Original Paper

Evaluation of a therapist-supported, smartphone-delivered online intervention for depression

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Abstract Word Count: 411
Manuscript Word Count: 4,641
Figures: 12
Tables 1

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Abstract

**Background:** Depression is very common, impairs functioning, and is often untreated. More than 60% of treatment for depressive disorder occurs in primary care settings which often lack time and expertise to treat depression effectively. To address this gap, we developed a therapist-supported, smartphone-delivered 8-week intervention called Ascend. This program was administered at the Meru Health Online Clinic in Finland and is approved by the Finnish national health care regulator.

**Objective:** We conducted three pilot studies to investigate whether the online Ascend intervention produced reductions in depression symptoms in self-referred adults with elevated symptoms of depression. We also explored the relationship between engagement in the intervention and changes in depression symptoms.

**Methods:** Across three pilot studies, 117 Finnish adults with self-reported depression and elevated depressive symptoms (Beck Depression Inventory-II; BDI-II > 9 or Physician Health Questionnaire-9; PHQ-9 > 4) enrolled in the 8-week online Ascend intervention. Ascend consists of cognitive-behavioral and mindfulness meditation exercises delivered through a smartphone application, 20-40 minutes per day of individual daily practice, anonymous online group chat with other users, and chat/phone access to a licensed therapist. Eight weekly themes were delivered in a fixed, sequential format. Depression symptoms were measured at baseline, week 2, 4, 6 and 8 during the intervention, immediately and 4-weeks post-intervention completion. Data were analyzed using intent-to-treat repeated-measures analysis of variance and linear regression models.
Results: We observed significant decreases in depression symptoms from baseline to 4-weeks post-intervention as measured by the BDI-II ($p < .001$, partial eta$^2$ effect size ($\eta^2_p = .54$) in Study 1, PHQ-9 ($p < .001$, $\eta^2_p = .34$) in Study 2, and PHQ-9 ($p < .001$, $\eta^2_p = .53$) in Study 3. We also found a dose-response relationship between indicators of treatment engagement and treatment response. Greater daily practice completed during the Ascend intervention predicted larger decreases in depressive symptoms at 4-weeks post-intervention in Study 1 ($p = .004$, $R^2 = .38$) and Study 2 ($p = .001$, $R^2 = .25$), and a parallel trend in Study 3 ($p = .06$, $\Delta R^2 = .07$). Greater weekly chat group use predicted larger decreases in depressive symptoms at 4-weeks post-intervention in Study 1 ($p = .002$, $R^2 = .38$) and Study 2 ($p = .001$, $R^2 = .23$), but not in Study 3 ($p = .73$, $R^2 = .00$).

Conclusions: Engagement in treatment and reduction in depression symptoms during the online Ascend intervention are promising. However, validation from controlled study designs is needed to establish the evidence-base for the Ascend intervention.

Keywords: depression; online intervention; mindfulness; cognitive therapy; digital therapeutics; digital health
Introduction

Depression is one of the most common mental disorders, impacting more than 300 million people worldwide according to the World Health Organization (WHO; [1]). Furthermore, depression carries the heaviest burden of disability among all mental and behavioral disorders [1]. People who suffer from depression often experience significant problems with employment, physical health, interpersonal functioning, and suicidal ideation and attempts. Thus, depression inflicts a significant burden on the individual, the network of family and friends, and society at large.

There are several effective psychological and pharmacological interventions for depression. However, the WHO estimates that less than 50% of people with major depression receive any care for their symptoms. Many people with depression do not have access to effective clinical care, and are not willing to use antidepressant medications. Others are hesitant to obtain mental health treatment due to individual and social stigma. Furthermore, when treated with antidepressants, roughly one-third of patients do not experience significant alleviation in symptoms. Finding and attending individual or group psychotherapy in-person may be very effortful for a person with depression. Thus, from a public health perspective, there is a need to examine other ways of delivering interventions for depression that bypass these obstacles.

Online interventions for mental disorders, especially depression and anxiety, have gained increasing popularity during the last decade. They have the advantage of being accessible always with delivery to individuals who previously did not have access to such mental health care. Further advantages include being self-paced, programmable to record practice, and having a sequence of clinical exercises tailored to
the individual. There is also the important ability to encourage and scaffold the implementation of clinical techniques such as cognitive reappraisal and mindfulness meditation practices in real-time and in natural contexts that each individual encounters. Furthermore, there is evidence that web-based interventions that include human support or coaching increases adherence which produces better outcomes [21].

A recent meta-analysis [2] of controlled trials from a ten year period of 2006-16 indicated that the efficacy of therapist-supported online cognitive-behavioral therapy (CBT) was equivalent to face-to-face CBT for reducing depressive symptoms, and superior to treatment-as-usual, waitlist control, and attention control. Meta-analysis did not yield support for an interaction of severity of depression and efficacy, which suggests that online therapies do not need to be limited to mild and moderate depression, as long as patient safety issues have been taken into consideration. Another previous meta-analysis [3] of fifteen randomized controlled online trials of mindfulness-based interventions demonstrated a small, significantly beneficial impact on depression ($g = 0.29$). Studies also suggest cost-effectiveness and cost-utility [4, 5] of online therapies for depression over traditional treatment modalities. Improved cost-effectiveness combined with high scalability makes online therapy a promising area for development and dissemination of clinical interventions worldwide.

The increased usage of smartphones presents a promising route to extend the reach of effective clinical interventions, as these devices tend to be always on and within reach [6,7]. To address the described issues related to providing treatment for depression, we developed a new smartphone-delivered digital intervention that includes
self-help modules, support from a personal remote therapist support, and chat group access to an anonymous patient peer-group support.

**Present Study**

The aim of this study was to examine participant engagement in and depression symptom reduction during the Ascend intervention, a newly developed smartphone-delivered, therapist-supported intervention for depression. For engagement, we examined dropout rate, number of days of practice, and use of an online chat group. For symptom reduction, we examined pre- to 4 weeks post-intervention changes in depression symptoms. We expected to find a significant decrease in depression symptoms as measured by the Beck Depression Inventory-II [8] in study 1, and the Patient Health Questionnaire 9-item version (PHQ-9; [9]) in study 2 and 3 (Hypothesis 1: depression symptom change). To investigate whether there was an engagement dose-response relationship, we examined whether (a) the amount of daily practice completed, and (b) weekly online chat group use during the 8-week Ascend intervention predicted change in depression symptoms at 4-weeks post-intervention (Hypothesis 2: engagement predicts reduction in depression symptoms).

The goal of this study was to examine engagement in Ascend, a new online intervention for depression, and determine whether the Ascend intervention reduced depression symptoms in a real-world setting. Findings provide initial evidence that the Ascend intervention was associated with adequate levels of engagement and depression symptom reduction in self-referred adults.

**Methods**

**Recruitment**
Participants were recruited in Finland from March to September 2017 via online Facebook advertisements for the Meru Health Online Clinic, a national remote health care provider approved by the Finnish National Supervisory Authority for Welfare and Health (Valvira). Participants were offered a free online intervention for depression that included smartphone delivered content, anonymous chat groups, and phone access to therapists. All participants were required to have a smartphone. For characteristics of the participants in all three studies, see Table 1.

Table 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Study 1 (n = 22)</th>
<th>Study 2 (n = 47)</th>
<th>Study 3 (n = 48)</th>
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<tr>
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Note: SD=standard deviation, No=number, % = percentage.

To enter the study, participants had to demonstrate elevated depressive symptoms based on the BDI-II (≥10) in study 1, and based on the PHQ-9 (≥5) in studies 2 and 3. Other inclusion criteria included the perceived ability of the participant by both the participant and therapist to commit to an 8-week online intervention with a minimum of 20 minutes of practices 6 days per week. The exclusion criteria included previous suicidality or suicidal attempts, active substance abuse, and any previous or current psychotic disorder. As part of the standard treatment procedure at the Meru Health
Online Clinic, Ascend program therapists conducted phone interviews prior to enrollment to go through the inclusion and exclusion criteria and to determine participant suitability for the online intervention.

**Procedures**

We informed participants that the goal of the study was to examine a new online intervention for depression, delivered through a smartphone application. Participants provided informed consent through the Ascend smartphone application for their anonymous data to be used for further intervention refinement and research purposes. Participants were not compensated for their participation. They enrolled in the program at no cost. Institutional review board exemption was granted by Pearl IRB for secondary analyses of previously collected and de-identified data.

We gave participants a link to download the Meru Health Ascend application to their smartphone to access the intervention content. They were given a unique identification number and asked to complete survey responses at multiple time points before, during and after the 8-week Ascend intervention. We trained participants on how to access an anonymous chat group, and to converse with the study therapist via direct one-to-one chat messaging or in few exceptions by phone calls.

**Ascend Online Program**

The online Ascend program consists of 8 modules delivered in a fixed order through a smartphone application over an 8-week period. They include practices derived from mindfulness-based stress reduction [10], mindfulness-based cognitive therapy [11], cognitive-behavioral therapy [12] and behavioral activation therapy [13] treatment protocols. Modules are introduced each week in the following sequence:
Introduction to mindfulness, Low mood and motivation, Self-compassion, Managing worry, Overcoming thinking traps, Rethinking your life values, Being aware of your relationships, and Relapse prevention. The content was designed to teach participants mindfulness meditation and skills derived from cognitive-behavioral therapy. The Ascend program has high standards of data security, and adheres to the General Data Protection Regulation requirements.

The Meru Health therapist provided ongoing individual support as needed and guidance for the online group during the Ascend intervention. The interaction took place primarily via chat-messaging, and in few instances, by phone calls. In addition, both before entering to the program and after its completion, all participants had a phone call with the therapist (see Recruitment above and this passage below). Study therapists used a Professional Dashboard which is a secure web-based tool to monitor participant engagement and chat with participants. The smartphone application hosted all the weekly program content including text, video, audio and graphics. The intervention included video lessons every week, audio-guided mindfulness-meditation practices, visual graphics that illustrated cognitive-behavioral principles, and journaling prompts.

The smartphone application consisted of the following components. A “Me” screen to accesses the daily practices and learning materials. A ”Program” screen to view the structure of the whole Ascend program, identify where on the timeline one is currently located, and access already completed modules and practices. A “Group” screen to view other anonymous participants written reflections of different practices and lessons. The Group screen did not allow any commenting but just viewing of other participant's and therapist's discussion threads. A “Notifications” screen was provided to
track psychotherapist messages and newly available lessons or practices. An “Other” screen to view the Emergency Plan, Privacy Policy, Terms of Use and a single button to contact the therapist via chat messaging.

After completion of the Ascend program, the therapist and participant had an interview via phone call for about 30 minutes to assess the participant’s experiences in the program and any further needs. If there were any signs of mental state deterioration during treatment, the study therapist conducted an additional phone-based assessment of the participant’s condition. For emergencies, such as severe suicidality, the Ascend intervention includes a written action plan which all participants reviewed with the therapist prior to starting the program.

Measures

Engagement

We used multiple measures to assess intervention engagement. We evaluated dropout from the intervention, operationally defined as less than 4 weeks of active participation during the 8-week intervention. We also measured number of days of practice of intervention exercises, and weekly participation in the online chat group.

Depression Symptoms

Beck Depression Inventory – II. Depressive symptoms were measured using the Beck Depressive Inventory-II (BDI-II), a scale containing 21 items rated 0 to 3 in terms of intensity, with total scores ranging from 0 to 63. BDI-II score of 14–19 suggests mild depression; 20–28 moderate depression, and 29–63 severe depression. To enter the Ascend intervention, the participant had to score a minimum of 10 at baseline. The BDI-II has demonstrated high internal consistency (Cronbach’s α = 0.9) in outpatient
samples [14]. Participants completed the BDI-II at baseline, 4, 8 and 12 weeks from intervention onset.

**Patient Health Questionnaire 9.** The PHQ-9 is the 9-item depression scale extracted from the full PHQ. Because each of the 9 items can be scored from 0 (not at all) to 3 (nearly every day), the PHQ-9 score can range from 0 to 27. PHQ-9 score of 5-9 suggest mild depression, 10-14 moderate depression, 15-19 moderately severe depression, and 20-27 severe depression. To enter the Ascend program, the participant had to score a minimum of 5 at baseline. Prior large-scale studies have shown that the PHQ-9 has excellent internal reliability, with Cronbach's α of 0.89 in primary care settings, and excellent test-retest reliability [9]. Participants completed the PHQ-9 at baseline, weekly during the intervention (8 assessments) and 4 weeks post-intervention completion (12 weeks post-intervention onset).

**Therapist Rating Questionnaire.** To assess the patient-therapist interaction, we used a single-item question: “How valuable has the therapist interaction been for you?” This rating ranged from 1 to 5, with higher values indicating greater value. The patient-therapist interaction was assessed at week 1, 3, 6 and post-intervention.

**Statistical Analysis**

**Engagement.** We computed descriptive statistics for the different indicators of intervention engagement. We plotted the number of days per week of practice during the intervention, and number of weeks of chat group use and used a repeated-measures analysis of variance (ANOVA) with Huynh-Feldt correction for autocorrelation of adjacent time points to examine whether there was significant change over time in number of days of practice completed and in online chat group use.
Depression symptom change. We implemented repeated-measures ANOVA and reported effect size as partial eta-squared ($\eta^2_p$) and Hedge's $g$ using SPSS version 25. We used an intent-to-treat analysis that included all participants regardless of whether they completed or dropped out of the intervention. We used the more conservative method of last observation carried forward to insert missing data points for the 4-weeks post-intervention dependent variable.

Relationship between engagement and change in depression symptoms. Using linear regression analysis, we examined whether change in depression symptoms from baseline to 4-weeks post-intervention was predicted by (a) the number of days of practice during the intervention and, separately, (b) weekly use of the online chat group. We used linear regression to first compute the standardized residual of depression symptoms at 4-weeks post-intervention, and then tested whether each engagement variable (daily practice, weekly chat group) predicted residual depression at 4-weeks post-intervention. We report variance explained as well as 95% confidence intervals (CI).

Results

Study 1

Engagement. Six of the 22 participants (27%) dropped out from the Ascend intervention. Participants practiced smartphone-delivered exercises on 42% of the days, $Mean (M) = 23.8$ days, $SD = 14.3$; range 1 to 49 days, during the 8 weeks (i.e., 56 days) Ascend intervention. A repeated-measures ANOVA, with Huynh-Feldt correction for autocorrelation of adjacent time points, showed that the mean number of days per week of practice decreased significantly, $F(4.02) = 15.02, p = .000, \eta^2_p = .43$, Hedge's $g =$
2.21, from week 1 ($M = 4.57$ days, $SD = 1.72$) to week 8 ($M = 1.52$, $SD = 1.83$) of the intervention (Figure 1). Participants engaged in the weekly online chat group on average 4.87 weeks ($SD = 3.12$; range: 0 to 8 weeks). A repeated-measures ANOVA, with Huynh-Feldt correction for autocorrelation of adjacent time points, showed that the percentage of participants who used the online chat group per week decreased significantly from week 1 (78%) to week 8 (52%), $F(5.21) = 2.65$, $p = .025$, $\eta^2_p = .11$, Hedge's $g = .68$. Participants reported a high and consistent level of value of the participant-therapist interaction across four time points during the 8-week intervention ($M = 4.12$).

Figure 1: Mean Number of Days Per Week of Smartphone-Delivered Practices Completed During the 8-week Ascend Intervention During Study 1

Error bars = standard error of the mean
**Depression symptoms.** We used an intent-to-treat analysis that included all participants. A repeated-measures ANOVA of depression symptoms measured with the BDI-II revealed a significant reduction from pre- to 4-weeks post-intervention (i.e., week 12 assessment), $F(1,21) = 24.44, p < .001, \eta^2_p = .54, g = 1.98$ (Figure 2).

Figure 2: Mean Depression Symptoms During Ascend Intervention Study 1

![Beck Depression Inventory - II](image)

Error bars = standard error of the mean

**Engagement – depression symptom relationship.** Using a linear regression, we found that greater number of days of practice significantly predicted a reduction in (baseline residualized) depressive symptoms (BDI-II) at 4-weeks post-intervention, $R^2 = .38, F(1,20) = 10.91, p = .004$, unstandardized coefficient beta = -.04, SE of beta = .01, 95% CI [-.07, -.02] (Figure 3).
Figure 3: Practice During Ascend Intervention Predicts Residualized Depression Symptoms in Study 1

Similarly, we found that greater number of weeks of chat group use predicted a reduction in depressive symptoms at 4-weeks post-intervention, $R^2 = .38$, $F(1,20) = 12.40$, $p = .002$, unstandardized coefficient beta = -.19, SE of beta = .06, 95% CI [-.31, -.08] (Figure 4).

Figure 4: Online Chat Group Use During Ascend Intervention Predicts Residualized Depression Symptoms in Study 1
Study 2

Engagement. Nine of the 47 participants (19%) dropped out (less than 4 weeks of active participation). Participants completed practices 51% of the days ($M = 28.6$ days, $SD = 13.8$; range 1 to 51 days) during the Ascend intervention. A repeated-measures ANOVA, with Huynh-Feldt correction for autocorrelation of adjacent time points, showed that the mean number of days per week of practice decreased significantly, $F(7,287) = 28.41, p < .001, \eta^2_p = .41, g = 1.61$, in a linear trajectory from week 1 ($M = 5.02$ days, $SD = 1.87$) to week 8 ($M = 1.69$, $SD = 1.83$) of the intervention (Figure 5). Participants engaged in the weekly online chat group on average 5.13 weeks
(SD = 2.88; range: 0 to 8 weeks). A repeated-measures ANOVA, with Huynh-Feldt correction for autocorrelation of adjacent time points, showed that the percentage of participants who used the online chat group per week decreased significantly from week 1 (78%) to week 8 (51%), $F(5.73) = 3.93$, $p = .001$, $\eta^2_p = .08$, Hedge’s $g = .59$.

Participants reported a high and consistent levels of value of the participant-therapist interaction across four time points during the 8-week intervention ($M = 4.13$).

Figure 5: Mean Number of Days Per Week of Smartphone-Delivered Practices Completed During the 8-week Ascend Intervention During Study 2

Error bars = standard error of the mean
**Depression symptoms.** A repeated-measures ANOVA of depression symptoms measured with the PHQ-9 revealed a significant reduction from pre- to 4-weeks post-intervention (i.e., week 12), $F(1,45) = 23.19$, $p < .001$, $\eta^2_p = .34$, $g = 1.38$ (Figure 6).

Figure 6: Mean Depression Symptoms During Ascend Intervention Study 2

![Figure 6: Mean Depression Symptoms During Ascend Intervention Study 2](image)

Error bars = standard error of the mean

**Engagement – depression symptom relationship.** Using a linear regression, we found that greater number of days of practice significantly predicted lower depression symptoms at post-intervention, $\Delta R^2 = .25$, $F(1,41) = 13.42$, $p = .001$, unstandardized beta = -.036, SE of beta = .01, 95% CI [-.055, -.016] (Figure 7).
We also found that greater number of weeks of chat group use predicted lesser residualized depressive symptoms at 4-weeks post-intervention, $R^2 = .23$, $F(1,43) = 12.78$, $p = .001$, unstandardized coefficient beta $= -.16$, SE of beta $= .05$, 95% CI [-0.26, -0.07] (Figure 8).
Study 3

Engagement. Five of the 48 participants (10.4%) dropped from the Ascend intervention. Participants completed practices 59% of the days ($M = 33$ days, $SD = 13.8$; range 3 to 56 days) during the Ascend intervention. A repeated-measures ANOVA, with Huynh-Feldt correction for autocorrelation of adjacent time points, showed that the mean number of days per week of practice decreased significantly, $F(5.75, 270) = 14.88, p = .000, \eta^2_p = .24, d = 1.09$, in a linear trajectory from week 1 ($M = 5.06$ days, $SD = 1.58$) to week 8 ($M = 3.46, SD = 2.39$) of the intervention (Figure 9). Participants
engaged in the weekly online chat group on average 6.44 weeks ($SD = 2.23$; range: 0 to 8 weeks). A repeated-measures ANOVA, with Huynh-Feldt correction for autocorrelation of adjacent time points, showed that the percentage of participants who used the online chat group per week decreased significantly from week 1 (92%) to week 8 (67%), $F(5.39) = 3.08$, $p = .008$, $\eta^2_p = .06$, Hedge's $g = .51$.

Figure 9: Mean Number of Days Per Week of Smartphone-Delivered Practices Completed During the 8-week Ascend Intervention During Study 3

[Chart showing the mean number of days per week of smartphone-delivered practices completed during the 8-week Ascend Intervention with error bars indicating standard error of the mean.]

**Depression symptoms.** A repeated-measures ANOVA of depression symptoms measured with the PHQ-9 showed a significant reduction from baseline ($M = 13.7$, $SD =$
5.0) to 4-weeks post-intervention ($M = 7.7$, $SD = 5.7$), $F(1,47) = 53.43$, $p < .001$, $\eta^2_p = .53$, $g = 2.05$ (Figure 10).

**Engagement – depression symptom relationship.** Using a linear regression, we found that greater number of days of practice predicted a trend toward lower depression symptoms at post-intervention, $\Delta R^2 = .07$, $F(1,46) = 3.62$, $p = .06$, unstandardized coefficient beta = -.02, SE of beta = .01, 95% CI [-.039, .001] (Figure 11).
We found that number of weeks of chat group did not predict residualized depressive symptoms at 4-weeks post-intervention, $R^2 = .00, F(1,46) = 0.12, p = .73$, unstandardized coefficient beta = -0.02, SE of beta = .07, 95% CI [-0.15, .11] (Figure 12).

Figure 12: Online Chat Group Use During Ascend Intervention Predicts Residualized Depression Symptoms in Study 3
Discussion

Principal Results

Findings from this study suggest that the online Ascend intervention was associated with adequate levels of engagement (dropout rate, number of daily practices completed, use of weekly online chat group) and with significant decreases in depression symptoms in three separate samples of self-referred adults. The effect sizes of reduction in depression symptoms across the three samples were consistently large suggesting that the Ascend intervention may be a helpful for depression in real-world clinical settings. Furthermore, there was a dose-response relationship between reduction in depression symptoms and (a) the number of days of practice completed...
and (b) participation in the program chat group during the 8-week Ascend intervention signaling a causal relationship between the intervention and depression improvement.

**Comparison with Prior Work**

_Engagement._ In our three studies, dropout from the Ascend program ranged from 10% to 27% of the sample. Prior studies of internet-delivered CBT have reported dropout rates of 26% for adults with anxiety, depression or post-traumatic stress disorder [15]. A large study (n = 1,843) comparing three different online interventions in adults with depressive symptoms reported dropout rates of 74% for MoodGYM, 67% for online interpersonal psychotherapy, and 70% for online CBT [19]. A more recent study [20] that employed a coach to guide people through online therapy for depressed patients reported a 37% dropout rate. Thus, the dropout rate observed in our three studies is favorable.

Completion of daily smartphone-delivered practices decreased over the course of the 8-week Ascend intervention (see Figures 1, 5, 9). Specifically, across the three studies we observed that 42% to 59% of assigned practices were completed. This suggests that further effort is needed to support sustained practice, especially because practice was shown to predict outcome. This may involve introducing more novel types of practices and/or different modes of delivery of practices in order to maintain the participant's attention and sustained engagement. Ongoing measurement of engagement during the intervention and tailoring the delivery to individual participants may help increase sustained practice. This could involve using individual participant feedback after each practice to direct what type of practice and modality to use to deliver subsequent practices. A brief motivational interview by the therapist may also identify
and overcome obstacles to engagement. This is a component of internet interventions that would benefit from further research. Sustained engagement may likely prevent depression relapses and increase the effect of the Ascend intervention.

Online chat group, often referred to as synchronous text-based dialogue, is an increasingly important component of online mental health interventions. In our three studies, number of weeks of synchronous chat group use across the three studies of the Ascend program ranged from 4.9 weeks to 6.4 weeks. A recent review [22] found that interventions using one-on-one synchronous chat groups improved clinical symptoms compared to waitlist, but not superior to treatment as usual (face-to-face and telephone counseling). Research has found that, compared to oral conversation, text-based chat communication involves approximately 50% fewer words [23]. In our study, however, the synchronous chat group, which included the group of participants and curation by the therapist, was only one component of the intervention. Synchronous group chat may be a useful tool for supporting and reinforcing learning via smartphone delivered exercises.

**Depression symptoms.** We observed a range of large Hedge's $g$ effect sizes from 1.38 to 2.05 for the reduction of depression symptoms from pre- to post-Ascend across the three studies. With regard to internet CBT interventions for major depressive disorder (MDD), a recent meta-analysis of 32 trials of internet CBT and computerized CBT (versus support, care as usual, and/or waitlist control) for MDD reported a significant reduction in depression symptoms ($g = 0.67$) [16]. For mindfulness-based interventions (MBI) delivered online only, a meta-analysis of 15 MBI trials resulted in a small but significant effect on depression symptoms ($g = 0.29$) [3]. This is relatively
smaller than the effect sizes reported in a meta-analysis of in-person, uncontrolled MBIs in patients with anxiety and mood disorders [24] for reduction of anxiety ($g = 0.97$) and mood symptoms ($g = 0.95$). A recent meta-analysis of in-person, uncontrolled MBIs in adults with cancer [25] revealed moderate pre- to post-reductions in anxiety ($g = 0.60$) and depression ($g = 0.42$). However, another meta-analysis of 18 RCTs examining 22 smartphone apps found significant depression symptom reduction compared to inactive controls ($g = 0.56$) but a smaller effect compared to active control conditions ($g = 0.22$). Importantly, the effect sizes did not differ significantly as a function of apps that incorporated mood monitoring, CBT or mindfulness training techniques [17].

**Relationship between engagement and change in depression symptoms.**

Identifying predictors of better outcomes is essential for determining how to refine and optimize a clinical intervention. We found that greater number of days of completing smartphone delivered practices predicted greater reduction in self-reported depression symptoms. The variance in depression symptom reduction explained by practice during the 8-week Ascend intervention ranged from 7% to 38%. We also found in two of the three pilot studies that greater number of weeks of chat group use predicted reduced depression symptoms, with variance explained varying from 23% to 38%. While these findings are promising, they also suggest that there likely are other factors that predict outcome and that may interact with subgroups of patients. It will be important to determine which specific practices and what amount of synchronous group chat use are most effective for reducing depression symptoms.

Furthermore, identifying patient characteristics that predict the impact of online interventions on depression symptoms is essential. A well-controlled study of self-
guided internet-delivered interpersonal psychotherapy vs. CBT vs. MoodGYM found that female gender, lower mastery and lower dysfunctional attitudes predicted lesser depression symptoms immediately following 4 weeks of treatment and/or 6-months follow-up regardless of intervention type [18]. Understanding how these patient characteristics interact with practice and chat use will be important to examine in future studies.

Given that novelty captures attention, one approach is to explore on an individual participant level, whether introducing new modalities of delivery of didactic content and practices might re-capture attention and dedication to practice. An algorithm could be used to detect when the number of days of practice begins to decrease and then introduce new videos, practices, or communication from other participants and psychotherapist to buttress against further reduction in practice. A different method would be to show each individual their own week-to-week relationship between practice and depression symptoms to further motivate engagement with the Ascend program.

**Limitations**

This pilot study does not include any control with or without an active comparison intervention or control group which limits the inferences that can be made regarding efficacy or comparison of the effect sizes between the Ascend program and other interventions. Participants were self-referred, which may bias the sample towards those who are particularly highly motivated to this intervention. Future studies will benefit from comparison of Ascend to gold-standard psychosocial (e.g., CBT) and pharmacological (e.g., selective serotonin reuptake-inhibitors) interventions, as well as comparison to control group without an active intervention. While this study provides initial evidence of
depression symptom reduction, future studies should include diagnostic interviewing to establish whether Ascend produces remission from mood disorders. In addition to changes in clinical symptoms, it will be important to measure putative mediators of the Ascend intervention related to mindfulness meditation (e.g., mindfulness skills) and CBT (e.g., cognitive reappraisal).

Conclusions

The overall finding from this pilot study is that the 8-week online Ascend intervention was associated with adequate engagement and significant reduction in depression symptoms that were predicted by the amount of practice. However, more rigorous controlled trials that compare the Ascend intervention with both other online mental health interventions and gold-standard clinical interventions such as cognitive-behavioral therapy for major depression are needed.
Acknowledgements

We wish to express our gratitude to the staff at Meru Health who collected and archived the data in Finland.

Conflicts of Interest

Dr. Goldin owns options of Meru Health Inc. Mr. Lindholm serves as the chief operating officer (COO) in Meru Health Inc. He owns a large share of the company's stocks and raises salary from the Meru Health. Mr. Ranta serves as the chief executing officer (CEO) in Meru Health Inc., owns a large share of stocks and raises salary from the company. Dr. Hilgert is employed as a chief therapist in Meru Health Inc., receives salary from the company and owns stocks and options of Meru Health Inc. At the time of the study, Mrs. Helteenvuori was employed as a therapist in Meru Health Inc., and received salary from the company. Dr. Raevuori is employed as a medical director in Meru Health Inc., and receives salary from the company. Dr. Raevuori owns stocks and options of Meru Health Inc.
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