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# Effects of app-based relaxation techniques on perceived momentary relaxation: Observational data analysis in people with cancer

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ABSTRACT

*Objective:* To examine the effects of six relaxation techniques on perceived momentary relaxation and a possible association of relaxation effects with time and practice experience in people with cancer.
*Methods:* We used data from participants with cancer in a larger study practicing app-based relaxation techniques over 10 weeks, assessed momentary relaxation before and after every third relaxation practice, and analyzed momentary relaxation changes with a linear mixed-effects model.
*Results:* The sample included 611 before-after observations from 91 participants (70 females (76.9%)) with a mean age of 55.43 years (SD 10.88). We found moderate evidence for variations in momentary relaxation changes across different techniques ($P = .026$), with short meditation, mindfulness meditation, guided imagery, and progressive muscle relaxation more frequently observed and leading to more relaxation than body scan and walking meditation. Furthermore, we found moderate evidence for increasing momentary relaxation changes over time ($P = .046$), but no evidence for an association between momentary relaxation and the number of previous observations (proxy for practice experience; $P = .47$).
*Conclusion:* We compared six app-based relaxation techniques in a real-life setting of people with cancer. The observed variations in perceived momentary relaxation appear to correspond with the popularity of the techniques used: The most popular relaxation techniques were the most effective and the least popular were the least effective. The effects increased over time, likely caused by dropout of individuals who gained no immediate benefit. Our findings open an interesting avenue for future research to better understand which relaxation techniques work best for whom in which situations.
*Trial Registration:* DRKS00027546; https://drks.de/search/en/trial/DRKS00027546

## 1. Background

People with cancer face complex challenges and often high levels of distress [1,2] that reduce their quality of life and well-being. Intense distress is linked to maladaptive coping strategies [3], while positive coping strategies, including relaxation techniques, can reduce cancer-related distress [2,4–6]. Most relaxation techniques can be learned independently and practiced silently or guided by audio recordings. Learning and practice can be aided by relaxation apps, which are convenient and offer users a choice of relaxation techniques to meet different needs and suit different preferences. Relaxation apps may provide extra features that help users integrate regular relaxation

*Abbreviations:* EMA, Ecological momentary assessment; EMI, Ecological momentary intervention; PMR, Progressive muscle relaxation; RCT, Randomized controlled trial.

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practice into their daily lives.

Integration into daily life is a key focus of “ecological momentary interventions” (EMIs) [7,8]. EMIs are typically brief, tailored, and quickly accessible whenever needed [8]. In apps, EMIs can also be combined with “ecological momentary assessments” (EMAs) that collect data on people’s thoughts, feelings, or behaviors in real time [9]. We incorporated EMIs and EMAs into a relaxation app we developed to reduce distress in people with cancer (CanRelax app 2.0 [10]).

Relaxation techniques include a wide range of practices that are similar yet different. To foster research on the similarities and differences, Smith, Hancock, Blake-Mortimer and Eckert [11] classified the relaxation techniques into six types, labeled as primarily targeting “stressed posture and position” (e.g., stretching exercises), “stressed skeletal muscles” (e.g., progressive muscle relaxation; PMR), “stressed breathing” (i.e., breathing exercises), “stressed body focus” (e.g., autogenic training), “stressed emotion” (e.g., imagery and visualization exercises), and “stressed attention” (e.g., mindfulness practices). All six types of techniques seem to enhance parasympathetic activity indicative of a relaxation response [12,13]. However, there is some evidence that different types of techniques may have different effects on psychological relaxation such as reduced worry or cognitive stress [11,13,14] and different mediating mechanisms [14–16] which may lead to some techniques being more useful than others in a particular clinical situation or to answer a specific research question [15,17]. Despite these potentially meaningful differences, different types of relaxation techniques are often subsumed under general terms and discussed interchangeably [15] and their relaxation effects are rarely studied.

Many existing studies have examined the mid- and long-term effects of relaxation techniques on health outcomes but skipped the most direct outcome, momentary relaxation. Existing studies have established that practicing relaxation techniques has beneficial effects on stress, anxiety, depression, and well-being in people with cancer [18,19]. However, many of these studies have relied on the assumption that relaxation techniques effectively induce momentary relaxation, without assessing relaxation through proximal outcomes [19,20]. Consequently, it remains unclear if momentary relaxation was achieved, if different relaxation techniques were equally effective in inducing momentary relaxation, and if there was a dose-response relationship over time, that is, if relaxation becomes easier with practice [17]. With the rise of app-based EMIs, there has been an increase in interest surrounding the use of these “micro-interventions,” and research has begun to investigate their potential usefulness and immediate benefits [21–28].

Building upon this research, we set out to compare the immediate effects of six different relaxation techniques on momentary relaxation to determine if they had different effects and if the effects increased over a 10-week period. Within the framework of a larger randomized controlled trial (RCT), we used EMAs to collect data on perceived momentary relaxation before and after app-based relaxation practices.

## 2. Methods

### 2.1. Overview

This paper is based on app usage data collected from a fully automated RCT with a waiting-list control group (German Clinical Trials Register DRKS00027546; registration date: 23 February 2022). The RCT investigated the effectiveness of the CanRelax app 2.0 in reducing distress in people with cancer over 10 weeks. For this paper, we used observational before-after data of an exploratory sample of 100 study participants with immediate access to the app. Participants were free to choose among different EMIs and practice as often as they liked. Findings should be considered explorative. We obtained electronic informed consent through the app from all participants before enrollment. The RCT was conducted according to the Declaration of Helsinki, the Human Research Act, and the Human Research Ordinance. We submitted the RCT study synopsis to the Ethics Committee of Zurich, Switzerland, and after review, they stated that the study does not fall under the regulation of the Human Research Act of Switzerland (Ethics ID: 2021–01071). We followed the STROBE reporting guideline where applicable. Further details of the RCT procedure and the CanRelax app 2.0 intervention have been described by Schläpfer, Schneider, Santhanam, Eicher, Kowatsch, Witt and Barth [10]. Our RCT findings will be reported elsewhere.

### 2.2. Participant recruitment

We recruited participants between July 2022 and February 2023 in Switzerland, Germany, and Austria. People were reached using social media posts (i.e., on Facebook, LinkedIn, and X (former Twitter)) and more traditional approaches (e.g., consultations with health care providers, printed flyers, newsletters, and a press release by the University Hospital Zurich). A project website presenting key information on the study and download links to the app stores helped to facilitate recruitment. The eligibility criteria were being at least 18 years of age, a smartphone user (Android/iOS), a fluent German speaker, and having received a cancer diagnosis within the last five years. Self-reported suicidal ideation and pregnancy at baseline were exclusion criteria.

### 2.3. Intervention

The CanRelax app 2.0 is a fully automated stand-alone intervention to reduce distress in people with cancer. The core component of the app is a media library with different EMIs for users to select at their choice and convenience provided internet connection is available. The EMIs included six audio-recorded relaxation techniques of varying lengths (5 to 40 min) in four versions each (in male and female voices, with and without instrumental background music) and a biofeedback-based breathing training with gameful visualizations (Breeze 2 [29]). The use of EMIs was tracked with automatic time stamping. This paper explores the relaxation effects of the six audio-recorded relaxation techniques irrespective of the version.

The audio-recorded relaxation techniques consist of four mindfulness-based techniques (body scan, mindfulness meditation, short meditation, and walking meditation) and two formal relaxation techniques (guided imagery and PMR). The *body scan* is a 40-min mindfulness-based relaxation technique to help increase awareness of the body and bodily sensations through a mental scan from feet to head [15]. *Mindfulness meditation* (15 min) entails a present-moment focus of attention and awareness and uses the calming effect of breathing to increase detachment from thoughts, feelings, and sensations. *Short meditation* is a simple 5-min breathing meditation with the attention focused on breath-related sensations. *Walking meditation* (5 min) uses slow rhythmic movement combined with concentration on the walking movement, body parts, and breathing [30]. All four mindfulness-based techniques are relaxation techniques primarily targeting “stressed attention” according to the classification by Smith, Hancock, Blake-Mortimer and Eckert [11]. As to the formal relaxation techniques, *guided imagery* (15 min) uses calming mental images involving sensory experiences to induce relaxation [15,19,31] and reduce “stressed emotion” [11]. And finally, *PMR* (15 min) aims at decreasing tension by actively contracting and releasing different muscle groups in the body [15,19,31,32], thereby relaxing “stressed skeletal muscles” [11].

### 2.4. Assessments

We used EMAs to examine momentary relaxation changes induced by the different relaxation techniques in the app. For this purpose, we developed a single-item measure of perceived relaxation that involved rating one’s momentary experience on a vertical 11-point visual analog scale (0 = *very relaxed*, 10 = *very tense*). A screenshot of the measure implemented in the app is available in Supplementary Fig. A.1. Every third time participants practiced a relaxation technique in the app, they were prompted to complete the EMA immediately before and after their relaxation practice. Hence, the number of assessments for each participant depended on the total number of relaxation techniques practiced. Similarly, the number of assessments for each type of relaxation technique depended on the relaxation techniques participants selected. This resulted in observational and hierarchically structured data nested within relaxation techniques and participants.

### 2.5. Statistical methods

To examine variations in momentary relaxation changes among the different relaxation techniques and a possible association of changes with time, we used a linear mixed-effects model [33]. We specified the before-after momentary relaxation changes as the outcome, a random intercept per participant, the relaxation technique as a factor covariate, and the number of days since the start of app use as a continuous covariate. Additionally, a second model was fitted using the number of previously obtained before-after pairs of EMAs as a continuous covariate instead of the number of days to examine potential training effects. We then tested the overall null hypothesis of no difference in momentary relaxation changes among the relaxation techniques using a multivariate Wald test [34]. Pairwise comparisons adjusted for multiple testing were performed using the single-step method of Hothorn, Bretz and Westfall [35]. To assess sensitivity, we repeated all analyses using potentially more efficient but less interpretable ANCOVA-type models, specifying the post-practice EMA as the outcome and the pre-practice EMA as an additional continuous covariate. All analyses were performed in the R programming language version 4.2.1 [36]. The lme4 package [37] was used for fitting linear mixed-effect models. The multcomp package [35] was used for obtaining multiplicity-adjusted pairwise contrasts. Only complete before-after pairs of EMAs were analyzed.

## 3. Results

The analyzed sample included 611 EMAs collected over 10 weeks from 91 participants (70 females (76.9%)) with a mean age of 55.43 years (SD 10.88). No EMAs were available for 9 participants. Most participants had completed tertiary education (48/91, 52.7%) and lived in Switzerland (82/91, 91.1%); 7 participants (7.8%) lived in Germany, and 1 participant (1.1%) in another (unspecified) country. Short meditation was the most prevalent relaxation technique (226 before-after pairs of EMAs measuring momentary relaxation change (37.0%)), followed by mindfulness meditation (137 (22.4%)), guided imagery (107 (17.5%)), PMR (57 (9.3%)), and body scan and walking meditation (42 (6.9%) each; see Fig. 1). The mean momentary relaxation change (with 95% confidence interval) showed a benefit of −1.28 (−1.94 to −0.625) for guided imagery, −1.21 (−1.74 to −0.686) for mindfulness meditation, and − 0.987 (−1.37 to −0.607) for short meditation; less clear benefit of −0.684 (−1.41 to 0.046) for PMR and − 0.619 (−1.41 to 0.168) for body scan; and no benefit of walking meditation (0.0238, −0.877 to 0.925).

The Wald test for overall differences in momentary relaxation change led to a $P$-value of $P = .026$, indicating moderate evidence for variation in momentary relaxation change among the different relaxation techniques. In the pairwise contrasts, guided imagery, mindfulness meditation, short meditation, and PMR led to comparable momentary relaxation changes, while there is some evidence that body scan and walking meditation led to smaller momentary relaxation changes than the other four techniques (Fig. 2). Results in Table 1 indicate some evidence for increased momentary relaxation changes over time (estimated change per day of −0.008 with 95% confidence interval from −0.016 to 0 and $P = .046$).

According to a second model fitted to formally assess whether the observed increase in momentary relaxation changes over time is related to a training effect (Table 2), there is no evidence for an association between the number of previously obtained EMAs (i.e., previously practiced relaxation techniques) and momentary relaxation changes (estimated change per day of −0.003 with 95% confidence interval from −0.01 to 0.004 and $P = .47$). The sensitivity analyses using ANCOVA models yielded very similar results, which are reported in the Supplementary Table B.1.

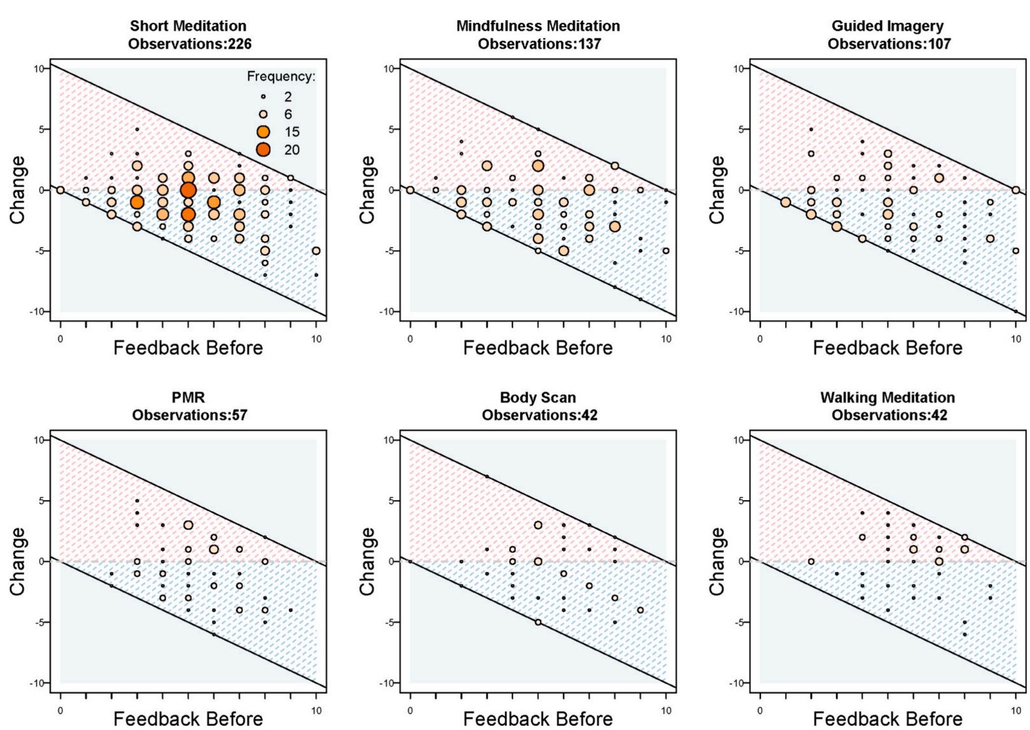


**Fig. 1.**. Momentary relaxation change (after-before) versus perceived momentary relaxation before relaxation practice, stratified by relaxation technique.
*Note.* The size of the points indicates the frequency of occurrence. The shaded blue region indicates a positive change in relaxation, whereas the red region indicates a negative change in relaxation. Observations can only occur between the two parallel lines.

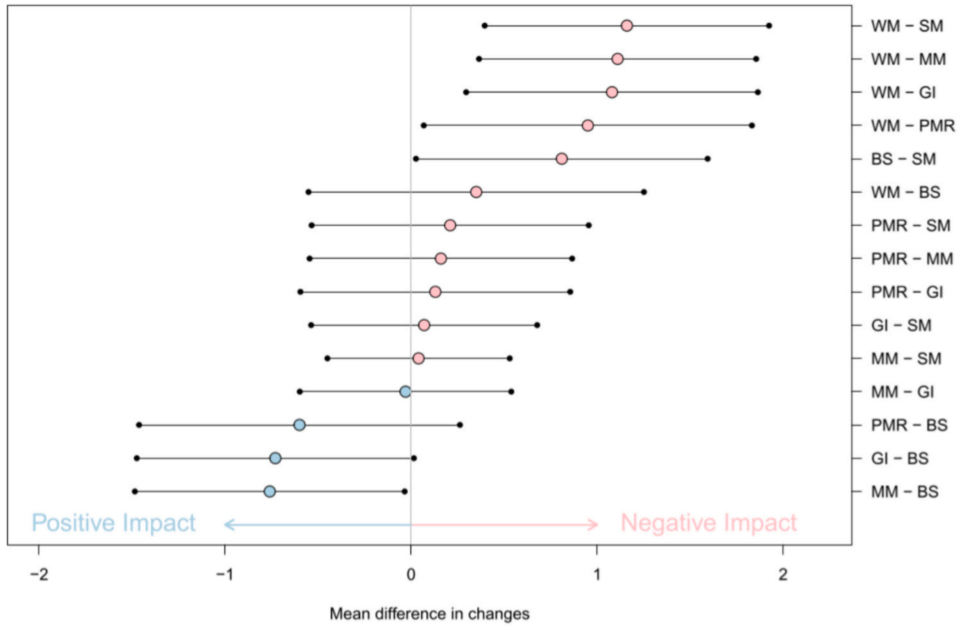


**Fig. 2..** Pairwise comparison of momentary relaxation changes with 95% confidence intervals between all pairs of relaxation techniques based on linear mixed-effect model adjusting for relaxation technique and number of days since the start of app use.
Note. WM: Walking Meditation; BS: Body Scan; SM: Short Meditation; GI: Guided Imagery; PMR: Progressive Muscle Relaxation; MM: Mindfulness Meditation.

**Table 1**
Estimated regression coefficients, 95% confidence intervals, and p-values from linear mixed-effect model with before-after momentary relaxation change as the outcome, a random intercept per participant, the relaxation technique as a factor covariate (short meditation taken as reference category), and the number of days since the start of app use as a continuous covariate.

| | Estimate | 95% Confidence Interval | *P*-value |
|---|---|---|---|
| Intercept (Short Meditation) | −0.612 | −1.106 to −0.118 | 0.016 |
| Mindfulness Meditation | −0.046 | −0.502 to 0.41 | 0.84 |
| Guided Imagery | −0.072 | −0.56 to 0.416 | 0.77 |
| Progressive Muscle Relaxation | 0.037 | −0.623 to 0.697 | 0.91 |
| Body Scan | 0.664 | −0.036 to 1.364 | 0.063 |
| Walking Meditation | 1.022 | 0.32 to 1.724 | 0.004 |
| Days | −0.008 | −0.016 to 0.0 | 0.046 |

**Table 2**
Estimated regression coefficients, 95% confidence intervals, and P-values from linear mixed-effect model with before-after momentary relaxation change as the outcome, a random intercept per participant, the exercise type as a factor covariate (short meditation taken as reference category), and the number of previously obtained pairs of EMAs (training) as continuous covariate.

| | Estimate | 95% Confidence Interval | *P*-value |
|---|---|---|---|
| Intercept (Short Meditation) | −0.898 | −1.307 to −0.489 | <0.0001 |
| Mindfulness Meditation | 0.045 | −0.444 to 0.534 | 0.86 |
| Guided Imagery | 0.075 | −0.53 to 0.68 | 0.81 |
| Progressive Muscle Relaxation | 0.206 | −0.538 to 0.95 | 0.59 |
| Body Scan | 0.809 | 0.034 to 1.584 | 0.041 |
| Walking Meditation | 1.159 | 0.397 to 1.921 | 0.003 |
| Training | −0.003 | −0.01 to 0.004 | 0.47 |

## 4. Discussion

Our analysis suggests that different relaxation techniques may have different effects on perceived momentary relaxation: Body scan and walking meditation were the least effective and least popular relaxation techniques, indicating a potential overlap between effects and popularity. The overall effect of the techniques on momentary relaxation increased over time, probably because individuals who gained no benefit stopped using the app.

Our main finding points to differences in effects between relaxation techniques, which aligns with some previous results, but the available evidence is not sufficient to draw definite conclusions. In line with our results, Smith, Hancock, Blake-Mortimer and Eckert [11] reported differences in the quality of relaxation experiences between PMR and breathing techniques, and both Lancaster, Klein and Knightly [38] and Balban, Neri, Kogon, Weed, Nouriani, Jo, Holl, Zeitzer, Spiegel and Huberman [16] found significant differences between the immediate effects of mindfulness meditation and PMR or breathing techniques, respectively. But other studies did not consistently find different effects of relaxation techniques [19,39,40]. One reported no different effects on perceived (subjective) momentary relaxation, but did identify physiological (objective) differences [19]. A lack of correspondence between subjective and objective momentary relaxation was also demonstrated by Meier, Unternaehrer, Dimitroff, Benz, Bentele, Schorpp, Wenzel and Pruessner [41] and Dib, Wells and Fewtrell [40], suggesting that momentary relaxation has different facets and results can be influenced by choice of measures and other factors [30,42].

The overlap between effects and popularity of relaxation techniques cannot be explained by the data or the setting of this research. The overlap we observed could indicate that people with cancer are good at choosing relaxation techniques that work for them; presenting people with a choice may be inherently valuable [43]. But we cannot rule out self-selection bias because our data were not randomized: people who find it easy to relax may be more drawn to certain techniques, which would then be associated with better relaxation effects. Randomized controlled trials should investigate this overlap further and determine whether different effects on momentary relaxation are caused by relaxation techniques or by self-selection.

Future work should also seek to determine whether relaxation gets easier with practice: is there a dose-response relationship between relaxation practice and momentary relaxation over time? Similar dose-response relationships were identified between meditation or mindfulness practice and changes in brain activity [for example, [44–46]] and for self-reported stress after 6 weeks [47]. Balban, Neri, Kogon, Weed, Nouriani, Jo, Holl, Zeitzer, Spiegel and Huberman [16] provided first experimental evidence for increasing positive affect benefits of breathing techniques with more practice over time. We extended this preliminary work by exploring the dose-response relationship between relaxation practices and perceived momentary relaxation.

In our study, momentary relaxation and the number of previous observations per participant (serving as a proxy for practice experience or training effect) were unrelated, despite an increase in momentary relaxation across all participants over time. Consequently, the observed increase in momentary relaxation cannot be attributed to enhanced practice experience or a training effect. Rather, it is plausible that participants who derived little immediate benefit from the intervention stopped using the app, leaving behind those who experienced larger benefits throughout the study period. Our 10-week study period might have been too short to reveal a meaningful dose-response relationship, since participants could accumulate only a few hours of relaxation practice experience. In comparison, meditation research studies have compared beginner practitioners with approximately 20 h of practice experience to experienced practitioners with >10,000 h of practice experience [44]. Ongoing commitment to continued relaxation practice might be necessary for a larger benefit and should be investigated in future research considering a longer study period and participants' previous experience.

### *4.1. Study limitations*

Our analysis was limited by its use of a non-established single-item EMA of perceived relaxation. Choosing a validated EMA with multiple factors – for example, the newly developed Relaxation State Questionnaire [20] – would have allowed more insight into the overall experience of momentary relaxation. Nevertheless, we chose a single-item EMA because it reduced the burden on participants and was particularly well-suited to the setting of our study. Moreover, visual analogue scales similar to our EMA have received initial validation [48] and have been used in prior studies across diverse populations to assess momentary changes in perceived stress [48–52] or, less commonly, perceived relaxation [53,54], traditionally in a paper-pencil format. Further, it is possible that the range in the length of relaxation techniques (5 to 40 min) resulted in a bias towards shorter practices. Finally, our results are based exclusively on app usage data; relaxation practices outside of the CanRelax app 2.0 (e.g., practiced silently, using a different app, or with a teacher) and previous experience with relaxation techniques were not considered in our dose-response analysis.

### *4.2. Clinical implications*

Many previous studies on momentary relaxation were laboratory-based [for example, 19, 38, 40, 41] but our research allowed users to experience situations closer to "real life" so it may better guide the choice of relaxation techniques in research and practice. Overall, our app-based relaxation techniques were well-used and had a positive relaxation effect. A promising finding is that the 5-min short meditation was especially popular and helpful for inducing momentary relaxation. Brief relaxation practices can be used in almost any situation and may serve as an important anchor at challenging moments in daily life.

Based on our exploratory research, we make two suggestions. First, if specific relaxation practices are offered to people with cancer, we recommend they select techniques with a positive relaxation effect (e.g., short meditation, guided imagery, mindfulness meditation, or PMR). Second, relaxation apps that offer users a choice of relaxation techniques may be particularly helpful, given people's inherent preference for choice [43], and may fill a wider range of needs and preferences than a "one size fits all" app.

## 5. Conclusions

The belief that relaxation techniques relax people is often assumed but rarely investigated. The preliminary conclusion of our exploratory study is that different relaxation techniques have different effects on perceived momentary relaxation, but additional research should confirm these results. We compared six commonly used, app-based relaxation techniques in a real-life setting of people with cancer. We found that the immediate effects of these techniques appeared to correspond with their popularity, and the effects increased over time. The most popular techniques (short meditation, guided imagery, mindfulness meditation, and PMR) were the most effective, while the least popular (body scan and walking meditation) were the least effective. Our findings open an interesting avenue for future research to better understand which relaxation techniques work best for whom in which situations.

## Data statement

Data and the analysis code are available from the Open Science Framework repository at: https://osf.io/9nqyb/

## CRediT authorship contribution statement

**Sonja Schläpfer:** Software, Project administration, Methodology, Investigation, Data curation, Conceptualization, Writing – review & editing, Writing – original draft. **George Astakhov:** Visualization, Formal analysis, Writing – review & editing. **Samuel Pawel:** Visualization, Formal analysis, Writing – review & editing, Writing – original draft. **Manuela Eicher:** Methodology, Funding acquisition, Conceptualization, Writing – review & editing. **Tobias Kowatsch:** Software, Methodology, Conceptualization, Writing – review & editing. **Leonhard Held:** Visualization, Formal analysis, Writing – review & editing. **Claudia M. Witt:** Methodology, Funding acquisition, Conceptualization, Writing – review & editing. **Jürgen Barth:** Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization, Writing – review & editing.

## Declaration of competing interest

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf and disclose the following relationships: ME, CMW, and JB received support from the Swiss Cancer Research foundation for the submitted work and TK from the University of Zurich for software engineering activities related to this work. In the last 3 years, GA has received consulting fees and honoraria from the University of Zurich. ME has received research grants from Kaiku Health/Varian and the ISREC Foundation; consulting fees from Roche; honoraria for scientific talks from Roche, Bristol Myers Squibb, and Novartis; and she is a board member of Roche ORIGAMA and academic societies. TK has received funding and research grants from the Swiss health insurer CSS, the Swiss digital health investor MTIP, the Austrian healthcare provider Mavie Next, the National Research Foundation Singapore, and the Swiss National Science Foundation; honoraria for scientific talks; support for academic meetings; and he is a board member and stock holder of Pathmate Technologies, a Swiss digital health startup company. CMW has received research grants from the Kelm foundation; honoraria for scientific talks; and she is a board member of academic societies. JB has received research grants from the Citizen Science Center Zurich and honoraria for scientific talks and workshops. The remaining authors have no competing interests to report.

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## Appendix A. Supplementary data

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