

App-Based Mindfulness Study in Autistic Adults

by

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ABSTRACT

Autistic adults face heightened risk of psychiatric disorders, with depression occurrence estimated at quadruple the rate of the general population. Mindfulness Based Stress Reduction (MBSR), an intensive 8-week in-person intervention, reduces depressive symptoms in adults with autism spectrum disorder (ASD). However, access to these programs is restricted due to financial, geographic, and scheduling limitations. Additionally, lapses in practice post-intervention cause these effects to be short-lived. This study examines antidepressant effects of an 8-week app-delivered mindfulness meditation intervention using Ten Percent Happier in adults with ASD and explores whether anchoring meditation practice to a preexisting behavior will improve therapy compliance and depression-related efficacy.

Ninety-seven participants were randomly assigned to either App Only (n=30), App + Habit training (n=27) or Waitlist Control (n=40). App Only and App + Habit groups were requested to meditate a minimum of 10 minutes per day, 5 days per week for 8 consecutive weeks using the mobile application. The App + Habit group received additional instruction to anchor leaving the bathroom each morning with meditation; The App Only group was only provided with education on habit formation. Participants completed the Beck Depression Inventory-II (BDI-II) at pre- and post-intervention. All groups received weekly ecological momentary assessments (EMAs) to assess frequency and length of practice. The App + Habit group was additionally assessed for cue-initiated

meditation frequency. Data were analyzed using repeated measures analysis of variance (ANOVA).

Pre-to-post changes on BDI-II scores indicated a group by time interaction ($p=0.04$) and a main effect of time ($p < 0.001$). Post-hoc analysis revealed the App + Habit group exclusively showed significant decline in depressive symptoms ($p < 0.001$). The App + Habit group showed greater number of days meditated, average minutes per day of meditating, and continuation of meditation practice 8-weeks after the intervention period, compared to the App Only group.

Findings support app-delivered mindfulness interventions as an accessible and cost-effective alternative to traditional in-person mindfulness training for Autistic adults. However, results suggest app-based mindfulness tools may only be effective when delivered with specific habit formation instruction. Additionally, habit formation instruction led to greater adherence to meditation practice after the study period ended.

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INTRODUCTION

With a prevalence rate of 2.21% (5.4 million) in the United States alone, ASD is the most prevalent neurodevelopmental condition to date [1]. In 2015, the cost of care for ASD in the United States was around \$268 billion. Adult services are the majority driving factor in these costs, and the annual cost could rise to \$461 billion by 2025 without more effective treatments being made widely available [6]. The large socioeconomic disparity between the general population and working-age autistic adults furthers the issue of accessibility. Though studies regarding unemployment rates outside of general intellectual disability are scarce, data from 2004 showed a 42% rate of unemployment in young Autistic adults, as opposed to the 1% reported by neurotypical (NT) individuals of the same age [7]. Luckily, programs like the DES Vocational Rehabilitation (VR) program aimed at increasing employment rates for individuals with ASD are on the rise, though there is still much work to be done to close these gaps. Considering the lifetime cost of Autism (\$2.4 million) vs the NT \$1.4 million, as well as the large socioeconomic disparity, the need to create interventions with these issues in mind is imperative [8].

Depression rates in autistic adults are 4x higher than that of the neurotypical population [9]. Corresponding with this, autistic adults face increased levels of social isolation, lower levels of independence, and difficulty with adaptive functioning. This creates daily challenges that may amplify stress responses and negatively impact executive functioning. Uncoincidentally, suicide rates are up to 7x higher than the

national average, creating an urgent need for effective and accessible interventions seeking to improve quality of life [10].

Previous studies examining mindfulness-based therapy in adults with ASD have shown reductions in depression, anxiety, and rumination [11,12]. From a neurological perspective, mindfulness has specific effects on the default mode network (DMN) and salience network (SN) connectivity, helping to increase SN activity to bring participants into the present moment. Simultaneously, meditation aids in reducing DMN activity, thought to play a role in internal mental state processing [13]. This results in more central awareness, bringing the mind back into the body and improving the ability to focus [14]. These benefits may be especially beneficial to adults with ASD, as they are directly correlated to the reported challenges faced by their demographic.

Previous studies suggest mindfulness has a direct effect on symptoms associated with depression, such as poor executive functioning and self-perception [15]. In addition to functionality, autistic adults face lower health-related quality of life than NT populations, which has been alleviated through mindfulness-based intervention [16]. Women on the spectrum are the greatest beneficiaries in these interventions, however all ASD groups show improvement [16]. This serves as a promising means to improve overall quality of life in autistic adults. It must be taken into consideration that, although found to be effective on symptoms, MBSR can be costly, ranging from \$300 to \$600+. Autistic adults of lower socio-economic status tend to experience greater symptoms of

ASD [2], rendering cost as a major disadvantage regarding the access of these critical interventions.

Managing appointments can be challenging with ASD, creating an additional roadblock to accessing MBSR treatment. The steps required to make an appointment, keep a calendar, and even arrange transportation can be taxing for these individuals. Teens with ASD have roughly a 50% lower licensure rate than NT (despite displaying strong interest and having average or above intellectual capacity), which may call for additional resources for getting to appointments, creating an additional hurdle [3]. Though there are some non-profits providing these services free or at a reduced cost, funding for such programs is limited. Providing an App-Based intervention with similar efficacy could be a means to reach even more people facing a range of obstacles in attending MBSR sessions.

Long-term users of mobile health apps, or mHealth apps, have a high rate of achieving their health goals. However, benefits are only achieved if users persist past the initial usage phase, where most either stop using or switch apps [4]. It is important to take into consideration adherence when designing novel mHealth applications.

Multiple mindfulness mHealth apps have been shown to improve depression symptoms in NT populations, demonstrating a positive effect on mood and wellbeing [18-20]. In a previous study examining the use of an mHealth app called Smiling Mind in autistic adults, boredom and distraction contributed to a large discontinuation of

participation [17]. Restrictive Repetitive Behaviors are one of the main markers of ASD, characterized by repetitions in movements, niche interests and adherence to rituals. Routines can be a consistent and predictable part of daily life, which autistic adults may find calming. Habit-forming measures to ensure long-term success may enhance the feasibility of mindfulness-based mHealth apps to reduce symptoms of depression in autistic adults, which this study investigates by piggybacking a new mindfulness habit onto an existing routine using pre-existing cues and Ecological Momentary Assessments (EMAs).

In a recent, in-person mindfulness trial for autistic adults, the amount of time spent practicing mindfulness correlated with depressive symptoms [21]. Due to the COVID pandemic, in person mindfulness-based interventions were halted for public safety. To continue exploring the effectiveness of mindfulness in the target population, and to explore an equally effective and more accessible treatment, attention was shifted to the use of mobile applications. The present study aims to examine the feasibility of more accessible, equally effective delivery methods for mindfulness interventions by introducing an app-based modality and evaluating the addition of habit training on antidepressant effects of MBSR. We hypothesized that the addition of cue-initiated habit training would enhance the efficacy of a Mindfulness-Based mHealth application on depression symptoms in Autistic adults when compared to app use alone.

METHODS

Participants were recruited via a database supplied by the Southwest Autism Research & Resource Center (SARRC) and the Simons Foundation Powering Autism Research (SPARK). These contacts consisted of adults who were 18+, had submitted documentation of an official ASD diagnosis, and had expressed interest in participating in research studies. Participants were contacted via email and a phone interview was conducted to determine eligibility. During the screening, the Wide Range Achievement Test was administered to determine approximate IQ, allowing for a minimum score of 70. Demographic information was collected to determine biological sex, age, psychotropic and supplemental drug use, additional diagnoses, ethnicity/race, BMI, and education level. Of the 130 originally recruited participants, twenty-nine were unable to be reached at various points during the collection period and were missing one or more of the demographics or surveys collected, resulting in 97 participants included in analyses. Arizona State University Institutional Review Board provided ethical approval for this study and all participants provided electronic consent prior to participation.

TABLE 1 Participant Demographics

	App Only	App + Habit	Waitlist Control	Baseline Group Differences (M/F Only)
Sample Size (M/F/U)	30 (8/22)	27 (10/17)	40 (13/22/5)	$\chi^2(2)=0.99, p=.61$, Cramer's $V=.10$
Age	37.5 (12.13) range: 18-66	41.13 (16.71) range: 19-77	35.52 (10.57) range: 20-55	$F(2,92)=0.26, p=.774, \eta^2=.006$ [0.00,0.05]
IQ	114.50 (9.10) range: 94-130	114.63 (10.82) range: 95-132	111.71 (11.13) range: 94-132	$F(2,57)=0.55, p=.59, \eta^2=.02$ [0.00,0.11]

TABLE 2 Pre-intervention and Post-intervention BDI-II Score Means and Standard Deviations

	App Only			App + Habit			Waitlist Control					
	Pre-Intervention	Post-Intervention	Paired <i>t</i> -test	Pre-Intervention	Post-Intervention	Paired <i>t</i> -test	Pre-Intervention	Post-Intervention	Paired <i>t</i> -test	Baseline Group	Baseline Time	Time x Group Interaction
BDI-II	13 (11.08), range: 0-40	10.30 (11.30), range: 0-	<i>t</i> (29)=1.94, <i>p</i> =.06	16.78 (11.80), range: 1-40	7.93 (8.72), range: 0-	<i>t</i> (26)=5.59, <i>p</i> <.001	20.33 (11.16), range: 0-	18.30 (11.30), range: 0-	<i>t</i> (39)=1.82, <i>p</i> =.08, <i>d</i> =.29	<i>F</i> (1,51)=1.93, <i>p</i> =.17, partial η^2 =.0	<i>F</i> (1,94)=33.75, <i>p</i> <.001, partial η^2 =.2	<i>F</i> (2,94)=7.34, <i>p</i> =.001, partial η^2 =.14

Participants who consented to the study were randomly assigned to three groups: App Only, App + Habit Intervention and Waitlist Control. All groups were given 1-year and 8 weeks of free access to the application 10 Percent Happier and asked to meditate 10 minutes daily, receiving corresponding EMAs.

The BDI-II was administered before participants began their trial, and upon completion of the 8-week intervention. The BDI-II is a self-report, 21 item revised version of the BDI-I used to measure the severity of major depression symptoms without specialty equipment or training required [30]. Intuitively, the higher scores represent the most severe end of the spectrum. Modifications from the BDI-I to more closely align with the Diagnostic and Statistical Manual of Mental Disorders 1V (DSM-IV) include the extension from a one week to a two-week timeframe inquiry, and the modification of four previously extrospective questions to promote introspective self-analysis [31]. Two additional items were replaced to assess sleep and appetite changes [31]. The BDI-II has been found especially useful in the assessment of depression symptoms in Autistic adults [32]. It is available for purchase through *Pearson Assessments*.

The App Only group was given education on habit formation via a training video at the start of the intervention. They received EMA's asking (i) "How many days did u meditate this week?" and (ii) asking "on average how many minutes did you meditate each time?" for the 16-week trial. The App + Habit group was provided with a training video which provided education on habit formation and instruction on how to anchor meditation practice to preexisting behavior - leaving the bathroom each morning. They

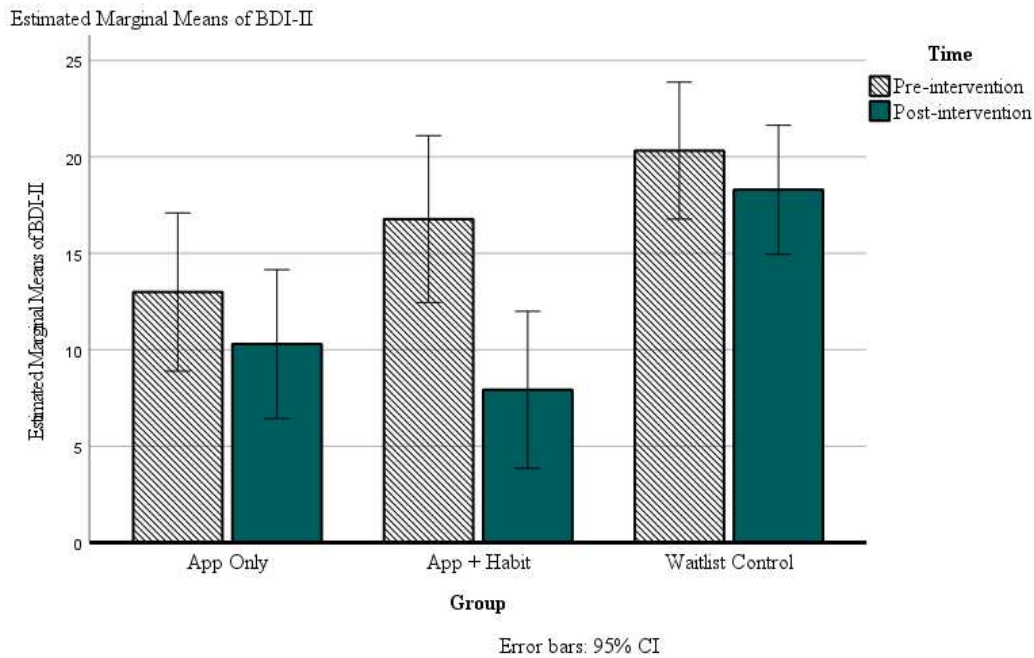
received EMAs (i) & (ii), as well as EMA (iii) which asked, “How many of those days did you use your cue?” in the same format as the App Only group. The Waitlist Control was given EMAs (i) & (ii) for the 8-week waiting period. At the end of the 8-week period, they were assigned to either A or B and given their respective EMAs for 16 weeks.

Independent samples t-tests and Chi-squared tests were used to evaluate baseline group differences on demographic variables and the BDI-II via IBM SPSS Statistics 27. Repeated measures ANOVA was used to examine group by time interactions on the BDI-II. One participant was excluded from analysis as they did not align with the M/F sex comparisons included in this leg of the study. EMA analysis results are not presented in this thesis.

RESULTS

No group differences were detected with respect to age, sex, or IQ [T1]. Repeated measures analysis revealed a group by time interaction [T2, Fig 1], with post-hoc analysis demonstrating a significant reduction in depressive symptoms for the App + Habit group, which was absent for the App Only and Waitlist control groups [T2, Fig 1].

FIGURE 1 Estimated Marginal Means of BDI-II



DISCUSSION

As hypothesized, the queued habit-formation group showed greater reduction of depressive symptoms relative to the App Only and Waitlist Control groups, suggesting that anchoring may be a successful strategy for autistic adults, and may mitigate declining adherence to intervention beyond the treatment period.

Regardless of the delivery modality, the discontinuation of mindfulness use remains a barrier in long-term treatment efficacy. In the neurotypical population, goal maintenance and interest have little influence on long-term success in forming new healthy habits, while associations with prior locations and routines show promising results [5]. People with ASD, being especially attached to consistent and predictable

rituals [29], stand to benefit from this strategy. EMA analysis at 6 month and 1 year post intervention will give insight as to whether Habit training supports increased adherence rates in addition to increased efficacy for depression symptom reduction.

Mindfulness is a new concept in the treatment in ASD, with the first published controlled trial taking place in 2012 [12]. Mindfulness-based therapy was investigated using 9-week trial targeting depression symptoms in the affected group, showing a significant reduction in symptoms for the treatment group [12]. In 2017, MBSR and CBT were compared in efficacy of treatment for symptoms of anxiety and depression in a group of 59 Autistic adults. Both CBT and MBSR groups supported a decrease in symptoms associated with time, with neither being more effective. A significant main effect on anxiety and depression scores was reported at 3 months post-treatment, though there was no main or interaction effect for the treatment group [11]. This study supported the effects of mindfulness interventions on depression symptoms and was able to confirm a main effect for the habit training group only. This comparison suggests that while mindfulness alone might be correlated with a positive outcome on depression symptoms for ASD, the addition of habit training may strengthen these effects.

The use of mHealth apps in the treatment of ASD symptoms is even more novel, with the most recent publication being this year (2022) [17]. The study encountered significant hurdles end-to-end, closing with only 16 participants out of the 169 eligible. Distraction and boredom were identified as barriers to completion. Using regular communication with participants to serve as motivational reminders was recommended

by the team along with more thorough recruitment through community resources [17]. Our study did not encounter such difficulties, with 75% of eligible participants completing surveys at the 8-week collection. It is possible that, as the previous study suggested, regular EMA check-ins contributed to the successful retention of participants by reminding and thus motivating them to practice.

LIMITATIONS

The Waitlist Control had less attrition compared to both App groups, which might be attributed to the anticipation of beginning of their 8-week trial and to gain access to an application which may benefit them. Therefore, results *may* reflect a biased sample. Additionally, the waitlist control was not restricted from engaging in meditation during the initial 8 week waiting period. The use of EMAs alone has been reported to bring attention to new habits/goals relating to diet, effectively increasing positive outcomes for the users [25]. However, since all groups received EMAs, this should not affect group comparison results. The female:male (F:M) ratio did not appear to be reflective of the ASD community (i.e., 1:4). In this study, the F:M was 61 female participants and 31 male. Sex showed no main effects or interaction effects, despite the discrepancy in expected vs realized ratio of F:M. Since we included only autistic adults of average or above average IQ, results do not generalize to the full spectrum of autistic adults. Finally, the sample size of this study may be underpowered to detect smaller effect sizes if they are present in the App Only or Waitlist Control groups.

CONCLUSIONS

The use of cues to anchor new habits to existing rituals was effective in increasing the depression reduction efficacy of the Ten Percent Happier mHealth application in autistic adults. Our results suggest that these additional methods may help to promote adherence in autistic adults. Implications could extend to a large category of functional mHealth applications designed to promote healthy habits and improve quality of life for the autistic community.

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