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A Randomized Controlled Trial of Multiple Versions of an Acceptance and Commitment Therapy Matrix App for Well-Being

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Abstract

Mobile apps may be useful in teaching psychological skills in a high-frequency, low-intensity intervention. The Acceptance and Commitment Therapy (ACT) matrix is a visual tool to help develop psychological flexibility by categorizing moment-to-moment experience and is well suited to a mobile app. This pilot study tested the effects of a simple and complex version of a novel app using the ACT matrix in two distinct samples: help-seeking individuals (n = 35) and students receiving SONA credit (n = 63). Findings indicated no differences between app conditions and a waitlist condition in the SONA credit sample. However, in the help-seeking sample improvements were found on well-being and valued action in participants who used the app, with greater improvements and app adoption for those using a complex version with additional skills. A mobile app based on the ACT matrix has benefits for help-seeking individuals, but supplementary features may be necessary to support consistent use and benefits.

Keywords: acceptance and commitment therapy; mHealth; mobile app; values; psychological flexibility

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Acceptance and commitment therapy (ACT; Hayes, Strosahl, & Wilson, 2011) is a contextual cognitive behavioral therapy that addresses a wide range of psychological problems to promote positive functioning. Across almost 200 RCTs (Hayes, 2017), ACT has been found to be efficacious in treating problems including depression, anxiety disorders, OCD spectrum disorders, addictions, eating disorders, chronic pain, weight management, and coping with health problems, among other areas (Bluett, Homan, Morrison, Levin, & Twohig, 2014; Hooper & Larsson, 2015; Lee, An, Levin, & Twohig, 2015). ACT seeks to treat this wide range of problems by focusing on a core set of mechanisms of change, referred to in combination as psychological flexibility, which is "the ability to contact the present moment more fully as a conscious human being, and to change or persist in behavior when doing so serves valued ends" (Hayes, Luoma, Bond, Masuda, & Lillis, 2006, p.7). Consistent with this theory, several RCTs have found that the treatment effects of ACT on varied psychological outcomes are mediated by improvements in psychological flexibility (Hooper & Larsson, 2015; Twohig & Levin, in press). However, there is still notable room for improving the impact of therapies including ACT in areas such as effect sizes, response rates, and access to treatment.

Self-guided interventions are a promising avenue for increasing the efficiency, effectiveness, and reach of ACT. For example, a number of clinical trials in the past decade have found ACT to be effective when delivered through self-help books (e.g., Ritzert et al., 2016), websites (e.g., Lappalainen et al., 2014; Levin, Haeger, Pierce, & Twohig, 2017), and most recently, mobile apps (e.g., Bricker, Wyszynski, Comstock, & Heffner, 2013; Torous, Levin, Ahern, & Oser, 2017). Common barriers that prevent individuals in need from accessing

treatment include financial limitations, lack of local providers, and concerns about mental health stigma (Andrade et al., 2014). Self-guided ACT interventions could overcome many of these barriers, as they can be delivered to large numbers of individuals for relatively low cost and are not dependent upon location (e.g., no requirement for face-to-face meetings).

Mobile apps in particular provide a number of promising, unique features that might enhance the impact of ACT (Pierce, Twohig, & Levin, 2016). As of 2015, 64% of adults in the United States own a smartphone (Smith, 2015), and most people are accustomed to having a phone nearby that regularly provides notifications from various apps throughout the day. This unique set of features in mobile apps is highly compatible with a high-frequency, low-intensity intervention approach that uses brief, frequent check-ins and very short skill coaching sessions to deliver therapeutic skills (e.g., Heron & Smyth, 2010). High-frequency, low-intensity interventions also map on well to teaching key psychological skills, providing a frequency of training that maximizes skill acquisition and strengthening, and doing so in varied life contexts to ensure generalization of skills. However, most of the ACT mobile apps developed and evaluated to date adopt a "toolbox-like" design that incorporates a variety of self-guided ACT intervention components and skills that users access at their own pace (e.g. Bricker et al., 2013; Ly, Asplund, & Andersson, 2014), rather than a low-intensity, high-frequency approach emphasizing a specific skill. Such combined "toolbox" apps are a reasonable approach, but this still raises the question of specifically how ACT might be translated into high-frequency, low-intensity formats.

Throughout the development and evaluation of ACT, there has been a strong emphasis on understanding mechanisms of change and treatment components (Hayes, Levin, Plumb-Vilardaga, Villatte, & Pistorello, 2013). This research helps support the translation of ACT into

high-frequency, low-intensity formats based on an understanding of the key components and processes that such brief interventions should emphasize. One such set of methods that fits well with the search for an effective high-frequency/low-intensity intervention in a mobile app format is the ACT matrix (Polk & Schoendorff, 2014). The matrix is a visual tool that helps individuals categorize their experiences along two dimensions to target psychological flexibility. The first is whether the experience is sensory (i.e. experiences of the external world through one's five senses) or mental (i.e. experiences of one's thoughts, feelings, and internal sensations). The second is whether their behavior is engaged to move away from unwanted inner experience or toward their values (personally chosen life directions). Thus, the matrix diagram includes four quadrants that map on well to key components of psychological flexibility: sensory-toward (i.e., toward moves or valued actions), sensory-away (i.e., away moves or experiential avoidance), mental-toward (i.e., values), and mental-away (i.e., internal barriers).

The matrix is designed to target the key components of psychological flexibility in ACT by emphasizing one's practice of discriminating experiences and behaviors in relation to these "toward" and "away" dimensions. Theoretically, as clients continue to practice discriminating experiences in relation to the matrix, their awareness and ability to take a distanced perspective on their internal experiences (i.e., self-as-context, acceptance, defusion, mindfulness) will increase, allowing them to more easily choose to engage in actions to move towards their values (i.e., committed action, values). A matrix-based intervention, which repeatedly reminds clients to notice experiences and behaviors, fits well with a high-frequency, low-intensity mobile app.

The matrix is a relatively new tool in ACT. To the best of our knowledge, the effects of using the matrix alone as an intervention have only been tested in one recent pilot RCT, which provided preliminary evidence for benefits of using the matrix in a mobile app format (Levin,

Pierce, & Schoendorff, 2017). This pilot RCT compared a simple matrix mobile app (e.g., prompts to notice if one's actions are a toward or away move) to a waitlist condition among 23 adults seeking help to improve health behaviors. Although food-related experiential avoidance and general progress toward values did not change significantly, health behaviors such as diet and exercise improved compared to waitlist among individuals who actively adhered to using the app. These results suggested promise for a high frequency, low intensity matrix-based app, but only among individuals who actively engaged with the intervention (i.e., minimal effects were found for the full intent-to-treat sample). Additionally, while satisfaction ratings were high overall, 45% of participants who used the app indicated that the app was "too simple" and additional features would be beneficial, raising the question of whether a pared-down version of the matrix is suitable as a standalone intervention and the limitations of a simple high-frequency, low-intensity intervention. Lastly, it is worth noting that while this initial trial focused on health behaviors (diet and exercise), the matrix is conceptually applicable to all types of behavior change, and a broader app could provide room for participants to focus on their highest-priority personal values.

The aims of the present study were to replicate initial research on a matrix mobile app as a high-frequency, low-intensity self-guided ACT intervention and extend it to a broader set of values and goals. In this pilot RCT, a waitlist condition was compared to a simple version of the matrix app (i.e., engaging in a basic toward-away discrimination task using matrix framework) and a complex version incorporating other matrix features (e.g., toolbox-like activities) in two samples: a sample of undergraduate research participants (n = 63) and a sample of adults expressing interest in receiving online self-help (n = 35). The samples were not limited to a particular problem area or level of distress, consistent with the matrix's transdiagnostic

application to varied, ideographic concerns, with study outcomes including depression, anxiety, stress, and positive mental health.

It was hypothesized that both matrix app conditions would be equally more effective in both samples on relevant outcomes and processes relative to the waitlist condition. This would suggest the act of discrimination training alone with the matrix app is sufficient for behavior change, in both clinical (adults seeking help) and non-clinical populations (adults seeking course credit). However, we did hypothesize that the complex matrix app would receive higher participant satisfaction ratings and higher program engagement, indicating that participants prefer additional features (e.g., complex app activities) that support continued app engagement. Overall, if these hypotheses were confirmed it would support the use of a simple ACT matrix mobile app for both clinical and non-clinical populations (e.g., school-based prevention) as well as highlight the benefits of including additional, complex features to improve program acceptability.

Methods

Participants

A total of 98 adults who owned a mobile phone were recruited for this study. Inclusion criteria were broad: being 18 years or older, residing in the U.S. or Canada, owning a mobile phone, and being interested in phone-based self-help. Two recruitment routes were used: advertising the study to university students who could receive credit for participation through the online SONA platform (Sample 1, $n = 63$), and directing adults from the community interested in self-help who were not receiving any incentive to participate to this study (Sample 2, $n = 35$). Participants who received SONA credit were granted 2 credits for completing assessments, and

an additional 1 credit for using the mobile app. The two samples were analyzed separately in accordance with the aim of evaluating the effects of the apps in distinct populations.

The two samples were generally similar in their demographics (see Table 1). Sample 1, consisting of participants who received SONA credit, was on average young (M = 20.24, SD = 3.88), 73.0% female, and 96.8% White (4.8% Hispanic/Latino). Sample 2, consisting of help-seeking participants, was slightly older (M = 24.57, SD = 7.68), 65.7% female, and 94.3% White (11.4% Hispanic/Latino). Of note, 82.9% of this sample were also college students. Established DASS cutoff scores (Lovibond & Lovibond, 1995) suggested a difference in depression, anxiety, and/or stress at baseline between groups; 77.1% of Sample 2 was experiencing at least moderate levels of depression, anxiety, and/or stress at baseline compared to only 39.7% of Sample 1 (see Table 1). In Sample 2, 51.4% of participants were experiencing at least moderate depression, 57.1% at least moderate stress, and 60.0% at least moderate anxiety.

Procedures

All research procedures were completed online. Participants provided informed consent online, after which they were automatically linked to the baseline assessment and randomly assigned to one of three conditions: using a simple version of the mobile app for four weeks, using a complex version of the mobile app for four weeks, or being on the waitlist for four weeks. Participants assigned to the active conditions were asked to complete a 15-20 minute interactive online tutorial prior to downloading the app. The tutorial provided definitions of "toward moves" and "away moves" and explained how toward moves are connected to personal values while "away moves" are connected to difficult internal experiences. The tutorial also guided participants to begin identifying examples of toward and away moves in their own lives.

In addition, the tutorial oriented participants to the format and features of their version of the matrix app.

Half of the participants in the two app conditions were randomly assigned to complete an additional online training session at the intervention midpoint. This 15-minute booster session sought to help participants reflect on their experiences using the app over the past two weeks and to promote ongoing engagement over the following two weeks. However, no effects were found from assigning participants to the booster sessions and so these results are not reported to maintain focus on the primary aims of the study.

All participants were asked to complete a mid-intervention assessment online two weeks after baseline. A final online assessment was completed four weeks after baseline.

Researcher contact. Participants in the app conditions were contacted twice by email after downloading the mobile app to check in on any difficulties encountered. Participants who did not download the app or ceased using the app were sent several email reminders to encourage usage and address any technical difficulties encountered.

Participants also had the option to receive four weekly summaries of their app usage. These email summaries provided graphs showing how responses (e.g., rate of toward and away moves) changed over time. Brief comments were added to provide tailored feedback based on the patterns observed in the participant's app usage data (e.g., highlighting increases in toward moves, prompting self-compassion if toward moves decreased).

Mobile app. Both versions of the matrix mobile app were hosted by the secure LifeData mobile platform, which allows researchers to develop interactive, native mobile applications integrated with notifications delivered directly through one's mobile phone.

*Simple version***.** The simple version of the matrix app delivered 5 random notifications each day between 9:00 A.M. and 9:00 P.M during the study period (for 28 days assuming the participant completed the tutorial and downloaded the app on day 1). Each notification asked the participant to identify whether they were engaged in more of a toward move or an away move at that time. Participants could select "Toward" or "Away" as a response. If a participant selected "Toward," a follow-up question was triggered asking the participant to rate the difficulty of starting the toward move from 1 to 100, with "Easy" anchored at 1 and "Very difficult" anchored at 100. This follow up question was designed to help participants recognize their efforts being put into toward moves, including acknowledging moves that took substantial effort to engage in. In addition to random prompts from the app, participants could also choose to open the app at any time and complete the same procedure.

*Complex version***.** The complex version of the app included all of the features described above under "Simple version" on the same schedule. This version also included a daily check-in, triggered each day at 8:00 P.M. The daily check-in asked the participant to rate their overall ability to move towards their values that day from 0 (never able to) to 10 (always able to) across the domains of relationships, work/study, leisure/fun, and self-care. Participants were also asked to rate the level of inner obstacles experienced from 0 (none) to 10 (a lot) and to rate overall how well they had been able to direct their lives toward what matters that day from 0 (not at all) to 10 (a lot). Participants could also set a goal for a specific life domain, which entailed identifying a value, writing a goal, and evaluating willingness to move toward the goal if difficult internal experiences showed up. In addition to the daily check-in, the complex version of the app also added a goal setting feature, a variety of quick values activities, and a variety of quick mindfulness/acceptance activities that participants could access at any time. Thus, the complex

matrix app added several activities and features above and beyond the simple tracking of toward and away moves, with an emphasis on continuing to notice toward and away moves as well as setting goals for toward moves.

Measures

Depression, Anxiety and Stress Scale (DASS). The 21-item DASS (Lovibond & Lovibond, 1995) was used to measure depression, anxiety, stress, and general distress (Henry & Crawford, 2005). The DASS assesses each of these on a separate subscale. Each item is rated from 0 (*did not apply to me at all*) to 3 (*applied to me very much, or most of the time*). Sample items include "I found it difficult to relax" (*stress*), "I felt down-hearted and blue" (*depression*), and "I felt scared without any good reason" (*anxiety*). The DASS has support for both reliability and validity (Lovibond & Lovibond, 1995) and has been found to be sensitive to detecting the effects of online self-guided ACT interventions (Levin, Pistorello, Seeley, & Hayes, 2014). Internal consistency was calculated for both samples combined and was adequate for the depression ($\alpha = 0.93$), anxiety ($\alpha = 0.86$), and stress ($\alpha = 0.86$) subscales.

Mental Health Continuum-Short Form (MHC-SF). The MHC-SF is a 14-item measure of well-being across the social, emotional, and psychological domains (Keyes, 2005). All items are framed with the question "During the past month, how often did you feel…?" and each item is rated on 6-point scale from *never* to *every day*. Examples of specific items included "happy," "good at managing the responsibilities of your daily life," and "that you had warm and trusting relationships with others. The MHC-SF has acceptable reliability and validity (Lamers, Westerhof, Bohlmeijer, Ten Klooster, & Keyes, 2011) and has been found to be sensitive to online self-guided ACT interventions (Levin, Haeger, et al., 2017). Internal consistency was excellent in this study ($\alpha = 0.93$).

Valuing Questionnaire (VQ). The VQ (Smout, Davies, Burns, & Christie, 2014) is a 10-item measure of values processes with two subscales, progress towards values and obstruction of values. Every item is rated on a 7-point scale. Sample items include "I worked toward my goals even if I didn't feel motivated to" (*progress*) and "When things didn't go according to plan, I gave up easily" (*obstruction*). Initial validation research has indicated acceptable reliability and validity (Smout et al., 2014). The VQ has been found to be sensitive to online self-guided ACT interventions and to mediate treatment outcomes (Levin, Haeger, et al., 2017). The VQ represents a key process measure in ACT due to the focus on increasing valued action, particularly with the current app, which emphasized increasing toward moves (actions consistent with personal values). Internal consistency was good for both the progress ($\alpha = 0.84$) and obstruction ($\alpha = 0.81$) subscales.

System Usability Scale (SUS). The 10-item SUS (Tullis & Albert, 2008) is a measure of usability and acceptability of technology-based programs. Each item is rated on a 5-point scale from "strongly disagree" to "strongly agree." Sample items used in this study include "I think that I would like to use the Matrix App frequently" and "I felt very confident using the app." Validation research supports the reliability and validity of the SUS (Bangor, Kortum, & Miller, 2008; Tullis & Albert, 2008).

Additional satisfaction questions were included in the posttreatment survey to evaluate participants' satisfaction with specific aspects of the interventions. These items were rated on a 6-point scale from *strongly disagree* to *strongly agree*. Sample items include "The app was easy to use" and "I felt the app was made for someone like me." These items were based on questions used to characterize program satisfaction in previous online ACT studies (e.g., Levin, Haeger, et al., 2017).

App usage. App usage data were collected directly through LifeData. Initial download, automatic notifications received, other sessions initiated, and responses to sessions were all automatically recorded through the mobile app platform. These data provided information on program access and program engagement.

Analysis plan

The help-seeking sample (n = 35) and SONA credit sample (n = 63) were analyzed separately due to the notable differences between samples (e.g., why they are participating, how they might respond to the intervention). Mixed model repeated measures (MMRM) analyses examined time by condition interactions to test whether changes in outcomes from pre to mid to post differed between conditions (simple matrix, complex matrix, and waitlist). The outcome measures for these analyses were depression, anxiety, and stress (measured by their respective DASS-21 subscales), generalized distress (DASS-21 total score) and positive mental health (MHC-SF). Process measures tested in these analyses were progress toward values (VQ Progress) and obstruction with valued living (VQ Obstruction). An intent-to-treat approach was used in which all participants who completed the baseline survey were included in analyses. Restricted maximum likelihood estimation was used to account for missing data. Cohen's d effect sizes were computed for omnibus effects and within-condition and between-condition comparisons. Since this is a pilot study with a relatively small sample, trends (with a p-value of less than .10) are reported although the standard alpha of .05 was applied to evaluate statistical significance.

Hierarchical generalized linear models (HGLM) were also computed for each sample to test for changes in the probability of reporting making towards moves compared to away moves in the matrix app over time and by treatment condition. Hierarchical modeling was necessary to

account for observations nested within participants. Random intercepts were allowed for participants. To estimate the probability of making a "towards move" compared to an "away move," logit link functions were used.

Descriptive statistics on program engagement and satisfaction were also reported separately for each sample to evaluate feasibility and acceptability of this intervention for help-seeking and SONA credit participants.

Results

Preliminary analyses

All dependent variables were examined for skewness and kurtosis. DASS total, depression, anxiety, and stress were notably skewed. After applying a square root transformation they demonstrated acceptable normality. All other variables appeared to be sufficiently normally distributed to proceed. Study completion rates were acceptable (77.55% of participants who completed the baseline survey completed the midtreatment survey; 79.59% completed the posttreatment survey).

The two samples were also compared on demographics (age, gender, race, ethnicity) as well as differences on study outcomes at baseline (depression, anxiety, stress, positive mental health, progress towards values, and values obstruction). Descriptive statistics for each sample at baseline are reported in Table 1. The SONA credit sample was significantly younger ($M = 20.24$, $SD = 3.88$) than the help-seeking sample ($M = 24.57$, $SD = 7.86$, Mann-Whitney U, $p < 0.001$). The groups were not significantly different on gender, race, or ethnicity. The help-seeking sample and SONA credit sample were significantly different on all study outcomes at baseline at the $p < 0.05$ level, with the help-seeking group reporting significantly higher depression, anxiety,

and stress, lower positive mental health, lower progress towards values, and higher obstruction of values.

To test whether randomization was successful, within each sample, one-way ANOVAs were used to identify any significant differences between conditions at baseline on study variables. In the help-seeking sample, conditions were equivalent with the exception of progress towards values ($F(2, 32) = 4.26$, $p = 0.02$). Participants in the simple matrix condition had significantly higher progress towards values at baseline ($M = 23.64$) compared to the complex matrix condition ($M = 16.60$; $t(22) = 3.36$, $p < 0.01$), while the waitlist ($M = 18.27$) was not significantly different from either active condition (ps > 0.05). To account for this difference, progress toward values at baseline was entered as a covariate in the MMRM analyses. There were no significant differences between conditions in the SONA credit sample on any outcome or process variables.

Help-seeking sample

After randomization, 14 participants were assigned to the simple matrix app, 10 participants were assigned to the complex matrix app, and 11 participants were assigned to the waitlist. Numbers were not equivalent across conditions because the samples were combined for randomization (help-seeking and SONA credit samples).

Primary outcomes. MMRM analyses tested time by condition interactions for distress, depression, anxiety, stress, and positive mental health to compare the effects of the three conditions on these outcomes. Estimated marginal means for each condition over time are reported in Table 2; within-condition and between-condition effect sizes are reported in Table 4. A significant time by condition interaction was found for distress ($F(4, 20.30) = 3.92$, $p = .02$) and anxiety ($F(4, 20.82) = 3.07$, $p = 0.04$) with a trend for depression ($F(4, 20.44) = 2.55$, $p =$

0.07)) and stress ($F(4, 20.38) = 2.61$, $p = 0.07$). There was no significant time by condition interaction for positive mental health (MHC-SF). In each case, the matrix app conditions led to improved outcomes over time relative to the waitlist. Post hoc analyses were conducted to further explore the specific patterns with each outcome.

Two-group time by condition interactions were tested for distress and anxiety to determine which groups differed. For distress, only the complex matrix and waitlist had a significant interaction with time in predicting distress ($F(2, 15.53) = 21.20$, $p < .001$), indicating that the simple matrix and waitlist were not significantly different over time. For anxiety, the complex matrix and waitlist had a significant time by condition interaction ($F(2, 15.26) = 18.51$, $p < .001$) , and there was also a trend towards a time by condition interaction for the simple matrix compared to the waitlist ($F(2, 14.57) = 3.66$, $p = .05$).

Post hoc within-group tests indicated that the complex matrix condition improved significantly on distress from baseline to posttreatment, with a large effect size ($t(21.08) = 3.51$, $p < 0.01$, $d = 1.26$), while the waitlist group trended toward improvement ($t(18.27) = 2.00$, $p = 0.06$, $d = 0.54$) and the simple matrix condition did not improve significantly over the same time period. None of the conditions were significantly different in distress levels at posttreatment.

For anxiety, post hoc tests indicated that the simple matrix condition improved from baseline to post ($t(20.74) = 2.95$, $d = 1.11$, $p = 0.01$), while the complex matrix condition trended toward improvement ($t(20.70) = 1.77$, $p = 0.09$, pre-post $d = 0.67$). The waitlist condition did not change significantly over time. Again, the conditions were not significantly different in anxiety at posttreatment.

Process outcomes. MMRM analyses also tested for time by condition interactions with progress toward values and obstruction with valued living (see Table 2). A significant time by

condition effect was found on progress towards values ($F(4, 22.56) = 3.16$, $p = 0.03$). Two-group time by condition interactions were tested to determine which groups differed. There was a significant time by condition interaction for the complex matrix and waitlist conditions ($F(2, 15.18) = 5.99$, $p = 0.01$). There was a trend towards interaction for the simple matrix compared to the complex matrix ($F(2, 14.14) = 3.22$, $p = 0.07$). There was no significant interaction for the simple matrix and waitlist conditions. In within-condition post hoc tests, only the waitlist improved significantly ($t(20.81) = -2.15$, $p = 0.04$, $d = 0.49$). None of the groups were significantly different at posttreatment, although there was a trend for a difference between the simple matrix condition having greater values progress than the complex matrix condition ($t(25.13) = 1.81$, $p = .08$, $d = -0.90$) and for the simple matrix condition having greater values progress than waitlist ($t(25.31) = 1.85$, $p = .08$, $d = 0.87$). Descriptively, all three groups improved on values progress, but the complex matrix condition had the lowest scores at baseline and improved by a larger amount compared to the simple matrix condition and waitlist. There was no significant time by condition interaction for values obstruction.

HGLM analyses examined whether the probability of reporting toward moves compared to away moves in the app increased over time (specifically, as the number of app notifications increased), and whether condition moderated changes in the probability of making a toward move over time. These analyses were conducted among participants in the active conditions who used the app at least once ($n = 8$ simple matrix users and $n = 10$ complex matrix users). Notification number significantly predicted the probability of making a toward move ($\exp(\gamma) = 1.005$, $p = 0.03$), such that the chance of making a toward move increased by 0.5% for each mobile app notification. This translates to a 15.00% increase in the probability of making a toward move after using the app consistently for four weeks compared to baseline. Condition did

not interact with number of notifications ($p = 0.14$), suggesting that mobile app version did not have an impact on this effect (i.e, both versions of the app had an equivalent impact on improvements in toward moves over time).

Program engagement and satisfaction. Approximately 140 prompted check-ins were delivered to users of the simple app, while 168 were delivered to users of the complex app (with the addition of 28 evening check-ins). As a benchmark for consistent engagement, we expected participants to complete at least half of the prompts delivered, or 70 in total.

The median number of total app contacts in the simple matrix condition was 5 (M = 42.93, SD = 50.59). Usage was extremely skewed, such that the sample was fairly evenly split between participants who did not use the app even once (42.9%) and participants who used the app more than 70 times (42.9%). Conversely, the median number of total app contacts (including toward/away check ins, daily check ins, and other skills) for the complex matrix condition was much higher at 42.5 (M = 53.60, SD = 45.58). All participants assigned to the complex matrix app used the app at least once, and 40% of the sample used the app 70 times or more. Of note, the median number of Toward/Away exercises completed was 25 (M = 36.50, SD = 36.35) and the median number of daily check-ins completed was 15 (slightly over 50% of the days using the app). Although 80% of participants used the other ACT skills in the complex matrix app at least once, the median number of other skills exercises completed was only 2.5 (range: 0 to 5 uses), suggesting that these skills were not a major treatment component for complex app users. A post hoc chi square test of association was conducted and indicated that app condition was a significant predictor of ever using the app ($\chi^2 = 5.71$, $p = .02$).

Satisfaction with the mobile app was high among those participants who completed the posttreatment survey (SUS: M = 82.92, SD = 12.59 in the simple matrix condition; M = 72.08,

SD = 13.27 in the complex condition). A mean score of 72.75 is the benchmark for a "good" rating, while 85.58 is the benchmark for a rating of "excellent" (Bangor et al., 2008).

Participants also rated their satisfaction with a series of statements they scored from 1 ("Strongly disagree") to 6 ("Strongly agree"). The mean score was 4 ("Slightly agree") or higher for satisfaction (*M* = 5.33), enjoyment (*M* = 4.83), helpfulness (*M* = 4.67), and ease of use (*M* = 5.50), although lower for interest in using the app in the future (*M* = 3.67) for the simple matrix condition. Ratings were slightly lower for the complex matrix condition, including satisfaction (*M* = 4.00), enjoyment (*M* = 3.17), helpfulness (*M* = 3.83), and interest in future use (*M* = 2.83), while ease of use was comparable (*M* = 5.83). There were no statistically significant differences between the simple and complex matrix app users on the SUS or the individual satisfaction items.

In providing qualitative feedback, three participants reported technical difficulties as the main problem they encountered using the app, two participants reported difficulty in understanding or applying the "toward/away" distinction, and three participants reported finding the timing or frequency of notifications inconvenient. One participant reported expecting to learn more specific skills. The most commonly reported barriers to using the app were not noticing the notifications and not having enough time, reported by 26.1% and 17.4% of the sample respectively.

SONA credit sample

MMRM analyses were repeated with the SONA credit sample to test for time by condition interactions on any of the outcome or process measures. There were no effects between conditions over time on any outcome or process measure (see Table 3 for descriptive statistics by condition and time).

As above HGLM analyses investigating change in the probability of reporting making a toward move in the matrix app over time were conducted among participants in the active conditions who used the app at least once (n = 19 simple matrix users and n = 22 complex matrix users). Notification number did not predict the probability of making a toward move (p = 0.98), and condition did not interact with number of notifications (p = 0.19) in predicting the probability of making a toward move. This indicates that participants were not significantly more likely to engage in values-consistent behavior over time while using either version of the app.

Thus, the positive findings with the matrix app in the help-seeking sample were not replicated at all in the SONA credit sample.

Program engagement and satisfaction. In this sample, the median number of app contacts was 107 (M = 97.42, SD = 46.44) in the simple condition and 91 in the complex condition (M = 80.17, SD = 61.41). 78.9% of participants in the simple app condition and 50% of participants in the complex app condition responded to at least 70 notifications. In this sample, a chi square test of association indicated that condition did not significantly predict ever using the app (χ^2 = 1.66, p = .20). Satisfaction with the mobile app was once again high among those participants who completed the posttreatment survey (n = 37, SUS: M = 79.03, SD = 16.11 in the simple matrix condition, M = 71.58, SD = 16.16 in the complex matrix condition). The mean score was 4 (“Slightly agree”) or higher for satisfaction (M = 4.94), enjoyment (M = 4.17), helpfulness (M = 4.00), and ease of use (M = 5.71), and lower for interest in using the app in the future (M = 3.59) for the simple matrix condition, while scores were similar or slightly lower for the complex app condition on satisfaction (M = 4.32), enjoyment (M = 3.95), helpfulness (M = 4.05), ease of use (M = 5.26) and interest in future use (M = 3.21).

Comparing samples on app usage and satisfaction

There was a significant difference between the help-seeking sample and the SONA credit sample in total app contacts (Mann-Whitney U, $p = 0.003$). Usage was higher among the SONA credit sample (median = 96, $M = 87.79$, $SD = 55.34$) than among the help-seeking sample (median = 28, $M = 47.38$, $SD = 47.84$). Conversely, there was not a significant difference between the two samples on the SUS or the satisfaction items. It is surprising that improvements were found in the help-seeking sample, but not the SONA credit sample, given the lower app engagement rates among the help-seeking participants and the equivalent app satisfaction ratings in the two samples. The SONA credit sample was incentivized to use the app, which may have contributed to the difference in the impact of the app.

Comparing effects by level of distress

In order to determine whether the difference in results by sample type could be due to levels of distress, the combined samples were divided into two subsamples with 49 participants each based on the median score for generalized distress, which was 29. Most individuals in the help-seeking sample were above the median on distress (26 out of 35), and most individuals in the SONA credit sample were below the median on distress (40 out of 63).

No significant time by condition interactions were found in the lower-distress group on any outcome or process measure. However, in the higher-distress group significant time by condition interactions did emerge for distress ($F(4, 31.49) = 3.13$, $p = .03$), anxiety ($F(4, 33.57) = 2.68$, $p < .05$), and stress ($F(4, 32.87) = 4.23$, $p = .01$). There was no significant time by condition interaction in the higher-distress group for depression, progress towards values, values obstruction, or positive mental health. Two-group time by condition interactions indicated that there were significant differences in change over time between the complex matrix and waitlist conditions for distress ($F(2, 24.12) = 3.76$, $p = .04$) and stress ($F(2, 23.51) = 6.72$), $p < .01$ but

not anxiety. There were significant differences in change over time between the simple matrix and waitlist for distress ($F(2, 19.21) = 7.37$, $p < 0.01$), anxiety ($F(2, 21.46) = 8.00$, $p < .01$) and stress ($F(2, 20.98) = 5.84$, $p < .01$). There were no significant differences between the simple and complex matrix conditions on any outcome variable.

Distress, anxiety, and stress in the higher-distress sample were further probed with within-condition and between-condition post hoc tests. The complex matrix condition ($t(33.08) = 4.02$, $p <.001$) and simple matrix condition ($t(33.14) = 4.65$, $p < .001$) both improved significantly from pre to post on distress, while the waitlist condition did not change significantly. There were no significant differences between conditions at post, although a trend was observed for the simple matrix having lower distress compared to waitlist ($t(39.64) = -1.95$, $p = .06$).

For anxiety, the simple matrix condition improved from pre to post ($t(33.90) = 4.74$, $p < .001$), and there was a trend for complex matrix condition improving ($t(33.84) = 2.01$, $p = .05$), but the waitlist did not improve. At post only the simple matrix and waitlist were significantly different on anxiety ($t(41.49) = -2.56$, $p = .01$) .

For stress, the simple matrix ($t(34.89) = 4.26$, $p < .001$) and complex matrix ($t(34.68) = 3.23$, $p < .01$) improved or time, while the waitlist did not. At post no conditions were significantly different, but there was a trend for the simple matrix being superior to waitlist ($t(39.11) = -1.94$, $p = 0.06$).

Overall, these results indicate that among participants higher in distress, the two matrix app conditions led to improvements in psychological distress relative to the waitlist condition. However, the simple and complex matrix both performed similarly, though the more of the post hoc tests were significant or trending for the simple matrix condition. These results with more

distressed participants are similar to those with help seeking participants, though with the simple matrix condition leading to better outcomes in the distressed sample.

Discussion

This pilot randomized controlled trial sought to evaluate the impact of two versions of a mobile app using the ACT matrix in two distinct samples, a help-seeking sample and a sample of research participants receiving SONA credit for participating. Preliminary support for the efficacy of the matrix app was found in the help-seeking sample, with distress, anxiety, depression, stress and progress towards values improving for those in the app conditions compared to the waitlist. The probability of making a towards move over time also increased among app users in the help-seeking sample, suggesting that values-consistent actions increased over time while using the app. Post hoc analyses indicated that these effects were largely driven by the complex app condition, suggesting the addition of more sophisticated features beyond a simple prompt for a toward-away matrix discrimination task improved outcomes. In contrast, the SONA credit sample, a sample not characterized by participants seeking help, did not improve on any outcome or process measure, suggesting the impact of the matrix app may be attenuated in non-clinical samples or otherwise do not generalize to this research credit context. When reevaluating the samples by dichotomizing on level of distress, results were similar, with no improvement in the lower-distress group and improvement on distress, anxiety, and stress in the higher-distress group.

Differences in outcomes between the samples may be explained by distress levels or by interest in seeking help. While both samples indicated moderate to high satisfaction with the app, participants in the help-seeking sample improved more despite lower levels of app usage. It appears that their interactions with the app were qualitatively different, resulting in a greater

impact on their behavior and symptoms. The help-seeking sample presented as more distressed at baseline and may have had more motivation and genuine interest to engage, contributing to a stronger overall treatment effect. While both samples reported moderate to high program satisfaction, these notable differences between samples suggest testing acceptable, user-friendly apps in non-motivated participants is not sufficient to measure program outcome and engagement. Participant motivation and readiness to change may be very important factors for testing efficacy of high-frequency, low-intensity mobile apps.

While effects were stronger for participants actively seeking help, there were also stronger effects for help-seeking participants who were randomized to the complex app condition in comparison to those who were randomized to the simple app condition. Participants with the complex app demonstrated greater app use, suggesting the novelty of additional exercises and activities may increase the appeal or credibility of a matrix mobile app. Interestingly, participants in the complex app condition did not routinely access most of the additional activities and features nor did they report higher satisfaction in comparison with participants in the simple app condition. Thus, it is unclear why the addition of other features beyond the simple matrix activity improved outcomes, but it may be that simply the perception of the app being more sophisticated and complex can enhance effects.

The median number of app contacts was significantly higher in the complex matrix condition as compared to the simple matrix condition in the help-seeking sample, despite limited use of the additional skills incorporated into the complex matrix app. Use of the daily check-in was relatively high (on average, about half of days), suggesting that this option may have additional appeal compared to random check-ins throughout the day. Engagement varied widely for help-seeking participants in the simple app condition, as participants seemed to engage fully

or not at all during the program. It appears that approximately 40% of the help-seeking sample found the simple app to be useful, while more than half of the sample randomized to the simple app did not find it to be worthwhile or perhaps found it difficult to understand, as some participants indicated. Rates of adherence (i.e., completing at least 70 check-ins) were similar for both versions: 40% in the complex app condition and 42.9% in the simple app condition. Keeping users engaged is a common problem in online interventions for mental health, with adherence rates for randomized controlled trials estimated at approximately 50-70% for depression and rates ranging from 50-90% for anxiety disorders (Christensen, Griffiths, & Farrer, 2009). The lower adherence in this intervention could be related to the nature of this intervention as focused on a particular skill and not targeted to specific problems or goals. The low adherence rates suggest limitations to acceptability not captured by overall user ratings.

Implications for Future Research

It appears that a low-intensity, high-frequency mobile app intervention designed to teach a specific skill (toward-away discrimination) to increase psychological flexibility has notable benefits among help-seeking and/or distressed individuals. The app appears to have been most effective in promoting increases in valued behavior, consistent with the theoretical aims of the ACT matrix. As such, these findings support the utility of teaching toward-away discriminations, whether in face-to-face therapy or in an online or mobile app format. The app could be particularly useful as an adjunct to therapy, as it provides a simple method to support the generalization of skills learned in ACT to daily life. Testing the effects of using the matrix app when combined with additional training, features (e.g., social networking integration, customization) and/or human support could help to determine the conditions that best support adherence and maintenance of treatment gains.

Non-clinical samples are often convenient for app-based studies, but this study suggests the use of such samples may disguise potential program benefits in some cases. Although we did not measure motivation to use the app and other potential explanatory variables, future research would benefit from investigating such variables, particularly if non-clinical samples are being used. Future studies might also include components designed to enhance autonomous motivation prior to using this type of app to determine whether or not addressing motivation prior to mobile app usage increases treatment effects or adherence.

Engagement may also be influenced by one's initial judgment of an app. 26% of mobile apps are used only once (Localytics, 2011) indicating the difficulty of engaging app users consistently over time. Although data regarding the "first impressions" of the randomized app conditions were not collected in the current study, engagement rates suggest that initial perceptions may have been important. The substantial proportion of participants in the help-seeking sample randomized to use the simple matrix app who did not use the app even once suggests that this version was lacking in initial perceived credibility or appeal. Further research might gather qualitative feedback such as "first impressions" from app users or collect data on expectations and satisfaction at multiple time points to distinguish whether initial perceptions of credibility or program satisfaction explain engagement.

Limitations

This study has limitations that should be considered in interpreting the results. The size of the help-seeking sample was relatively small and therefore power was limited for some analyses. These results should be replicated in an RCT fully powered for efficacy testing. As a low-intensity intervention, it would be reasonable to expect small effect sizes, which might have been difficult to detect. In addition, while researcher contact in this study was relatively minimal (i.e.,

reminders to try using app or complete assessments), there was consistent researcher contact making this study less than naturalistic. In the future it would be beneficial to study mobile app engagement under more naturalistic conditions. This study also did not use any clinical or severity cutoffs to determine the samples, and as such the results might be different in a more distressed or clinical population. Finally, both samples were young and ethnically homogeneous, and as such it is unclear if these results would generalize to other populations.

Conclusions

As a whole these findings suggest notes of both value and of caution in a matrix mobile app. The matrix mobile app resulted in improvements in distress and anxiety with trends for depression and stress in the help-seeking sample. It is notable that self-reported progress toward values and the reported rate of toward moves both increased over time among help-seeking participants, as values-consistent behavior change is the primary aim of ACT. These results suggest that a matrix mobile app has the potential to be beneficial in supporting behavior change in some populations, and therefore may be worth further development given the ease of dissemination of this type of app. In addition, the present findings also indicate several potential routes to improve efficacy. Although the app was designed to improve well-being regardless of distress levels, using the app did not result in improvements in a SONA credit sample, which suggests that motivation may be particularly important in this type of high-frequency, low-intensity intervention and should be assessed prior to app use. In addition, improvements in the help-seeking sample were primarily driven by the version of the app with additional features, even though these features were not used often, suggesting that the perceived credibility of an app may be higher when it includes a variety of additional features. Finally, adherence was

relatively low, which suggests that it may be helpful to include additional features (i.e. supportive contact, personalized rewards or reminders) to support consistent use.

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Table 1. *Descriptive statistics by sample at baseline*

	Help-seeking sample	**SONA credit sample**
Age	*M* = 24.57, *SD* = 7.86	*M* = 20.24, *SD* = 3.88
Gender	65.7% female, 34.3% male	73.0% female, 27.0% male
*Race**	94.3% White 2.9% Native Hawaiian/Pacific Islander 2.9% Black 2.9% Other	96.8% White 1.6% Asian 1.6% Pacific Islander
Ethnicity	88.6% not Hispanic/Latino, 11.4% Hispanic/Latino	95.2% not Hispanic/Latino, 4.8% Hispanic/Latino
Distress	*M* = 50.17, *SD* = 28.46	*M* = 29.02, *SD* = 23.42
Depression	*M* = 17.37, *SD* = 12.31	*M* = 9.11, *SD* = 9.19
Anxiety	*M* = 13.09, *SD* = 9.40	*M* = 7.43, *SD* = 8.48
Stress	*M* = 19.71, *SD* = 9.70	*M* = 12.48, *SD* = 8.75
Positive mental health	*M* = 49.91, *SD* = 15.27	*M* = 60.25, *SD* = 10.87
Values progress	*M* = 19.94, *SD* = 6.84	*M* = 23.33, *SD* = 5.05
Values obstruction	*M* = 20.03, *SD* = 5.78	*M* = 16.22, *SD* = 6.28

**Note:* Percentages may equal more than 100% due to the option to report multiple racial identifications.

Table 2. *Estimated marginal means and SE for each outcome and timepoint, by condition – help seeking sample*

	Waitlist		Simple Matrix App		Complex Matrix App	
	M	*SE*	*M*	*SE*	*M*	*SE*
DASS Total - Pre	7.16	0.95	6.49	0.86	7.43	1.27
DASS Total - Mid	7.19	0.95	6.03	0.90	5.53	1.28
DASS Total - Post	6.47	0.89	5.94	0.82	5.78	1.21
DASS-D - Pre	3.78	0.58	3.56	0.53	5.04	0.79
DASS-D - Mid	3.85	0.60	3.61	0.58	4.17	0.82
DASS-D - Post	3.49	0.64	3.67	0.63	3.95	0.86
DASS-A - Pre	3.38	0.59	2.87	0.55	4.03	0.81
DASS-A - Mid	3.55	0.68	2.07	0.69	2.66	0.91
DASS-A - Post	3.30	0.66	1.67	0.65	3.31	0.88
DASS-S - Pre	4.84	0.64	4.02	0.57	4.12	0.84
DASS-S - Mid	4.69	0.65	3.72	0.62	2.98	0.86
DASS-S - Post	4.02	0.58	3.80	0.53	3.30	0.78
MHC – Pre	46.44	4.37	46.79	3.91	53.78	5.74
MHC – Mid	45.23	4.81	45.42	4.84	59.53	6.32
MHC – Post	45.27	4.12	52.16	3.91	58.92	5.49
VQ-Pro – Pre	18.27	1.89	23.64	1.67	16.6	1.98
VQ-Pro – Mid	17.52	1.80	23.00	1.88	21.55	2.02
VQ-Pro – Post	20.28	1.87	25.4	2.03	20.09	2.11
VQ-Obs – Pre	20.09	2.34	21.95	2.16	19.85	3.19
VQ-Obs – Mid	19.38	2.81	19.61	2.87	16.11	3.70
VQ-Obs – Post	18.45	2.58	19.72	2.54	17.37	3.44

Note. DASS Total = Total distress, DASS-D = Depression, DASS-A = Anxiety, DASS-S = Stress, MHC = Positive mental health, VQ-Pro = Values progress, VQ-Obs = Values obstruction. All DASS scores in the table have had a square root transformation applied.

Table 3. *Estimated marginal means and SE for each outcome and timepoint, by condition – SONA credit sample*

	Waitlist		Simple Matrix App		Complex Matrix App	
	M	*SE*	*M*	*SE*	*M*	*SE*
DASS Total - Pre	4.60	0.51	5.25	0.54	4.74	0.46
DASS Total - Mid	3.89	0.51	4.63	0.53	4.55	0.48
DASS Total - Post	4.18	0.54	4.45	0.57	4.36	0.51
DASS-D - Pre	2.33	0.37	2.81	0.39	2.31	0.34
DASS-D - Mid	2.36	0.36	2.34	0.36	2.20	0.34
DASS-D - Post	2.24	0.36	2.31	0.37	2.01	0.34
DASS-A - Pre	2.00	0.39	1.82	0.41	2.37	0.36
DASS-A - Mid	1.23	0.35	1.86	0.36	2.27	0.33
DASS-A - Post	1.76	0.37	1.79	0.38	2.05	0.34
DASS-S - Pre	3.03	0.31	3.76	0.33	3.09	0.29
DASS-S - Mid	2.66	0.34	3.45	0.35	3.00	0.32
DASS-S - Post	2.85	0.37	3.16	0.38	2.99	0.35
MHC – Pre	60.00	2.43	57.63	2.49	62.54	2.22
MHC – Mid	59.08	2.37	59.79	2.38	65.62	2.21
MHC – Post	61.68	2.63	58.96	2.67	68.09	2.48
VQ-Pro – Pre	23.30	1.14	22.53	1.17	24.00	1.04
VQ-Pro – Mid	22.92	1.32	23.98	1.30	24.33	1.25
VQ-Pro – Post	24.21	1.34	24.22	1.35	26.61	1.28
VQ-Obs – Pre	15.70	1.43	16.37	1.46	16.54	1.3
VQ-Obs – Mid	15.82	1.51	15.10	1.49	16.72	1.42
VQ-Obs – Post	15.56	1.43	14.86	1.45	16.36	1.35

Note. DASS Total = Total distress, DASS-D = Depression, DASS-A = Anxiety, DASS-S = Stress, MHC = Positive mental health, VQ-Pro = Values progress, VQ-Obs = Values obstruction. All DASS scores in the table have had a square root transformation applied.

Table 4. *MMRM results for the help-seeking sample*

	Time x Condition		Pre-Post Within Condition *d* [95% CI]			Between Condition Post *d* [95% CI]		
Measure	*F*	*d*	Simple	Complex	Waitlist	Complex vs. Simple	Simple vs. Waitlist	Complex vs. Waitlist
Psychological Distress (DASS)	3.92*	0.88	0.41 [-0.22, 1.04]	1.26** [0.65, 1.87]	0.54† [-0.58, 1.66]	0.09 [-0.40, 0.58]	0.29 [-0.53, 1.11]	0.39 [-0.53, 1.31]
Depression (DASS)	2.55†	0.71	-0.11 [-0.50, 0.28]	1.08** [0.59, 1.57]	0.35 [-0.40, 1.10]	-0.18 [-0.52, 0.16]	-0.11 [-0.65, 0.43]	-0.29 [-0.91, 0.33]
Anxiety (DASS)	3.07*	0.77	1.11** [0.48, 1.75]	0.67† [0.12, 1.22]	0.23 [-0.55, 1.01]	-1.01 [-1.54, -0.48]	1.01 [0.36, 1.66]	-0.01 [-0.72, 0.70]
Stress (DASS)	2.61†	0.72	0.23 [-0.13, 0.59]	0.86* [0.46, 1.26]	0.71* [0.05, 1.37]	0.45 [0.12, 0.78]	0.19 [-0.34, 0.72]	0.65 [0.04, 1.26]
Positive Mental Health (MHC-SF)	1.62	0.49						
Values Progress (VQ)	3.16*	0.75	0.31 [-1.74, 2.36]	0.62 [-1.16, 2.40]	0.49* [-3.13, 4.11]	-0.90† [-2.44, 0.64]	0.87† [-1.39, 3.13]	-0.03 [-2.77, 2.71]
Values Obstruction (VQ)	0.37	0.27						

Note. : †$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$. Baseline values progress was included as a covariate on all analyses except values progress. Negative *d* values indicate change in opposite direction of expected effects (i.e., greater symptoms/obstruction, lower mental health/values progress; better outcomes in waitlist than active condition or in simple app over complex app).

Figure 1. Diagram showing participant flow of the RCT.