6
Frequency of mindfulness practice in the past 12 months		
Never	1	3.6
Rarely	13	46.4
Occasionally	5	17.9
Monthly	3	10.7
Weekly	6	21.4
Experience with mobile mindfulness apps		
Yes	18	64.3
No	10	35.7
Experience with art in mindfulness practice		
Yes	15	53.6
No	13	46.4

A.3 Qualitative Analysis Codes

Table 2: Affinity Diagram Codes

Code	Definition	Occurrences	Assignment Criteria
Ease of Use	The app's perceived ease of use	7	Comments regarding the simplicity of the app and ease of use
Auto-fill	The auto-fill feature of the enhanced version	19	Assigned when participants mentioned the auto-fill feature
Variation	Participants' perceptions of the level of variation (e.g., features, shapes, colours)	11	Comments on the presence or lack of variation and its impact on the user experience
Visual Feedback	Changes in line width in response to finger/stylus movement	10	Comments regarding the changes in line width and how they were perceived
Audio Feedback	Changes in volume in response to finger/stylus movement	12	Comments regarding the changes in volume and how they were perceived
Textual Feedback	The app's lack of textual/verbal feedback	3	Comments on the absence of text-based guidance
Focus	The ability to concentrate when using the app	18	Assigned based on participants' discussions on maintaining focus
Relaxation	App-induced feelings of relaxation and stress-relief	8	Comments on the level of relaxation experienced when using the app or after a session
Sense of Achievement	Feelings of accomplishment during app use	5	Comments on how the app made participants feel a sense of achievement
Finger/Stylus Movement	Movement of the finger or stylus while interacting with the app	26	Comments on the finger/stylus movement and how colouring at different speeds made participants feel
Evolution of the User Experience	Changes in the user experience over the course of the study	13	Assigned when participants discussed changes in their experience over time
Acceptance	Participants' embrace or resistance towards the app	28	Comments on the constraint's imposed by the app and how the lack of control made participants feel
Processing Feelings	Participants' thought patterns during and after app use	25	Comments on the emergence of thoughts and the subsequent processing of those thoughts during app use
Impermanence	The impermanence of drawings and the infinite scroll feature	6	Assigned when participants mentioned the transient nature of the app
Mindfulness	Whether participants experienced an increased sense of mindfulness by the end of the study, along with insights into how or why this change occurred	21	Direct and indirect comments regarding perceived mindfulness levels
Accessibility	The app's mobile nature	11	Comments on the app's convenience as a mobile app
Future Use	Participants' intentions for using the app after the experiment	23	Comments on why participants would or would not use the app again, and insights into how they envision incorporating the app into their daily routines
Drawing Styles	Approaches to filling in the shapes or tilings	10	Assigned when participants described how they approached filling in the shapes
Boredom	Feelings of boredom or monotony during app use	12	Assigned when participants expressed boredom or articulated specific strategies used to increase engagement
Shapes	Shapes or tiles generated by the app	5	Feedback on the shapes
Timer	In-app timer	4	Feedback on the timer