Ecological Momentary Assessment During a Remote Mindfulness Intervention Assessing Changes in Lifestyle Factors and Psychological Outcomes

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Ecological Momentary Assessment During a Remote Mindfulness Intervention Assessing Changes in Lifestyle Factors and Psychological Outcomes

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

EMA	Ecological Momentary Assessment
MBSR	Mindfulness Based Stress Reduction
MLM	Multilevel Modeling
T/*t*	Time
RCT	Randomized Control Trial

SUMMARY

Stress and related issues of anxiety disorder and depression pose huge mental and public health risks in the population in general, and on college campuses in particular. Prior research shows that mindfulness interventions help to relieve symptoms of stress, anxiety, and depression, as well as decrease rumination, and increase sleep and exercise behaviors. Yet, the causal mechanisms of these variables and the sequencing of effects are unknown. I utilized a randomized controlled trial, 55 in control arm, and 57 in intervention arm (mean age= 21.39), using a 4-week KORU mindfulness intervention as the intervention arm, with pretest and posttest assessment of the relevant variables, as well as daily ecological momentary assessments (EMA) of formal and informal mindfulness practices, state mindfulness, rumination, sleep, exercise, mood, wellbeing, and stress. In the pre-post analysis, Koru was effective in improving mindfulness, rumination, worry, mood, stress, anxiety, three aspects of psychological wellbeing (Autonomy, Environmental Mastery, and Self-acceptance), and physical activity. In the EMA analysis, Koru was effective in improving mindfulness (i.e., Curiosity and Decentering), rumination, and sleep. Rumination was found to be a significant mediator between both mindfulness subscales and psychological outcomes. Furthermore, the effect of Curiosity on rumination was significant with a lag of up to three days; the effect of Decentering was detectable over two days. The effects of rumination on stressor count, depression, and wellbeing, however, did not extend beyond the same day. Exercise was only a significant mediator in the pathways from Curiosity to depression and well-being and did not extend beyond the same day. Sleep was not a significant mediator for any mindfulness to outcome variable pathway. Lastly, self-reported practice quality, both formal and informal, did not drive changes in mindfulness and did not attribute to changes in the pathway proposed.

CHAPTER 1
INTRODUCTION

Stress and related issues of anxiety and depression pose large mental and public health risks in the population in general, and on college campuses in particular. The most recent National College Health Assessment from the American College Health Association (2019) reports that 20% of undergraduate students indicate being diagnosed with or treated by a professional for depression within the last year; for anxiety, that number is 24%; a majority (58%) indicate their level of stress as "more than average" or "tremendous". At the Georgia Institute of Technology, 91% of students stated being "very stressed" on a recent student mental health support study (Singleton et al., 2017). Additionally, the percentage of students seeking help at Georgia Tech's Counseling Center who reported ever having attempted suicide rose from 6% in 2014 to 10% in 2017.

There is growing evidence that mindfulness training can help build stress resilience and may shield individuals from anxiety and depression (Goyal et al., 2014; Gu et al., 2015). Mindfulness is the practice of bringing one's attention to the present on a moment-to-moment basis and without judgment, that is, with acceptance (Kabat-Zinn, 1990). Mindfulness reduces stress, distress, anxiety, and depression while also increasing quality of life, regardless of whether participants are clinically diagnosed with a disorder or not (Khoury et al., 2015). In non-clinical populations, mindfulness helps to increase focus, sustained attention, positive affect, and over-all well-being, while decreasing self-perceived stress, anxiety, depressed mood, negative affect, and rumination (Eberth & Sedlmeier, 2012; Verhaeghen, 2017).

Mindfulness studies in college samples are relatively rare, but promising, showing that mindfulness interventions reduce psychological stress (Burhstahler & Stenson, 2019; Galante et

al., 2018; Greeson et al., 2014; Kang, Choi, & Ryu, 2009; O'Driscoll et al., 2019; Oman et al., 2008; Song & Lindquist, 2015), reduce anxiety and depression (Burgstahler & Stenson, 2020; Greif & Kaufman, 2019; Kang, Choi, & Ryu, 2009; Khoury et al., 2015; Liu, 2019; Moffit-Carney & Duncan, 2019; Shapiro et al., 1998; Song & Lindquist, 2015; Tubbs et al., 2019; Yuksel & Yilmaz, 2020, with an average effect size of d = 0.77; Regehr, Glancy, & Pitts, 2013), as well as increase the quality of sleep (Lentz & Brown, 2019), increase academic performance (Greif & Kaufman, 2019; Lin & Mai, 2016; Mrazek et al., 2013; Song & Linquist, 2015), increase positive affect (Patel, Nivethia, & Mooventhan, 2018) and decrease alcohol consumption (Hoyer& Correria, 2020; Mermelstein & Garske, 2015; Shuai et al., 2020).

In the present study, I utilized an intervention aimed specifically at college students, the Koru mindfulness intervention protocol (labeled Koru hereafter). In Koru, participants are taught practices like body scan meditation, breathing meditation, belly breathing, dynamic breathing, *gatha* meditation, labeling-of-thought and feeling meditation, and walking meditation in small groups of 10-14 students (Rogers & Maytan, 2019). Koru is based on other popular mindfulness programs, such as Mindfulness-Based Stress Reduction (Kabat-Zinn, 1990). One of the adaptations to emerging adults includes shortening the intervention to four weeks and ten minutes of guided meditation a day, compared to eight weeks and 30 minutes of meditation per day for the MBSR program. This difference makes Koru more accessible to college students without sacrificing effectiveness**.** To date, two randomized control trials (RCT) have been conducted with the Koru protocol in student populations (Greeson et al., 2014; Weis, Ray, & Cohen, 2020). Both studies reported beneficial effects of the intervention on trait mindfulness, self-compassion, sleep quality, and stress; Weis et al. also note effects on anxiety and attention but found no effect on sleep duration; Greeson et al. found no effect of the intervention on gratitude. The effects Weis et

al (2020) found were maintained over an eight-week posttreatment period compared to control for the variables of mindfulness, self-compassion, and anxiety (Greeson et al. did not conduct follow-up assessments).

One crucial question in the literature concerns the mechanisms of change in mindfulness studies. With any intervention, it is essential to assess how it works and what causes the changes to occur (Kazdin, 2007). More specifically, knowledge of mechanisms allows for a deeper understanding of the timing of the different potential effects, as well as their causal structure, and can lead to more targeted interventions. To acquire such knowledge, it is critical to collect repeated measures on multiple proposed mediators to investigate which account for the most variance in mental health outcomes (Kazdin, 2007). A number of mediating mechanisms have been proposed. For instance, within the mindfulness literature, an assumed key component of the proposed changes is that mindfulness itself helps to guide awareness towards one's emotional state, bodily sensations, and thoughts (Kabat-Zinn, 1990). Mindfulness might then provide individuals with the tools to bring attention to their habitual types or patterns of thought and might thus help break the cycle of ruminative or negative thoughts, which are key features of depression and anxiety (Godfrin & Heeringen, 2010). In accordance with this idea, meta-analyses have shown that changes in trait mindfulness after a mindfulness intervention mediate changes in mental health outcomes (i.e., stress, anxiety, depression), explaining 33% of the variance (Gu et al., 2015; 12 studies). Likewise, changes in mental health outcomes have been associated with changes in negative repetitive thinking (i.e., worry and/or rumination), explaining 26% of the variance (Gu et al., 2015; 6 studies). Additionally, there is tentative evidence that increases in mindfulness lead to lifestyle changes such as increases in exercise and sleep quality. These, in turn, might affect stress positively (Greeson et al., 2014; Lin & Mai, 2016; Mayer, Polak, & Remmerswall, 2019).

Broader theoretical models propose a more detailed flow of effects. For instance, Vago and Silbersweig (2012) proposed a consensus model, the S-ART model, to describe the cascade of effects that occur during a mindfulness intervention. The main idea is that through mindfulness meditation participants will first gain self-awareness (S-A), for instance of their ruminative thoughts and maladaptive behaviors, then engage in self-regulation (S-R) in order to stop maladaptive behaviors or decrease rumination, which then leads to self-transcendence (S-T), an increased decentering, which in turn leads to increases in psychological well-being (such as a decrease in anxiety, stress, and depression, and increase in sleep and exercise). Hölzel et al. (2011) propose a similar model, where participants first learn to pay attention to thoughts, which leads to body awareness, then emotion regulation (decrease in rumination), ending in changes in perspective on the self, which finally increase overall well-being.

Although we know what the broad-stroke effects and what some of the mediators are, what is unknown is the actual time course and causal structure of these effects. For instance, Hölzel et al (2011) caution that the cascade of effects proposed in their model is tentative due to the lack of studies with high temporal resolution. That is, most studies using mindfulness interventions have a simple pre-post design, with no measurement occasions in between these two-time points. Only two studies, to my knowledge, has examined the timeline of changes in depression, stress, and anxiety over the course of the eight weeks of Mindfulness-Based-Stress Reduction (MBSR) training. Bergen-Cico et al (2013) found that stress and depression decreased during the fourth week of their five-week intervention, with medium to large effect sizes; anxiety, however, did not change at any point during the five-week intervention. One possible interpretation is that anxiety is not affected until the final week of MBSR. Baer et al (2012) found that at the end of the second week of an MBSR program, trait mindfulness significantly changed, while perceived stress

changed at week four. Clearly, more fine-grained data are necessary. Therefore, in the present study, I measured mindfulness, rumination, physical activity, sleep, stressor count, depression, and well-being on a daily basis using ecological momentary assessment (EMA), in order to chart their time course and interrelationships in detail. Specifically, I measured the number of stressors, mood, and well-being as possible intervention outcomes, rumination, sleep, and exercise as possible mediators of these outcomes, with mindfulness as the predictor.

Additionally, surprisingly little is known about the role of actual meditation practice during a mindfulness intervention; even less is known about the role of informal practice. Formal practice typically involves silent meditation; informal practices typically involve mindful activities that can be performed over the course of a normal day, such as mindful showering, mindful eating, or mindful walking. Studies tend to focus on the quality and quantity of only the formal practice, and they rarely ask about engagement in informal practices. This is an important oversight because informal practices are believed to be integral in taking mindfulness 'off the cushion' and into everyday life (Thich Nhat Hanh, 1975). Informal practice also could be crucial in securing the translation of changes in state mindfulness into changes in trait mindfulness, as Hanley et al propose (2014). Additionally, Carlson et al (2007) suggest that informal practices can be a mediator of change in daily activities and lifestyle. Informal practice might also be worth investigating from the point of view of efficiency and attractiveness because formal practice tends to take more time than informal practice, which can take as little as one minute. Therefore, informal practice might be more effective or attractive to people who believe sitting and meditating for 10-30 minutes a day is impossible, and/or could be a gateway into engaging in formal practice. More importantly, informal practices are possibly more accessible since informal practice can be attached to any daily activity (Hanley et al., 2014). Lastly, investigation in this informal versus

formal meditation might give us more information about how to tailor interventions to individuals. For this reason, I explicitly requested participants do both formal and informal practice daily and investigated the relationship of quality of both forms of mindfulness practice to psychological outcomes in this study.

One last aspect born out of necessity that makes this study unique is that the mindfulness intervention was preformed remotely. The reality of the COVID-19 pandemic made mindfulness training in person all but impossible and has encouraged teachers and organizations to teach online and/or remotely. In response to the crisis, Koru Mindfulness encouraged teachers to hold remote online classes, providing resources to help transfer the meditation course to an online format within the teacher-specific app. The present study is a result of that effort: I was poised to start my study when the university effectively shut down and teaching mindfulness in person to a group of any size became impossible. I decided to move forward with the study using remote online delivery in large part because I realized the potential need for this intervention, particularly in a situation where students were exposed to a set of new and potentially serious stressors: isolation, relocation, potential illness of themselves and/or their loved ones, uncertainties about the future, and so on.

To my knowledge, less than a handful of studies have investigated the effectiveness of remote online delivery. Spijkerman, Pots and Bohlmeijer (2016) conducted a systematic review of RCTs using online delivery of mindfulness-based interventions and were able to locate three studies that approximated our format, that is, with virtual online classrooms (as opposed to a purely self-paced website program with no actual interaction with a teacher or peers). None of these studies used college students as their population. My own literature search was unable to uncover additional studies. Thus, as far as I know, this is the first study to examine remote delivery of a

mindfulness intervention in a population of college students, and the first to investigate this with the Koru protocol.

In summary: For this study, I explored the potential mechanisms of change that occur with a remotely delivered mindfulness practice. From the literature review, I examined how mindfulness, rumination, and quality of mindfulness practice (both formal and informal) affect stress, affect, mood, and well-being, and how sleep and exercise play a role in that as well. To do so, I used a classic controlled pretest-posttest design, as well as examined the sequencing and causal structure of the effects of the intervention on a day-to-day basis, using measures of state variables, collected through Ecological Momentary Assessment (EMA). I have one clear hypothesis and two exploratory research questions.

The hypothesis was that the mindfulness intervention will lead to increases in trait mindfulness, mood, psychological well-being, quality of mindfulness, sleep quality, and exercise. The mindfulness intervention will also lead to decreases in trait stress, depression, anxiety, and rumination/worry. The first exploratory question concerns the cascade of effects, that is, the causal mechanisms that occur as participants go through the mindfulness intervention. For this exploratory question, I expected to see that as mindfulness increases, rumination decreases leading to increases in mood and well-being, and decreases in stress within the same day. Additionally, I expected to see that as mindfulness increases, sleep increases leading to increases in mood and well-being, and decreases in stress within the same day. Lastly, I expected to see that as mindfulness increases, exercise increases leading to increases in mood and well-being, and decreases in stress within the same day. I also explored lagged time effects using different delays, to get a better understanding of the causal mechanisms of these variables. The second exploratory question concerns the question of informal versus formal mindfulness practice quality and whether

these have differential mediating effects on the outcome measures. I expected correlations between self-rated quality of practice and determined mediating pathways. This could possibly take the form of individual differences, where some participants might report a high quality in one type of practice (formal or informal) and not in the other, and therefore only show significantly correlations between the favored type of practice and mediating pathways.

CHAPTER 2
METHODOLOGY

Participants

During the Fall 2020 semester, I recruited 128 Georgia Tech Students as participants; half were randomly assigned to the mindfulness intervention group, half to the control group. Although 128 were initially recruited, only 112 completed the study, drop out was due to scheduling conflicts for 8 students (4 in the control group, 4 in the intervention group), and 8 (7 in the control group, and 1 in the intervention) could not be reached after multiple attempts to contact. Students had to be 18 years or older to participate. I excluded individuals who had previously participated in a mindfulness intervention (including Dialectical Behavioral Therapy) or had a current mindfulness/meditation practice. This information was verified with a screening email with the potential participants before the pre-test. The sample had a mean age of 21.4, with 94 females, 16 males, and 2 non-gender-binary individuals. The sample consisted of 64 Whites, 34 Asians or Asian Americans, three African Americans; eight listed their race/ethnicity as multiracial, and three as "other". Students majored in psychology (31), biology (3), biochemistry (2), chemistry (2), computer science (6), earth sciences (1), neuroscience (3), physics (1), architecture (12), business (4), design (1), engineering (31), or literature, media, and communications (4).

Intervention and design

This study was a randomized controlled trial, where half of the participants were randomly placed in a control group or in the mindfulness training group. The mindfulness training followed the 4-week Koru protocol. Over the course of the four weeks, participants were taught multiple mindfulness and meditation techniques (body scan meditation, breathing meditation, belly breathing, dynamic breathing, *gatha* meditation, labeling-of-thought and feeling meditation, and walking meditation). Participants were requested to complete ten minutes of formal practice per day in one of these techniques every day (recorded guided mediations were provided on the Koru Mindfulness app available on the participant's phones); every week, they also picked an everyday activity (such as brushing their teeth, taking a shower, or drinking their morning coffee) to perform mindfully every day. Participants wrote a daily brief reflection about their practice as well as completed a brief gratitude exercise (these were not used in the analyses). All of these activities were logged via the Koru Mindfulness app.

The online format was adapted from the in-person format. Meetings were conducted using BlueJeans' online meeting software. Participants were encouraged to keep their video feed on, with sound muted during meeting times, with permission to mute the video feed during meditations. The first class included establishing ground rules, such as giving participants permission to "pass" instead of speaking, encouraging students to engage, to be mindful of their speech, and to show up authentically. Participants were encouraged to find and/or set up a quiet space for the meetings. In the first class, a form of dynamic breathing is practiced that can be perceived as awkward and requires monitoring on the part of the teacher; during this exercise, participants were requested to turn away from their cameras but still be in frame. The online format also provided opportunities. For instance, it allowed for screen sharing of documents such as the

meditation poem used for *gatha* meditation. Lastly, the paper evaluations of the class were moved to an anonymous Google Form. I taught all of the sessions as a part of my teacher certification process (certification received December 2020).

Procedure

During the Fall 2020 semester, one group of the five participant intervention group cohorts filled out the pre-test surveys online to serve as a baseline for psychological traits. Then they took thrice-daily EMA surveys on their smartphones for one week prior to the start of the intervention, to serve as a baseline for psychological states, and to control for reactivity of completing the surveys. After this week was over, participants began attending weekly 75-minute mindfulness sessions (14 participants or fewer per session) for four weeks. During this time, they continued the EMA surveys, while also completing 10 minutes of guided meditation per day from the KORU app, and one informal practice per day. The EMA protocol was as follows: Participants received notifications on their smartphones three times a day, once in the morning, once during the day, and once in the evening. The morning notification reminded participants to fill out the morning EMA battery. The day notification reminded participants to fill out the day EMA battery. The evening notification reminded participants to fill out the evening EMA battery. Each EMA battery took about one to two minutes total. In order for an EMA assessment to count, participants had to have completed it within 10 minutes after notification (Hufford et al., 2002; Keng et al., 2016). Participants were allowed to schedule two-hour windows for each survey. After the five weeks (baseline and KORU), the participants completed the post-test battery, which was identical to the pre-test battery survey. At mid-week of the first KORU intervention, the next group than started the same procedure, and at the mid-week of the second KORU intervention, the third group began. This same pattern continued until all five groups completed the intervention. Thus the timing of

the intervention (and thus of the testing of a corresponding cohort of waitlisted participants) was staggered, with the first group starting in week 3 of the semester, and the last group in week 12.

Participants in the control group followed the same schedule of assessments, just sans intervention to control for time-of-testing effects. The control group was also the same size as the intervention group for each testing occasion.

Materials

Pretest and Posttest Measures

Participants completed all of the pre-posttest surveys online in Qualtrics on their mobile phones, tablet, or computers. The full set of measures took no longer than 30-45 minutes to complete. All participants received pre-posttest surveys no matter if they were in the control or experimental group. The pre-posttest surveys included the following valid and reliable measures. Cronbach alpha coefficients are reported as obtained in the present sample.

Mindfulness Measures

Self-awareness/mindfulness was measured using the *Five Facet Mindfulness Questionnaire* (Baer et al., 2006; FFMQ). The FFMQ assesses trait mindfulness on five dimensions, Observing, Describing, Acting with Awareness, Nonjudging of Inner Experience, and Nonreactivity to Inner Experience, with thirty-nine items. Observing measures how much a person notices their internal and external experiences like thoughts, emotions, sounds, etc. A sample item is "when I'm walking, I deliberately notice the sensations of my body moving" (α =.69). Describing indicates how well someone can express how they feel or what they are experiencing in words. A sample item is "I'm good at finding words to describe my feelings" (α =.75). Acting with awareness assesses how much a person is attending to the present moment; a sample item is "when I do things, my mind wanders off and I'm easily distracted" (α =.92). Nonjudging of inner

experience assesses if someone is able to acknowledge their thoughts without judging them or ruminating about them; a sample item is "I criticize myself for having irrational or inappropriate emotions" (α =.90). Finally, Nonreactivity to inner experience assesses how much someone can detach from their thoughts and emotions, essentially how well they can let their thoughts pass without letting them take over; a sample item is "I perceive my feelings and emotions without having to react to them" (α =.79).

Quality of mindfulness practice was measured using the *Practice Quality-Mindfulness* scale (Del Re, Flückiger, Goldberg, and Hoyt, 2013; PQM). This questionnaire assesses the quality of a mindfulness practice session, adapted to assess quality of practice over the last few weeks. A sample item is "During the last few weeks of practice, I have attempted to feel each experience as bare sensations in the body (tension in throat, movement in belly, etc.)" (α = .88).

Outcome Measures

Perceived stress was measured by the *Perceived Stress Scale* (Cohen et al., 1983; PSS), which assesses participants' perceptions about their ability to control their lives and events in it. A sample item is "In the last month, how often have you been upset because of something that happened unexpectedly" (α = .83; it is important to note that in the Qualtrics survey, item 6 was inadvertently left off).

Affect was measured using the *Positive and Negative Affect Schedule (*Watson et al., 1988; PANAS). Participants indicate on a Likert scale from "very slightly" to "not at all" the extent to which they experienced each of twenty emotions or feelings within the last few weeks. Sample positive emotions are "interested" and "alert" (α =.85); sample negative emotions are "distressed" and "irritable" (α =.82).

Well-being was measured using the *Psychological Well-Being Scale* (Ryff & Keyes, 1995; PWB). The PWB contains 42 items in 6 subscales measured on a 6- point Likert scale from strongly agree to strongly disagree. The six subscales are Autonomy, Environmental Mastery, Personal Growth, Relations with Others, Purpose in Life, and Self-Acceptance (Ryff & Keyes, 1995). Sample items are: for autonomy, "I have confidence in my opinions, even if they are contrary to the general consensus" (α =.79); for environmental mastery, "In general I feel I am in charge of the situation in which I live" (α =.35); for personal growth, "I think it is important to have new experiences that challenge how you think about yourself and the world" (α =.66); for positive relations with others, "people would describe me as a giving person, willing to share my time with others" (α =.74); for purpose in life, "some people wander aimlessly through life, but I am not one of them" (α =.72); and lastly for self-acceptance, "when I look at the story of my life, I am pleased with how things have turned out" (α =.56).

Mood and anxiety were measured by the depression and anxiety subscales of the *Depression Anxiety Stress Scale-21 (*Lovibond & Lovibond, 1995; *DASS-21*). All three subscales contain seven items. The depression subscale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest/involvement, anhedonia, and inertia; a sample item is "I couldn't seem to experience any positive feelings at all" (α =.83). The anxiety subscale assesses autonomic arousal, skeletal muscles effects, situational anxiety, and subjective experiences of anxious affect; a sample item is "I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion" (α =.78). The stress subscales assess chronic nonspecific arousal; a sample item is "I found it hard to wind down" (α =.78).

Mediator Measures

Psychological Factors

Rumination was measured by the *Ruminative Responses Scale* (Nolen-Hoeksema, S., 2000; RRS) from the Response Styles Questionnaire (RSQ), which measures rumination. A sample item asks how often they "think about how you feel alone" ($\alpha = .90$).

Worry was measured using the *Penn State Worry Questionnaire* (Stober & Bittencourt, 1998; PSWQ). A sample question (reverse-scored) is "If I didn't have enough time to do everything, I didn't worry about it" ($\alpha = .86$).

Lifestyle Factors

Sleep quality was measured by the *Pittsburg Sleep Quality Index* (Buysse et al., 1988; PSQI). Participants indicate sleep duration and frequency and cause of sleep disturbances ($\alpha = .70$).

Quantity of physical exercise was measure by the *Five Item Physical Activity Questionnaire* (Cho, 2016), which assess type, frequency, intensity, and duration of physical activity ($\alpha = .67$).

Ecological Momentary Assessments (EMA)

All of the EMA batteries were completed on participants mobile phones via ExpiWell software. At pre-test, participants set up the Expiwell app, and if they were in the experimental group also the KORU app. Participants were asked to schedule their survey windows during times of no serious conflict to increase compliance.

Morning EMA Survey

The morning EMA battery included the following valid and reliable measures.

Psychological State Outcome Measures

State mindfulness was measured by the *Toronto Mindfulness Scale*, using the four-highest loading items for each of two factors (Curiosity and Decentering), as in Ruscio et al (2016). A sample item for curiosity: "I was curious about my reaction to things" (α = .58 on day 1 and α = .82 on day 35), and a sample item for decentering is "I was more concerned with being open to my experiences than controlling or changing them" (α = .50 on day 1 and α = .84 on day 35), Participants rated how strongly they agree with the statements on a 4-point Likert scale.

Stressor count was measured by the *Daily Inventory of Stressful Events* (5 items; Sliwinski et al., 2006). Participants indicated whether they experienced any arguments, health problems, or events in their social network in the past 24 hours (α = .86 on day 1 and α = .79 on day 35).

State depression was assessed using the *4-item PROMIS short-form depression scale* (Bjorner et al., 2013); a sample item is "I feel worthless" (α = .82 on day 1 and α = .92 on day 35). It was my intent to also collect anxiety data, but this scale was inadvertently left off due to an error with Expiwell.

Well-being was measured by the *Psychological Well-Being Scale* (Diener, 2009; PWB) as adapted by Runyan et al (2017), using the three items with the highest loading on the common factor in the scale (α = .82 on day 1 and α = .95 on day 35).

Formal and Informal Practice Quality

Quality of mindfulness practice was measured using the *Practice Quality-Mindfulness* scale (Del Re, Flückiger, Goldberg, and Hoyt, 2013; PQM). This questionnaire assesses the quality of a mindfulness practice session on two factors: attention and receptivity. A sample item measuring attention is: "During practice today, I attempted to feel each experience as bare sensations in the body (tension in throat, movement in belly, etc.)." A sample item measuring

receptivity is: “During practice, I was actively trying to fix or change certain experiences, in order to get to a ‘better place’” (α =.63 on day 1 and α =.92 on day 35). Additionally, I asked for an informal practice reflection, utilizing a reformatted quality assessment from the formal practice quality questionnaire (α =.87 on day 1 and α =.77 on day 35). This scale was only administered is participants indicted that they performed a meditation or mindfulness practice between this probe and the previous probe.

Psychological State Mediator Measures

State rumination was assessed using the 6-item *Short Cognitive Inference Test* (Stawski et al., 2011). Sample item: “Did you think about personal worries?” (α =.93 on day 1 and α =.89 on day 35),

Lifestyle Factors Mediator Measures

Sleep Quantity was measure by asking participants to input how many hours they slept.

Day Survey

The day survey contains all the morning EMA surveys except the sleep quantity measure,

Evening EMA Survey

The evening EMA battery included all of the morning EMA survey measures, except that the sleep quantity measure was replaced with an exercise quantity measure, which consisted of three items asking participants if they engaged in physical activity that day and what kind of activity from a predetermined list of activities,

CHAPTER 3
DATA ANALYSIS

Hypothesis 1

To examine changes due to the intervention course, I performed a pre-posttest analysis using a 2 (time; pretest vs. posttest) x2 (group; control vs. intervention) ANOVA on the means of each trait measure, testing for the main effects of time and group, and, crucially, for a time by group interaction. This allowed me to assess differential change in each outcome measure between the intervention and the control groups. I also obtained Cohen's *d* for each subscale to investigate the effect size to compare against the wider mindfulness literature along with partial eta squared. I also investigated state-trait correlations at pretest to check on the validity of the measures. I correlated the average of the first week of the state measures as a pretest state variable to the pretest measure of the trait variables within each respective construct.

To test whether multilevel modeling (MLM) was warranted on state measures, I tested empty models on the outcome variables grouped by participant and obtained within-person ICCs ranging from 0.25 to 0.74, resulting in a design effect between 30.00 and 86.84. Given that the latter numbers exceed the traditional design effect threshold of 2, MLM is necessary to account for the dependencies that nesting of the data create. Specifically, the nesting has daily repeated measures (level 1, where the thrice daily EMA surveys were averaged into one data point per day) within a person (level 2) nested within either the control or intervention group (level 3; this variable was dummy coded). Note that MLM time series analyses are robust against missing data, and this sample only had 8.9% of the total 3,135 daily data points missing (Snijders and Bosker, 2012). The response rate was identical between intervention and control at 91%. Response rate frequency tables are shown below in Figure 1. Multilevel restricted maximum likelihood regression analyses

were performed using the *lme* function of the R package *nlme* (version 3.1-143; Pinheiro et al., 2020).

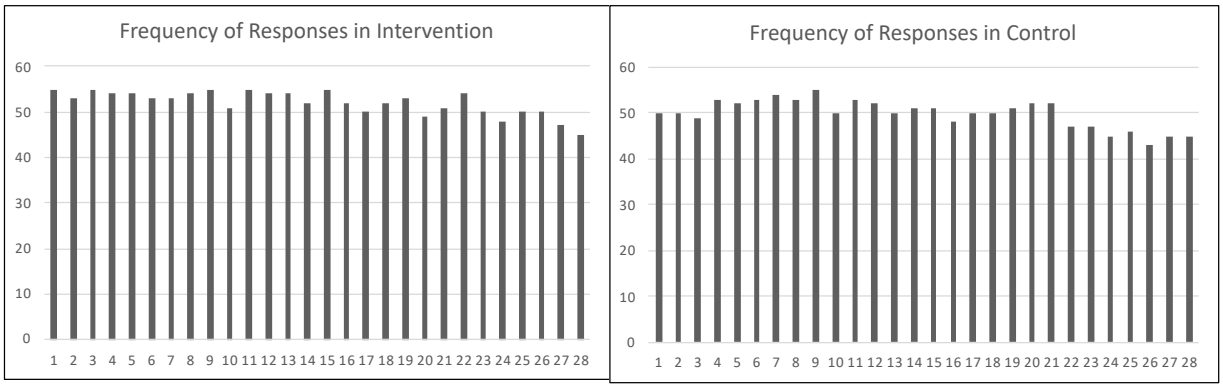

Figure 1. Response rates out of 57 participants for the intervention group and 55 participants for the control group during the 4 weeks of Koru and data collection.

To test hypothesis 1, which examines the time course of the effects of KORU, longitudinal changes in the state variables were analyzed using multilevel linear modeling to account for both between-person and within-person variations as in Bolger, Davis, and Rafaeli (2003). The equation for this analysis was as follows:

$$Y = y_{00} + y_{01}W_j + y_{10}T_{ij} + y_{11}W_jT_{ij} + u_{0j} + u_{1j}T_{ij} + E_{ij} \quad (1)$$

Using the example of trait mindfulness, this equation contains the intercept, y_{00}, where the trait mindfulness level of the control group is at Time 0. The second term's coefficient, $y_{01}W_j$, represents the difference between the control groups' and the mindfulness group's trait mindfulness at Time 0. The third term's coefficient, $y_{10}T_{ij}$, represents the change in trait mindfulness over time (T) for the control group, and the fourth term's coefficient, $y_{11}W_jT_{ij}$, represents the difference in the rate of change between the control groups and the mindfulness group. These parameters represent the fixed effects of the model. The random effects are contained in the next two terms. The coefficient for u_{0j} and $u_{1j}T_{ij}$ represents the normally distributed

random deviations above or below the average of the subjects in the group. To analyze the slope and the intercept variation in just the intervention group, I utilized the same equation without the *W* coefficient and group by time interaction:

$$Y = y_{00} + y_{10}T_{ij} + u_{0j} + u_{1j}T_{ij} + E_{ij} \quad (2)$$

These equations will be implemented for each of the following measures: state mindfulness (Curiosity and Decentering), stress, mood, well-being, rumination, and sleep. Exercise is the only variable that has a binary outcome, therefore I used logistic regression to assess the change over time:

$$Y = p_{ij} + e_{ij} \quad (3)$$

$$Logit(p_{ij}) = y_{00} + y_{01}W_j + y_{10}T_{ij} + y_{11}W_jT_{ij} + u_{0j} + u_{1j}T_{ij} + E_{ij} \quad (4)$$

The coefficients represent the same as before but are now in odds ratio units. To assess change just in the intervention group the equation looked like this:

$$Logit(p_{ij}) = y_{00} + y_{10}T_{ij} + u_{0j} + u_{1j}T_{ij} + E_{ij} \quad (5)$$

Exploratory Question 1

For my analysis I used multilevel moderated mediation, where the moderator (intervention vs control) was at level two and the mediation was all at level 1. This allows me to see if the potential influence of state mindfulness on my three outcome variables, depression, stress, and well-being, was mediated by sleep, rumination, or exercise. Multilevel restricted maximum likelihood moderated mediation analyses were performed using the *lme* function of the R package *nlme* (version 3.1-143; Pinheiro et al., 2020). All variables were centered within person; the variables were stacked to allow dummy codes to represent whether a variable is an outcome or a predictor. Models were run with and without autocorrelation. Mediation was determined by Arioan's test (Aroian, 1974), which is a two-tailed *z* test. The equation is as follows:

$$z = \frac{a*b}{\sqrt{b^2*s_a^2 + a^2*s_b^2 + s_a^2*s_b^2}} \quad (6)$$

where *a* and *b* are the coefficients for the *a* and *b* path, respectively, and s_a^2 and s_b^2 are the variances for the *a* and *b* path, respectively.

Lastly, I also investigated different time (*t*) lags between mindfulness variables, mediators, and outcome variables. I first looked at if mindfulness at *t* (day 1) predicted mediators at *t* + 1 (day 2) and outcomes *t* + 2 (day 3), then investigated how extensive the lagged time could be between two variables.

Exploratory Question 2

For this analysis I again used multilevel mediation, where the mediation was all at level 1 as in exploratory question 1, now using informal or formal practice quality as the predictor. The same methods were used as in exploratory question 1.

CHAPTER 5
RESULTS

Construct Analysis

As a first step, I examined the relationship between my state and trait measures at pretest as a construct validity analysis. Pretest measures for state EMA were the average scores over the pre-test week (to enhance reliability). Results are presented in Table 1. All state measures related significantly to their respective trait measures, except trait/state mindfulness, where the correlation was not significant and close to zero. Thus, state mindfulness as measured by the TMS does not significantly relate to trait mindfulness as measured by the FFMQ.

Table 1. Construct analysis showing correlations between state variables (centered table spanner) and trait variables, with associated *p*-values.

	Pearson *r*	*p*
Mindfulness (Decentering)		
Non-reaction	.12	.214
Observation	.04	.700
Act with Awareness	.02	.852
Describing	.03	.745
Non-judgement	.04	.650
Mindfulness (Curiosity)		
Non-reaction	.12	.227
Observation	.01	.947
Act with Awareness	-.03	.752
Describing	.04	.686
Non-judgement	.05	.583
Depression		
Depression (DASS)	.58	.000
Negative Affect (PANAS)	.27	.006
Well-being		
Autonomy	.30	.002
Environmental Mastery	.32	.001
Personal Growth	.30	.002
Positive Relationships	.19	.052
Purpose in Life	.25	.009
Self-Acceptance	-.31	.001
Rumination		
Rumination	.50	.000
Worry	.42	.000
Stressor		
Stress (PANAS)	.13	.198
Perceived Stress	.21	.030
Sleep		
Sleep	-.30	.002
Physical Activity		
Physical Activity	-.30	.002

Hypothesis 1

Analysis of pre-post data

I conducted 2 x 2 ANOVAs to examine the pre-posttest changes in means between the intervention and the control group for each outcome variable. The results of this analysis are reported in Figure 2; Table 2 represents the crucial analysis of the time by group interaction for all 21 outcome measures, indicating whether the observed change over time in the intervention group was more beneficial than that in the control group. (Because all these analyses are planned contrasts, no correction for multiple comparisons is necessary). Cohen's *d* represents the net intervention effect, that is,

$$d = [(M_{\text{post,trained}} - M_{\text{pre,trained}}) - (M_{\text{post,control}} - M_{\text{pre,control}})]/\text{SD}_{\text{pre,pooled}}. \quad (7)$$

When needed, the sign for the Cohen's *d* was reversed, such that positive values indicate a more beneficial outcome for the intervention group and negative values indicate a more beneficial outcome for the control group.

Results showed significant interactions in favor of the intervention in sixteen out of 21 cases. For seven out of the 21 outcome measures, a pattern was observed where the intervention group's outcome improved while the control group's declined: For the intervention group, this meant increases in the FFMQ subscales for Non-Reactivity and Observing, in the PANAS Positive Affect subscale, in the PWB subscale for Environmental Mastery, and in physical activity, and decreases in the Anxiety and Stress subscales in the DASS-21. For nine out of the 21 outcome measures, a pattern was observed where the intervention group's outcome improved while the control group's remained stable: For the intervention group, this meant increases in the FFMQ subscales for Acting with Awareness, Describing, and Non-Judging, and two subscales of the PWB (Autonomy and Self-acceptance), and as well as decreases in the PSS, in the PANAS

Negative Affect subscale, the RRS, and the PSWQ. Thus, compared to control intervention, the intervention helped to improve all aspects of mindfulness (Non-Reactivity, Observation, Acting with Awareness, Describing, and Non-Judgment), three aspects of psychological well-being (Autonomy, Environmental mastery, and Self-acceptance), as well as anxiety, stress, positive affect, negative affect, rumination, worry, and physical activity.

For the remaining five outcome measures, no significant time by group interaction was obtained, namely for the Depression subscale in the DASS-21, three subscales of the PWB (Autonomy, Personal Growth, and Self-Acceptance), and the PSQI.

Table 2. Results of statistical tests for the group by time interaction in repeated-measures ANOVAs on all outcome variables.

	F(2, 109)	p	Partial η^2	Cohen's *d*
FFMQ Nonreactivity	23.42	0.000	0.18	0.93
FFMQ Observing	11.34	0.001	0.10	0.69
FFMQ Acting with awareness	5.73	0.018	0.05	0.42
FFMQ Describing	4.12	0.000	0.04	0.38
FFMQ Nonjudging	15.69	0.000	0.13	0.80
Penn State Worry Questionnaire	9.53	0.003	0.08	0.56
Ruminative Responses Scale	4.31	0.040	0.04	0.40
PANAS Positive affect	13.70	0.000	0.11	0.72
PANAS Negative affect	6.13	0.015	0.05	0.45
Perceived Stress Scale	15.67	0.000	0.13	0.80
DASS21 Depression	3.10	0.081	0.03	0.33
DASS21 Anxiety	5.46	0.021	0.05	0.37
DASS21 Stress	11.13	0.001	0.09	0.65
PWB Autonomy	9.59	0.002	0.08	0.46
PWB Environmental mastery	13.31	0.000	0.11	0.66
PWB Personal growth	0.15	0.697	0.00	0.07
PWB Positive relations	3.22	0.076	0.03	0.29
PWB Purpose in life	1.34	0.249	0.01	0.16
PWB Self-acceptance	13.89	0.000	0.11	0.58
Pittsburgh Sleep Quality Index	0.56	0.456	0.05	-0.13
Five Item Physical Activity Questionnaire	6.70	0.011	0.06	0.39

Note. FFMQ = Five Facets Mindfulness Questionnaire; PANAS = Positive And Negative Affect Schedule; DASS21 = Depression Anxiety Stress Scale-21; PWB = Psychological Well-Being scale. *d* is net intervention gain; it is scored such that a positive sign indicates larger benefit in the intervention group than the control group.

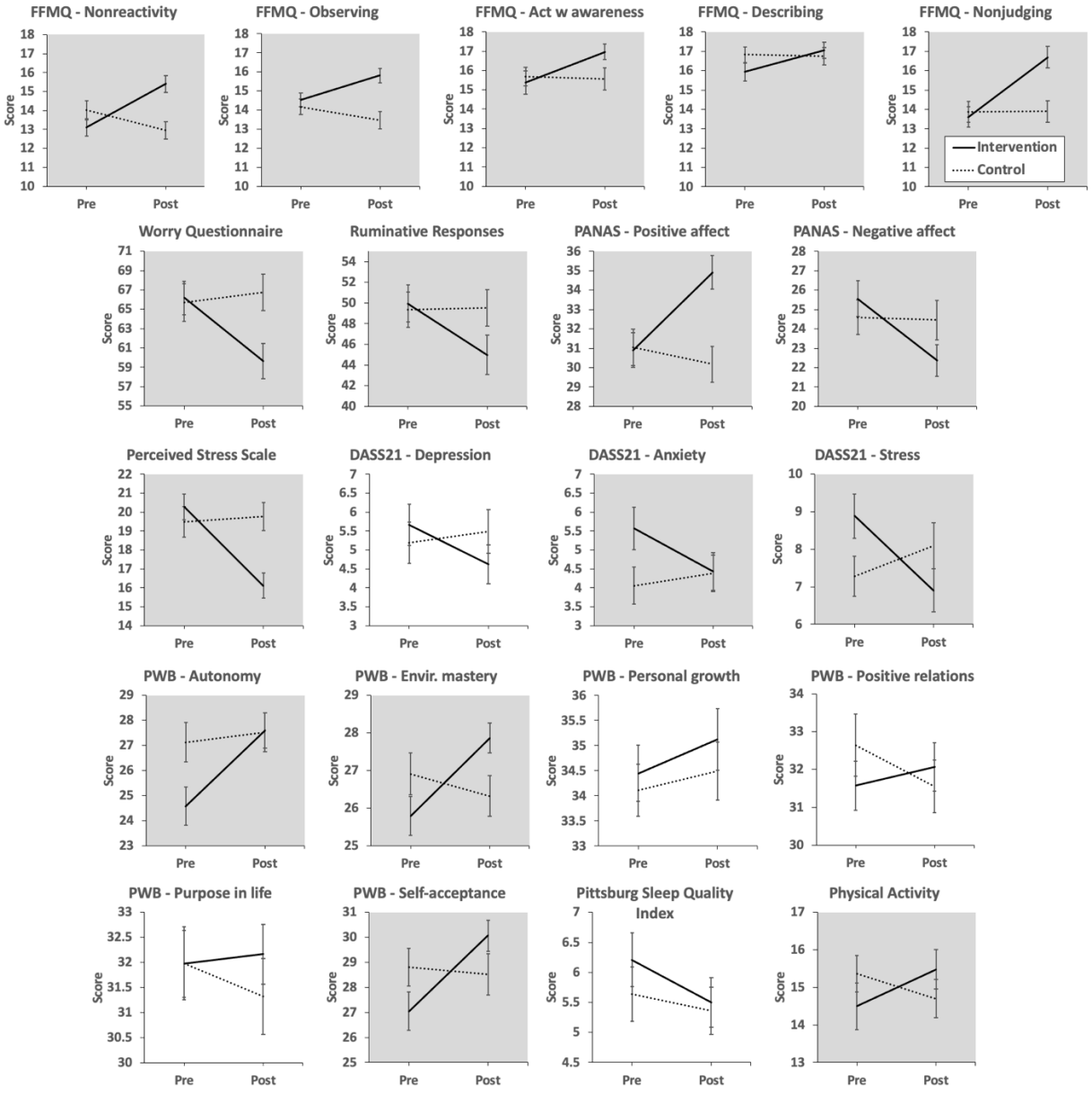

Figure 2. Results presented as a function of time (pretest and posttest) and group (intervention vs. waitlist control, in full and dotted lines, resp.). FFMQ = Five Facets Mindfulness Questionnaire; PANAS = Positive And Negative Affect Schedule; DASS21 = Depression Anxiety Stress Scale-21; PWB = Psychological Well-Being scale. White background: no significant time by group interaction; light grey background: significant time by group interaction favoring the intervention group; dark grey background: significant time by group interaction favoring the control group.

Multilevel modeling of day-to-day change

Results of the MLM analysis for the ten EMA variables are presented in Tables 2 and 3 and Figures 3 and 4 as day-to-day change. Scores for variables that were measured more than once a day (viz., mindfulness, stress, mood, anxiety, well-being, rumination, and practice quality) were averaged within each day. These analyses were all performed specifying autocorrelation. The model that specified autocorrelation was the better fitting model for all variables except sleep and physical activity; in the latter two cases I defaulted back to the more parsimonious model of no autocorrelation. To test for non-linear trends, models adding a quadratic term for time were applied to all variables as well. None of these analyses showed evidence for non-linearity.

Table 3 shows the parameter estimates for all variables. The first set of values for each variable represent the fixed effects, that is, the average results for a typical person in the control and intervention groups, respectively. Those averages are shown in the thicker colored lines in Figure 3. The second set of values for each variable represent the random effects, that is, the variability at the different levels of analysis. The upper-level random effects show the extent to which people vary from the average, and the lower-level random effects represent the extent to which people vary day to day. The first are shown as the thinner grey spaghetti lines in Figure 3, the second are shown in Figure 4 as the raw data for a few people within each group. Lastly, Table 4 shows the parameter estimates for all the variables only in the intervention group. This table follows the same format as Table 3. Visually, the data show that the intervention group had steeper effects over time on almost all of the variables. The formal tests presented in Table 3 support this conclusion, as indicated by the time by group interaction results.

None of the group estimates were significantly different, meaning that initial levels of all the variables were statistically identical for the intervention and the control group. Out of eight

analyses, four showed steeper rates of change in the intervention when compared to control, all in the expected direction. That is, Curiosity, Decentering, and sleep had stronger positive effects in the intervention group than the control group, and rumination had stronger negative effects in the intervention group than control group.

The remaining four variables, namely physical activity, stressor count, PWB, and the PROMIS Depression subscale, did not show significant differences between the intervention and control group. Examination of the stress plot in Figure 5 suggests lower variability in stress in the intervention group compared to the control group. Formal analysis bore this out: The control group had a residual *SD* of 1.7 while the intervention group had a residual *SD* of 0.8. These two standard deviations were significantly different from each other, $F(54, 58) = 4.23$, $p < 0.05$. Thus, the intervention group showed less variability in the number of stressors reported than the control group. For physical activity, PWB, and PROMIS Depression, the intervention group did not have a significantly different standard deviation than control.

Two additional variables were only relevant within the intervention group, namely quality of informal and formal mindfulness practice. Rate of change for both were found to be significantly different from zero. Informal mindfulness had a stronger positive quality increase over time than formal mindfulness.

Table 3. Fixed and random effects for control and intervention. The estimates reported are slopes, except for Physical Activity which is represented as an odds ratio

Curiosity						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	11.19	0.39	2741	28.74	.000
	Time	0.002	0.01	2741	0.17	.869
	Group	0.68	0.55	110	1.24	.160
	Time:Group	0.07	0.02	2741	4.2	.000
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.8	-.16			
	Time	0.07				
	Residual	1.37				
	Autocorrelation Phi	0.35				

Decentering						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	9.96	0.37	2741	26.83	.000
	Time	0.008	0.01	2741	0.61	.545
	Group	0.58	0.52	110	1.11	.224
	Time:Group	0.07	0.02	2741	4.02	.000
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.66	-.17			
	Time	0.08				
	Residual	1.30				
	Autocorrelation Phi	0.36				

Rumination						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	2.37	0.24	2741	10.09	.000
	Time	-0.001	0.01	2741	-0.09	.929
	Group	0.16	0.33	110	0.47	.745
	Time:Group	-0.03	0.01	2741	-2.64	.009
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.63	-.12			
	Time	0.04				
	Residual	1.30				
	Autocorrelation Phi	0.26				

Sleep						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	7.27	0.12	2195	63.24	.000
	Time	0.00	0.01	2195	-0.80	.418
	Group	-0.15	0.16	110	-0.94	.348
	Time:Group	-0.01	0.01	2195	2.06	.039
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	0.72	-.67			
	Time	0.02				
	Residual	0.98				
	Autocorrelation Phi	0.02				

Stress						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	0.75	0.13	2741	5.64	.000
	Time	0.00	0.01	2741	-0.33	.745
	Group	-0.10	0.19	112	-0.55	.585
	Time:Group	-0.01	0.01	2741	-1.00	.328
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	0.77	.00			
	Time	0.00				
	Residual	1.30				
	Autocorrelation Phi	0.22				

Physical Activity						
	Fixed effects	**Logit Est.**	**Odds Ratio**	**SE**	**z stat**	**p**
	Intercept	-0.91	0.4	0.25	-3.68	.000
	Time	0.02	1.02	0.01	1.20	.229
	Group	-0.34	0.71	0.34	1.00	.318
	Time:Group	0.01	1.01	0.02	0.46	.646
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.35	.00			
	Time	0.06				

Depression						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	5.36	0.23	2741	23.06	.000
	Time	0.004	0.01	2741	0.45	.651
	Group	0.21	0.32	110	0.63	.510
	Time:Group	-0.01	0.01	2741	-0.77	.433
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.59	-.12			
	Time	0.05				
	Residual	1.34				
	Autocorrelation Phi	0.26				

Well-Being						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	10.97	0.42	2741	26.07	.000
	Time	0.01	0.01	2741	1.04	.298
	Group	0.31	0.59	110	0.53	.596
	Time:Group	0.02	0.02	2741	0.93	.352
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.99	-.18			
	Time	0.08				
	Residual	1.95				
	Autocorrelation Phi	0.18				

Table 4. Fixed and random effects in the intervention group. The estimates reported are slopes except for Physical Activity which is represented as an odds ratio

Curiosity						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	11.96	0.38	1400	31.5	.000
	Time	0.071	0.01	1400	5.08	.000
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.71	-.16			
	Time	0.09				
	Residual	1.62				
	Autocorrelation	0.4				

Decentering						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	10.57	0.34	1400	31.9	.000
	Time	0.08	0.02	1400	5.08	.000
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.39	-.19			
	Time	0.1				
	Residual	1.56				
	Autocorrelation	0.44				

Rumination						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	2.53	0.22	1400	11.31	.000
	Time	-0.03	0.01	1400	-3.63	.000
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.56	-.33			
	Time	0.04				
	Residual	1.30				
	Autocorrelation	0.29				

Sleep						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	7.12	0.12	1154	62.01	.000
	Time	0.01	0.01	1154	2.07	.039
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	0.77	-.78			
	Time	0.03				
	Residual	0.92				
	Autocorrelation	-0.002				

Stress						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	0.64	0.11	1400	5.78	.000
	Time	-0.01	0.01	1400	-1.78	.075
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	0.76	-.51			
	Time	0.02				
	Residual	0.82				
	Autocorrelation	0.25				

Physical Activity						
	Fixed effects	**Logit Est.**	**Odd Ratio**	**SE**	**z stat**	**p**
	Intercept	-1.31	0.27	0.27	-4.87	.000
	Time	0.03	1.03	0.01	1.99	.046
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.53433985	-.24			
	Time	0.06304372				

Depression						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	5.57	0.23	1400	23.94	.000
	Time	-0.01	0.01	1400	-0.56	.562
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.61	-.30			
	Time	0.06				
	Residual	1.42				
	Autocorrelation	0.26				

Well-Being						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	11.29	0.39	1400	28.79	.000
	Time	0.03	0.02	1400	2.07	.038
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.79	-.19			
	Time	0.09				
	Residual	2.06				
	Autocorrelation	0.23				

Informal Practice Quality						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	4.56	0.43	388	10.53	.000
	Time	0.09	0.04	388	2.39	.017
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	2.08	-.81			
	Time	0.20				
	Residual	2.18				
	Autocorrelation	0.55				

Formal Practice Quality						
	Fixed effects	**Value**	**SE**	**df**	**t**	**p**
	Intercept	4.53	0.23	694	19.74	.000
	Time	0.04	0.02	694	2.06	.040
	Random effects	**SD**	**Correlation slopes + intercept**			
	Intercept	1.00	-.65			
	Time	0.13				
	Residual	1.78				
	Autocorrelation	0.52				

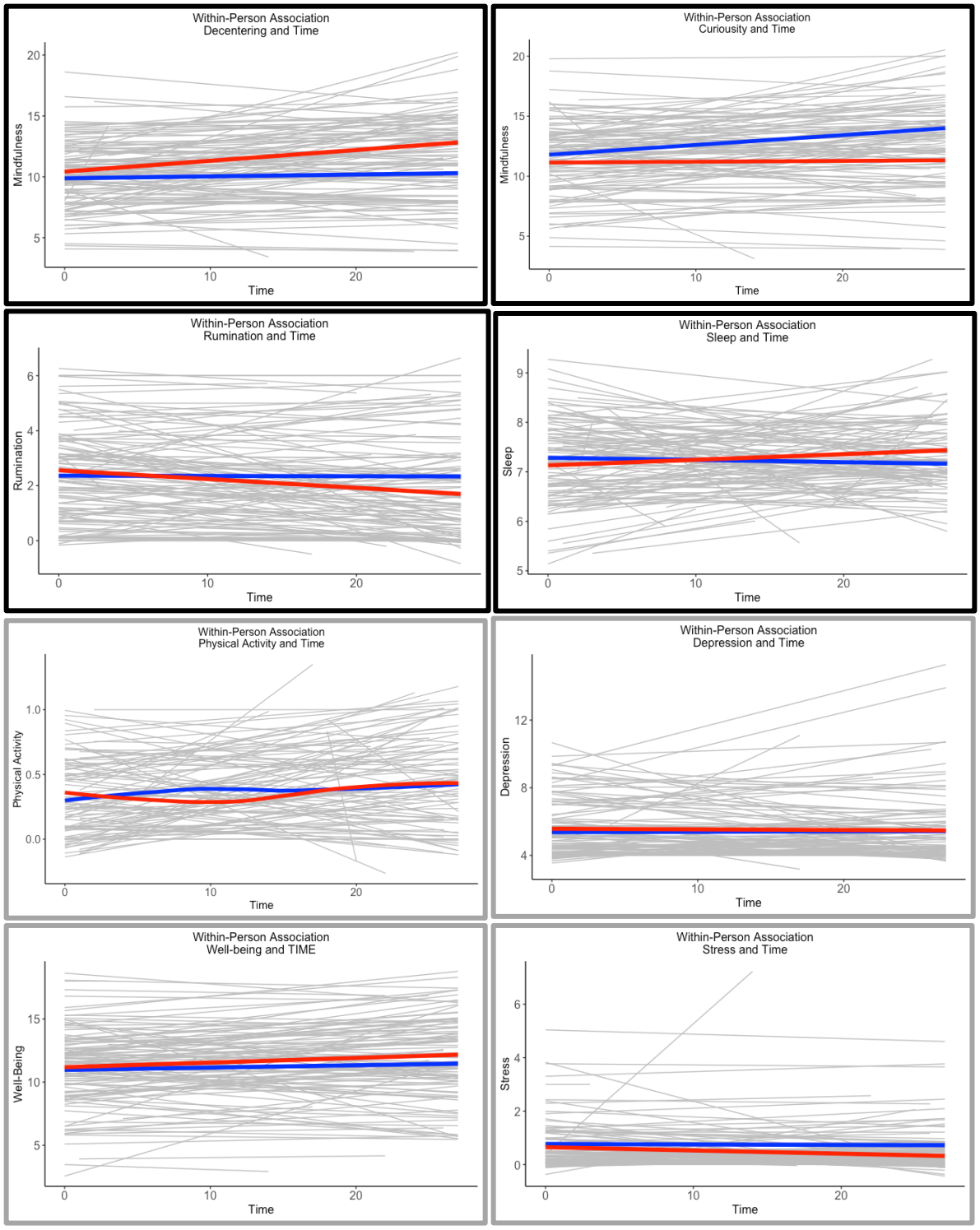

Figure 3. Fixed effects of the intervention (red) and control (blue) condition. The grey lines represent each individual participant's slope over time. Significant time by group interactions are indicated with black borders around the panels.

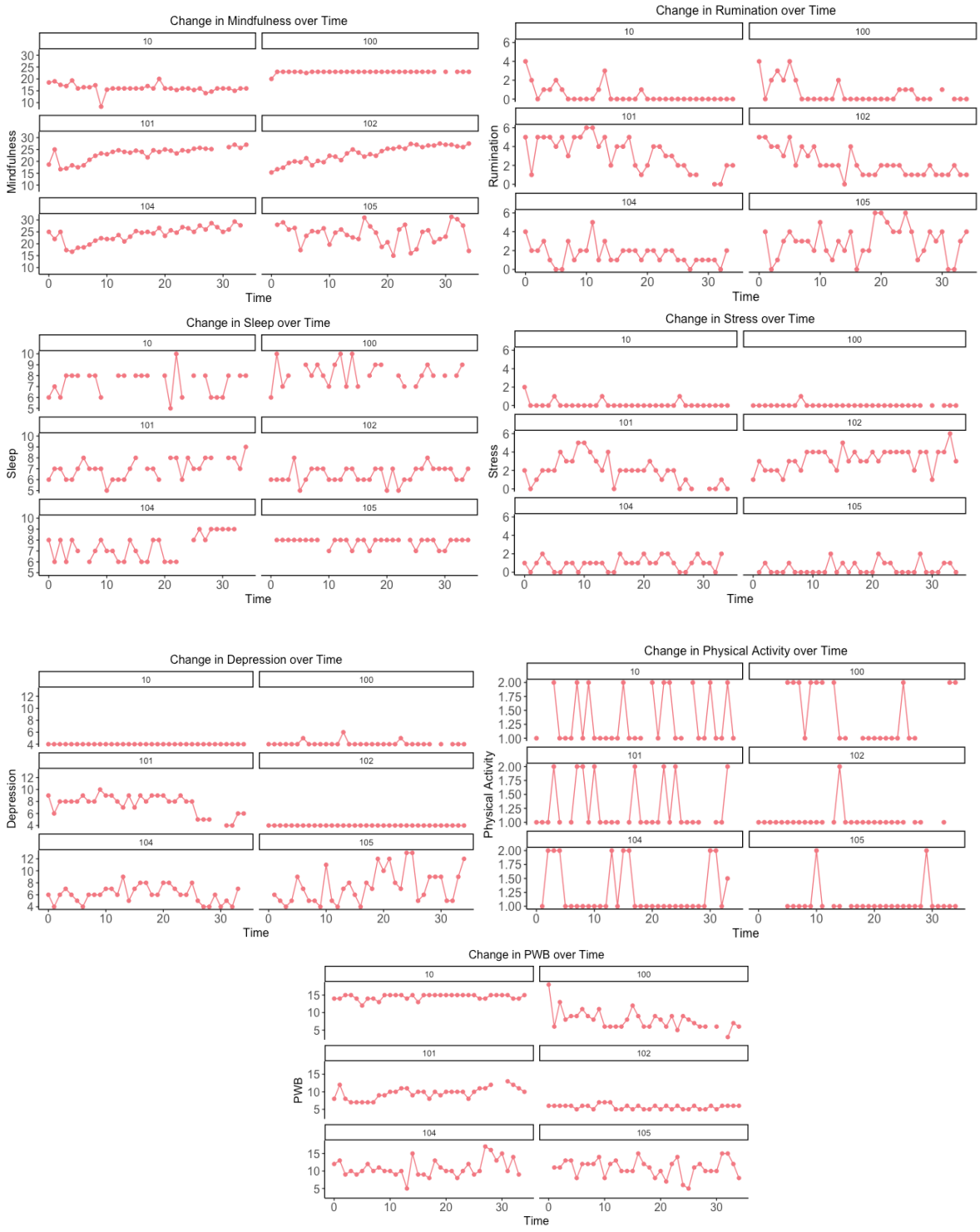

Figure 4. Representative samples of daily scores to illustrate the variability in scores over time. ID numbers are listed at the top, where control was ID's 10 and 102, while intervention was ID's 100, 101, 104, and 105.

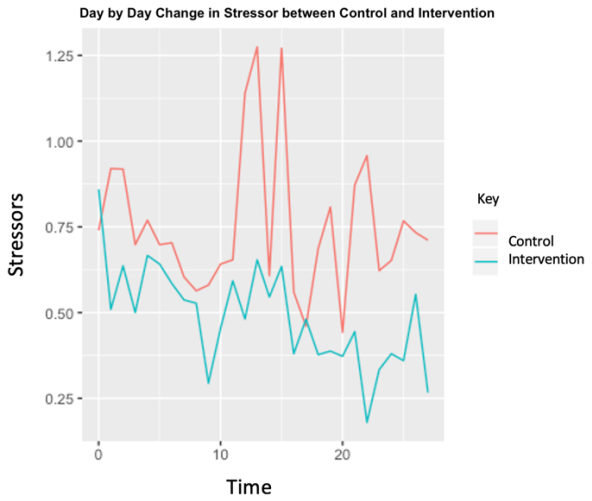

Figure 5. Average day by day change for the control group and the intervention group.

Coupling pre-post changes with day-to-day changes

Correlations between state slopes and trait change

In a first analysis, I correlated the change in pre-post-test trait measures to change in the EMA state measures in the intervention condition. Because within the EMA data only Decentering, Curiosity, rumination, and sleep significant yielded significant slopes, I restricted my analysis to these four variables. The correlation matrix in Table 6 shows that the rates of change in Curiosity and Decentering are related to pre-post-test changes in depression, anxiety, stress, mindfulness (subscales Non-Reaction, Observation, Awareness, and Non-Judgement), positive and negative affect, perceived stress, PWB (subscales Environmental Mastery and self-acceptance), as well as pre-post changes in rumination. In contrast, changes in sleep over time were not correlated with any pre-post-test change scores, nor with the slopes of change in any of the other EMA data.

Table 5. Correlation matrix for trait-to-trait changes over the course of the intervention (i.e. pre-post changes.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Depression	1.																				
2. Anxiety	.46**	1.																			
3. Stress	.54**	.60**	1.																		
4. Non React	-.18	-.11	-.23	1.																	
5. Observe	-.40**	-.26	-.38**	.28*	1.																
6. Awareness	-.39**	-.36**	-.49**	.23	.61**	1.															
7. Describe	-.18	-.11	-.04	.43**	.32*	.23	1.														
8. Non-Judgement	-.17	-.24	-.41**	.31*	.33*	.2	.23	1.													
9. Physical Activity	-.04	-.08	-.09	.24	-.07	-.05	.12	.05	1.												
10. Positive Affect	-.50**	-.35**	-.41**	.26	.49**	.44**	.26	.25	.11	1.											
11. Negative Affect	.58**	.44**	.56**	-.35**	-.51**	-.58**	-.17	-.42**	-.18	-.51**	1.										
12. Sleep	.28*	.29*	.26*	-.05	-.12	-.23	.14	-.09	.03	-.1	.24	1.									
13. Perceived Stress	.54**	.30*	.54**	-.45**	-.53**	-.51**	-.08	-.29*	-.07	-.52**	.65**	.18	1.								
14. Autonomy	-.14	-.18	-.24	.49**	.26	.31*	.39**	.50**	.1	.15	-.37**	.04	-.2	1.							
15. Enviromental Mastery	-.45**	-.28*	-.54**	.39**	.39**	.41**	.27*	.40**	.13	.47**	-.50**	-.12	-.56**	.31*	1.						
16. Personal Growth	-.47**	-.42**	-.34**	-.03	.46**	.36**	.01	.12	.03	.51**	-.31*	-.38**	-.40**	.02	.27*	1.					
17. Personal Relationships	-.59**	-.47**	-.45**	.2	.48**	.43**	.22	.39**	.04	.57**	-.47**	-.39**	-.42**	.29*	.44**	.58**	1.				
18. Purpose in Life	-.40**	-.34**	-.17	.19	.31*	.30*	.13	.05	-.08	.30*	-.21	-.1	-.32*	-.01	.28*	.49**	.38**	1.			
19. Self Acceptance	-.52**	-.27*	-.46**	.38**	.58**	.45**	.33*	.46**	.12	.54**	-.59**	-.1	-.49**	.40**	.51**	.28*	.47**	.37**	1.		
20. Rumination	.51**	.38**	.50**	-.19	-.37**	-.38**	-.19	-.33*	-.05	-.46**	.49**	.40**	.47**	-.14	-.32*	-.45**	-.46**	-.15	-.49**	1.	
21. Formal Practice Quality	-.32*	.02	-.23	.07	.15	.13	.14	.2	-.01	.02	-.15	-.12	-.18	.18	.21	.22	.18	.	.2	-.21	1.

Table 6. Correlation matrix for state-to-state changes over the course of the intervention (i.e. EMA variable changes)

	22	23	24	25	26	27	28	29	30	31
22. Curiosity	1.									
23. Decentering	.80**	1.								
24. Stressor	-.15	-.13	1.							
25. Depression	-.17	-.22	.19	1.						
26. Well-Being	.31*	.31*	-.2	-.42**	1.					
27. Rumination	-.28*	-.32*	.2	.49**	-.46**	1.				
28. Sleep	-.13	-.16	.06	-.07	.06	-.25	1.			
29. Physical Activity	.1	-.06	-.01	.27*	-.21	.29*	-.25	1.		
30. Informal Practice Quality	-.04	-.02	.11	.04	-.13	.17	-.21	-.18	1.	
31. Formal Practice Quality	-.11	-.06	.18	.05	-.12	.19	-.27*	-.11	.90**	1.

Table 7. Correlation matrix for state-to-trait changes over the course of the intervention (i.e. changes in the pre-posttest and EMA variables).

	Dep	Anx	Str	NR	O	A	D	NJ	PA	Pos	Neg	Slp	Per S	Auto	EM	PG	PR	PL	SA	Rum	Form
Curiosity	-.23	-.27*	-.43**	.14	.42**	.33*	.04	.23	-.13	.32*	-.34*	-.18	-.23	.16	.33*	.09	.19	-.04	.36**	-.39**	.22
Decentering	-.30*	-.27*	-.48**	.37**	.52**	.38**	.13	.40**	-.06	.43**	-.43**	-.19	-.35**	.33*	.48**	.18	.31*	.05	.48**	-.41**	.24
Stressor	-.11	.04	.07	-.23	.11	-.09	-.12	-.12	-.05	.01	.01	.27*	-.12	-.18	-.12	.	.1	.03	-.03	-.07	-.25
Depression	-.01	-.21	.04	-.31*	-.27*	-.1	-.14	-.13	-.1	-.13	.2	.01	.15	-.23	-.18	-.05	-.04	.08	-.21	.14	-.15
Well-Being	-.14	-.06	-.07	.15	.21	.11	.04	.19	-.1	.12	-.11	-.17	-.04	.2	.15	.09	.35**	.	.24	-.31*	.28*
Rumination	.12	.1	.16	-.22	-.29*	-.07	-.1	-.30*	-.02	-.21	.18	.16	.13	-.14	-.12	-.22	-.14	.18	-.14	.26*	-.17
Sleep	.	.04	.18	-.13	-.06	-.17	-.05	-.09	-.25	.1	.03	.17	.02	-.01	-.19	.05	-.1	-.13	-.19	-.09	-.11
Physical Activity	-.17	.	-.22	-.21	-.12	-.11	-.1	-.13	-.12	.04	.11	.15	-.04	-.34**	.08	-.11	-.06	-.01	.04	.14	-.03
Informal Practice Quality	.02	-.11	.07	.2	.	-.06	.13	.05	.35**	-.09	-.01	-.14	-.12	.04	.1	.02	.08	.16	.03	.01	.05
Formal Practice Quality	-.03	-.04	.03	.23	.05	.01	.16	.	.34**	-.07	.05	-.09	-.2	.02	.15	.1	.17	.29*	.07	.	.08

Note. Dep = Depression, Anx= Anxiety, Str= stress, NR= Non-React, O= Observe, A= Awareness, D= Describe, NJ= Non-Judgement, PA= Physical Activity, Pos= Positive Affect, Neg= Negative

Affect, Slp= Sleep, Per S= Perceived Stress, Auto= Autonomy, EM= Environmental Mastery, PG= Personal Growth, PR= Personal Relationships, PL= Purpose in Life, SA= Self-Acceptance, Rum= Rumination, and Form= Formal Practice Quality.

Relationship between initial level and change.

I examined the relationships between the random slopes and the random intercepts as well as initial pre-test scores in Table 4 and the change in pre-post-test within the intervention group, presented in Table 7. Within Table 4 the EMA variables, significantly negative correlations were observed for depression (r = -.30), sleep (r = -.78), stress (r = -.52), formal practice quality (r = -.65), and informal practice quality (r = -.81). No significant positive correlations were obtained. The random intercept-slope correlations were not significant for Decentering (r = -.20), Curiosity (r = -.16), rumination (r = -.25), physical activity (r = -.24), and PWB (r = -.20). For depression and stress, these findings indicate a Matthew effect, that is, individuals with more beneficial initial scores show the most change; for sleep, and formal and informal practice, this is a reverse Matthew effect.

The correlations between initial scores on the pre-test and the pre-post-test change on the trait variables is presented in Table 7. Significantly positive correlations were observed for all subscales of the PWB (r = .30 .32, .54, .47, .32, .30 for Autonomy, Environmental Mastery, Personal Growth, Purpose in Life, and Self-Acceptance respectively), indicating a Matthew effect. Significantly negative correlations were observed for positive and negative affect (r = -.49, and -.49, respectively), physical activity (r = -.56), rumination (r = -.49), worry (r = -.48), sleep (r = -.48), PSS (r = -.60), and all the DASS subscales (r = -.57, -.53, -.57, for Depression, Anxiety, and Stress respectively), indicating a reverse Matthew effect of positive emotions, physical activity, and sleep, and a reverse Matthew effect for all other variables. The intercept-slope correlations were not significant for any of the subscales of the FFMQ.

Table 8. Correlation matrix for pre-test scores (row) and change in pre-post test score (columns).

	Change from Pre-test to Post-test																				
Pre-Test Score	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
1. Non React	.05	.28**	.23*	-.09	.10	.09	-.09	.05	-.14	.12	-.04	.13	.20*	.13	.11	.15	.11	-.16	.04	-.07	-.12
2. Observe	.01	.22*	.20*	-.08	.04	.06	.00	.01	-.08	.12	-.07	.09	.11	.14	.10	.10	.00	-.07	.09	-.01	-.04
3. Act with Awareness	-.10	.09	.04	-.13	-.09	-.07	.08	.07	.04	.13	-.06	-.04	-.03	.08	.07	.05	-.09	.07	.14	.11	.13
4. Describe	-.02	.22*	.18	-.10	.01	.03	-.01	.03	-.03	.12	-.03	.07	.09	.13	.10	.13	.04	-.06	.10	-.01	.00
5. Non Judgment	.17	.29**	.28**	.04	.07	.23*	-.16	-.05	-.17	.00	.09	.22*	.21*	.17	.16	.21*	.17	-.26**	-.12	-.10	-.15
6. Positive Affect	-.12	-.13	-.01	-.10	-.14	.50*	.15	-.02	.07	.16	-.25**	.00	-.04	-.08	-.19*	.01	-.04	.06	.18	.11	.08
7. Negative Affect	.21*	.02	-.01	.07	.11	.22*	.44*	-.08	-.16	-.12	.04	.20**	.09	-.01	.04	.07	.24*	-.25**	-.15	-.16	-.11
8. Rumination	.19	.15	.03	.16	.10	.20*	-.15	-.44**	-.09	-.26**	.06	.16	.11	.09	.11	.01	.25**	-.15	-.16	-.13	-.03
9. Worry	.09	.10	-.02	.03	.20*	.15	0.2*	-.11	-.45**	-.15	-.06	.08	.07	-.09	.05	.09	.26**	-.30**	-.17	-.14	-.17
10. Sleep	.06	.00	-.02	.10	.05	-.03	-.06	-.12	-.09	-.54**	.01	.00	.09	-.03	-.04	-.08	.14	-.06	-.05	-.06	-.04
11. Physical Activity	-.13	-.02	.22*	-.15	.01	-.08	.10	-.09	.04	.15	-.51**	-.15	-.13	-.04	.03	.17	-.04	.11	.06	.17	.11
12. Autonomy	.16	.23*	.07	.05	.18	-.01	-.12	-.27**	-.06	-.05	-.05	.35**	.19*	.16	.12	.08	.25**	-.23*	-.22*	-.14	-.31**
13. Enviromental Mastery	.15	.37**	.32**	.19*	.23*	.20*	.32*	-.29**	-.34**	-.10	-.08	.16	.44**	.18	.20*	.16	.36**	-.33**	-.31**	-.16	-.35**
14. Personal Growth	-.06	.26**	.37**	.05	.13	.19*	-.12	-.21*	-.16	-.09	-.14	.00	.25**	.54**	.32**	.23*	.14	-.21*	-.25**	-.17	-.28**
15. Positive Relationships	-.06	.31**	.30**	.07	.05	.14	-.07	-.24*	-.20*	-.06	-.15	.07	.09	.15	.35**	.17	.10	-.13	-.12	-.22*	-.13
16. Purpose in Life	.02	.18	.18	.03	.02	-.03	-.13	-.20*	-.21*	-.14	-.12	-.06	-.01	.18	.21*	.35**	.14	-.07	-.18	-.15	-.17
17. Self Acceptance	.10	.30**	.16	.17	.17	.16	-.21	-.36**	-.26**	-.05	-.02	.11	.19*	.17	.17	.16	.39**	-.18	-.28**	-.13	-.22*
18. Perceived Stress	.21*	.12	.10	-.04	.09	.30**	-.33**	-.17	-.27**	-.21*	.10	.15	.27**	.03	.08	.06	.26**	-.56**	-.24*	-.18	-.19
19. Depression	.20*	.15	.05	.09	.02	.33**	-.22*	-.03	-.18	-.18	.14	.21*	.12	.12	.14	.08	.25**	-.24*	-.51**	-.15	-.20*
20. Anxiety	.15	.12	-.01	.12	.17	.15	-.15	-.11	-.28**	-.17	.05	.25**	.16	.02	.10	.09	.25**	-.15	-.16	-.53**	-.23*
21. Stress	.26**	.18	.13	.06	.23*	.22*	-.30**	-.16	-.32**	-.14	.08	.24*	.12	-.01	.16	.11	.38**	-.30**	-.22*	-.29**	-.50**

Exploratory Question 1

For my exploratory mediation analysis, I first examined the correlation matrices (Table 5, 6, and 7). Table 5 shows that changes in trait measures correlated with changes in other trait measures in the hypothesized direction, where three factors of the FFMQ (viz. Observation, Awareness, and Non-Judgment) significantly and negatively correlated with rumination (a proposed mediator). None of the FFMQ subscales significantly correlated with changes in sleep quality or changes in physical activity, both again proposed mediators. Rumination significantly correlated with almost all outcomes variables proposed – decreases in rumination led to decreases in depression, anxiety, stress, negative affect, and increases in positive affect and three factors of the PWB scale (Environmental Mastery, Personal Relationships, Purpose in Life, and Self-Acceptance).

Change scores in trait measures showed intercorrelations, as well as correlations with change in state measures, shown in Table 8. As expected, changes in state Curiosity and

Decentering correlated significantly with changes in trait rumination, but changes in Curiosity and Decentering did not correlate significantly with any of the subscales of the FFMQ. Changes in neither aspect of state mindfulness correlated with changes in trait sleep or physical activity, so that no mediation would be achievable with the latter two variables. Lastly, changes in state rumination significantly correlated only with changes in two subscales of trait mindfulness (Observe and Non-React), and trait rumination.

The most important precondition for mediation in day-to-day change lies in Table 6, state-to-state change, showing that both aspects of state mindfulness significantly related to state rumination, which then significantly related to depression and well-being. Alternatively, sleep and physical activity, my other two proposed mediators, did not significantly correlate with changes in Curiosity or Decentering, but physical activity did relate to depression and rumination. In light of these findings, I still will examine rumination, physical activity, and sleep as potential mediators of change with multilevel modeling to account for within person changes and variability more accurately. In a first set of analyses, I explore within-day meditation; in a second set, I explore lagged mediation.

Within-day mediation: Rumination as a mediator between state mindfulness and outcomes

Rumination was a significant mediator in the relationship between the two aspects of mindfulness (Decentering and Curiosity) and depression, stress, and well-being, as indicated by Aroian tests for mediation (see Table 9). In all six analyses, higher levels of mindfulness (both Curiosity and Decentering) predicted lower levels of rumination (parameter *a*), and lower levels of rumination predicted lower levels of depression and stress, and higher levels of well-being (parameter *b*). Intervention did not have a moderating effect on the mindfulness-rumination relationship in any of the six analyses, suggesting that increases in both aspects of mindfulness

naturally lead to decreases in rumination. Likewise, intervention did not have moderating effects on the rumination-outcome relationship in any of the six analyses, suggesting that decreases in rumination naturally lead to improvements in depression, stress, and well-being.

In three out of six models (Decentering and Curiosity on well-being and Curiosity on depression), a direct effect of mindfulness on depression, stress, and well-being remained after adjusting for rumination (parameter *c'*). The other three models (Decentering and Curiosity on stress and Decentering on depression) did not result in significant direct effects from mindfulness on outcomes. In three models (Decentering and Curiosity with well-being and Curiosity and depression) both total and direct effects were significant. In the last two models (Decentering and Curiosity with stress) neither total nor direct effects were significant. With respect to the moderating relationship of intervention on *c*, two models showed a significant moderating effect: In the intervention arm, increases in Decentering lead to stronger increases in well-being and stronger decreases in depression compared to the control group.

Lastly, the percent mediated in the Curiosity and Decentering path to well-being was 25% and 34%, respectively, for the intervention group, compared to 7% and 2%, respectively, for the control group. The percent mediated for the Curiosity and Decentering path to depression was 59% and 75%, respectively, for the intervention group, and 39% and 54%, respectively, for the control group. The percent mediated for the Curiosity/Decentering path to stressor was 98% and 61%, respectively, for the intervention, and 77% and 46%, respectively, for the control group.

Physical activity as a mediator

Physical activity was a significant mediator only for the relationship of curiosity to depression and well-being, as indicated by Aroian tests for mediation (see Table 9). Higher levels of Curiosity predicted higher levels of exercise (parameter *a*), and higher levels of exercise

predicted lower levels of depression and higher levels of well-being (parameter *b*). Intervention did not have a moderating effect on the mindfulness-rumination relationship in any of the analyses, suggesting that increases in both aspects of mindfulness naturally lead to increases in exercise. Likewise, intervention did not have moderating effects on the exercise-outcome relationship in any of the analyses, suggesting that increases in exercise naturally lead to improvements in depression, stress, and well-being. The other four models did not result in significant mediation according to Aroian test, namely Decentering on depression, well-being and stress and Curiosity on stress.

In the two significant mediation models (Curiosity on depression and well-being), a direct effect of mindfulness scores on depression and well-being remained after adjusting for rumination (parameter *c'*). With respect to the moderating relationship of intervention on c, one of the two models showed a significant moderating effect, namely when in the intervention arm increases in Curiosity lead to stronger increases in well-being compared to the control group. Curiosity and depression did not show a significant moderating effect of intervention. All significant and non-significant mediated paths can be found in Table 9.

Lastly, the percent mediated in the Curiosity path to well-being for the intervention was 8%, compared to 7% for the control group. The percent mediated for the Curiosity path to depression for the intervention was 4% and 3% for the control group.

Lagged Mediation Analysis

In my analysis of whether mindfulness at time *t* predicts mediators at *t* + 1 and stress, well-being, or depression at *t* + 2, I found that both aspects of mindfulness at *t* predicted rumination at *t* + 1. Rumination at *t* + 1 did not predict stress, well-being, or depression at *t* + 2, except in three models. Specifically, Decentering and Curiosity at *t* predicted rumination at *t* + 1 and stressor count

at $t + 2$ significantly, and Curiosity at t predicting rumination at $t + 1$ and depression at $t + 2$. It is important to note that of these three models only one showed significant mediation via Aroian's test, namely Decentering at t predicting rumination at $t + 1$ and stressor count on $t + 2$. Therefore, mindfulness at t consistently predicted rumination at $t + 1$, but rumination at $t + 1$ did not consistently predict stress, well-being or depression at $t + 2$. Because mediation of rumination to the outcomes appeared to be significant only within the same day, I conducted the rest of the lagged analysis by only altering the lag of rumination from mindfulness variables and keeping the three outcome variables lagged on the same day as rumination. For this, all tests yielded significant mediation according to Aroian's test.

Analyses using a two-day lag between mindfulness and rumination all resulted in significant prediction for mindfulness to rumination, and from rumination to outcomes on the same day; significant mediation was obtained for all models involving Decentering, and the model connecting Curiosity to wellbeing. When testing a three-day lag period, Decentering at t did not significantly predict rumination at $t + 3$, but Curiosity at t did significantly predict rumination at $t + 3$, and rumination at $t + 3$ significantly predicted depression, stress, and well-being on that same day. Within these models, only the pathways connecting Curiosity to depression and well-being were significantly mediated by rumination. Additionally, I ran the models specifying autocorrelation. Six models showed a better model fit, as indicated in Table 9; the remaining models were not specified with autocorrelation. Lastly, mindfulness at t did not significantly predict exercise or sleep at $t + 1$ and therefore was not included in this analysis.

Exploratory Question 2

For the second exploratory mediation analysis, I first analyzed the correlation matrices found in Table 5. Changes in state measures generally correlated with changes in other state

measures in the proposed direction, but practice quality, both formal and informal, were not related to either Curiosity or Decentering. Informal and formal practice quality did relate to each other. Formal practice quality was significantly and negatively correlated with changes in sleep quantity. Because practice quality was not related to either aspect of mindfulness, I did not continue into a mediation analysis.

Table 9. Regression parameters in the moderated mediated pathways tested. Cells with significant coefficients are highlighted in grey. Standard errors are presented in parentheses. Additionally the Aroian test stastic for the moderated mediation pathways, with standard error in parentheses, and corresponding p-values are presented as well. Models with significantly better model fit with autocorrelation have the autocorrelation Phi coefficient presented.

Path	a	b	c	c'	mod a	mod b	mod c	Aroian Test	*p*-value	Autocorrelation
				t → *t* → *t*						
Decenter → rumination → depression	-.15 (0.03)	.39 (0.04)	-.15 (0.04)	-.05 (0.03)	-.07 (0.06)	.02 (0.08)	-.13 (0.06)	-4.49 (0.013)	**.000**	
Curiosity →rumination → depression	-.12 (0.03)	.40 (0.04)	-.13 (0.04)	-.07 (0.03)	-.04 (0.06)	.04 (0.08)	-.08 (0.05)	-3.62 (0.013)	**.000**	
Decenter → rumination → stressor	-.16 (0.03)	.19 (0.03)	-.07 (0.03)	-.04 (0.02)	-.08 (0.06)	-.04 (0.05)	.01 (0.05)	-3.99 (0.007)	**.000**	
Curiosity → rumination → stressor	-.12 (0.03)	.19 (0.03)	-.03 (0.02)	-.00 (0.02)	-.05 (0.06)	-.03 (0.05)	-.04 (0.04)	-3.31 (0.007)	**.000**	
Decenter → rumination → well-being	-.15 (0.03)	-.35 (0.04)	.23 (0.05)	.18 (0.04)	-.08 (0.06)	-.08 (0.09)	.21 (0.08)	4.39 (0.012)	**.000**	
Curiosity → rumination → well-being	-.12 (0.03)	-.37 (0.04)	.20 (0.05)	.17 (0.04)	-.05 (0.06)	-.10 (0.09)	.16 (0.09)	3.6 (0.012)	**.000**	
Curiosity → PA → depression	-.02 (0.008)	.30 (0.08)	-.12 (0.04)	-.14 (0.04)	.02 (0.02)	.24 (0.17)	-.11 (0.08)	-2.04 (0.003)	**.041**	
Curiosity → PA → well-being	-.02 (0.009)	-.64 (0.14)	.20 (0.05)	.14 (0.05)	.02 (0.02)	-.44 (0.29)	.31 (0.10)	1.96 (0007)	**.050**	
Decenter → PA → depression	-.01 (0.008)	.26 (0.08)	-.14 (0.04)	-.13 (0.04)	-.02 (0.02)	.18 (0.16)	-.21 (0.09	-1.12 (0.002)	.262	
Decenter → PA → well-being	-.01 (0.007)	-.61 (0.15)	.24 (0.05)	.16 (0.05)	-.02 (0.02)	-.38 (0.30)	.32 (0.10)	1.31 (0.005)	.189	
Decenter → PA → stressor	-.01 (0.007)	.03 (0.04)	-.07 (0.03)	-.04 (0.03)	-.02 (0.02)	.08 (0.09)	-.04 (0.06)	-0.56 (0.001)	.572	
Curiosity →PA → stressor	-.02 (0.009)	.05 (0.05)	-.03 (0.02)	-.03 (0.02)	.02 (0.02)	.10 (0.09)	-.06 (0.04)	-0.86 (0.001)	.391	
Decenter → sleep → depression	.02 (0.02)	-.03 (0.03)	-.15 (0.04)	-.16 (0.04)	-.02 (0.04)	.11 (0.07)	-.13 (0.09)	-0.49 (0.000)	.640	
Curiosity → sleep → depression	.00 (0.02)	-.03 (0.03)	-.13 (0.04)	-.14 (0.04)	.04 (0.04)	-.09 (0.07)	-.06 (0.08)	0.00 (0.000)	1.000	
Decenter → sleep → stressor	.02 (0.02)	-.07 (0.03)	-.07 (0.002)	-.07 (0.002)	-.01 (0.04)	.03 (0.04)	.01 (0.05)	-0.31 (0.001)	.760	
Curiosity → sleep → stressor	.00 (0.02)	-.07 (0.02)	-.03 (0.02)	-.03 (0.02)	.05 (0.04)	.03 (0.04)	-.03 (0.04)	0.00 (0.000)	1.000	
Decenter → sleep → well-being	.01 (0.02)	-.03 (0.05)	.24 (0.05)	.26 (0.05)	-.01 (0.4)	-.06 (0.11)	.25 (0.10)	-.74 (0.000)	.460	
Curiosity → sleep → well-being	.00 (0.02)	-.03 (0.05)	.20 (0.05)	.21 (0.05)	-.05 (0.04)	.02 (0.10)	.15 (0.10	-0.14 (0.000)	.890	
				t → *t* + *1* → *t* + *2*						
Decenter → rumination → depression	-.11 (0.03)	.07 (0.04)	-.08 (0.03)	-.05 (0.03)	-.03 (0.06)	.02 (0.06)	-.04 (0.07)	-1.53 (0.005)	.125	
Curiosity →rumination → depression	-.06 (0.03)	.08 (0.03)	-.04 (0.03)	-.02 (0.03)	-.08 (0.06)	.06 (0.07)	-.09 (0.06)	-1.53 (0.003)	.125	
Decenter → rumination → stressor	-.09 (0.03)	.06 (0.02)	-.06 (0.02)	-.05 (0.02)	-.04 (0.06)	-.04 (0.04)	.01 (0.04)	-2.06 (0.003)	**.039**	
Curiosity → rumination → stressor	-.07 (0.03)	.07 (0.03)	-.01 (0.02)	-.11 (0.05)	-.07 (0.06)	-.04 (0.04)	-.04 (0.03)	-1.89 (0.003)	.059	
Decenter → rumination → well-being	-.10 (0.03)	-.04 (0.04)	.11 (0.04)	.11 (0.05)	-.04 (0.06)	-.09 (0.08)	.11 (0.09)	0.92 (0.004)	.357	
Curiosity → rumination → well-being	-.07 (0.03)	-.06 (0.04)	.20 (0.05)	.02 (0.05)	-.07 (0.06)	-.07 (0.08)	.15 (0.09)	1.187 (0.004)	.235	
				t → *t* + *1* → *t* + *1*						
Decenter → rumination → depression	-.10 (0.03)	.42 (0.04)	-.07 (0.04)	-.01 (0.03)	-.03 (0.06)	.07 (0.08)	-.05 (0.06)	-3.16 (0.013)	**.002**	
Curiosity →rumination → depression	-.06 (0.03)	.43 (0.04)	-.00 (0.03)	-.05 (0.03)	-.07 (0.06)	.06 (0.08)	-.09 (0.05)	-1.96 (0.013)	**.050**	
Decenter → rumination → stressor	-.09 (0.00)	.14 (0.03)	-.03 (0.02)	.01 (0.02)	-.04 (0.06)	-.04 (0.05)	.01 (0.03)	-4.67 (0.003)	**.000**	0.094
Curiosity → rumination → stressor	-.07 (0.03)	.14 (0.03)	-.01 (0.02)	0.00 (0.02)	-.06 (0.06)	-.03 (0.05)	-.02 (0.03)	-2.05 (0.005)	**.040**	0.096
Decenter → rumination → well-being	-.09 (0.03)	-.43 (0.05)	.10 (0.04)	.06 (0.4)	-.05 (0.06)	-.15 (0.10)	.05 (0.07)	2.82 (0.014)	**.005**	
Curiosity → rumination → well-being	-.07 (0.03)	-.43 (0.05)	.07 (0.04)	.05 (0.04)	-.07 (0.06)	-.14 (0.10)	.10 (0.07)	2.24 (0.013)	**.025**	
				t → *t* + *2* → *t* + *2*						
Decenter → rumination → depression	-.08 (0.03)	.43 (0.04)	-.07 (0.03)	-.02 (0.03)	-.01 (0.06)	.03 (0.08)	-.02 (0.06)	-2.58 (0.013)	**.010**	
Curiosity →rumination → depression	-.05 (0.03)	.44 (0.04)	-.03 (0.03)	-.001 (0.03)	-.06 (0.06)	.03 (0.08)	-.04 (0.05)	-1.64 (0.013)	.101	
Decenter → rumination → Stressor	-.08 (0.03)	.14 (0.03)	-.05 (0.02)	-.02 (0.02)	-.01 (0.06)	-.04 (0.05)	-.03 (0.04)	-2.28 (0.005)	**.023**	0.088
Curiosity → rumination → Stressor	-.05 (0.03)	.14 (0.03)	-.02 (0.02)	.00 (0.02)	-.06 (0.05)	-.04 (0.05)	-.05 (0.04)	-1.54 (0.005)	.124	0.093
Decenter → rumination → well-being	-.08 (0.03)	-.42 (0.05)	.10 (0.04)	.08 (0.04)	-.02 (0.06)	-.12 (0.10)	.10 (0.08)	2.53 (0.013)	**.012**	
Curiosity → rumination → well-being	-.06 (0.03)	-.42 (0.05)	.01 (0.05)	.01 (0.05)	-.07 (0.05)	-.11 (0.10)	.10 (0.09)	1.93 (0.013)	**.053**	
				t → *t* + *3* → *t* + *3*						
Decenter → rumination → depression	-.05 (0.03)	.42 (0.04)	-.03 (0.03)	.00 (0.03)	-.04 (0.06)	.08 (0.08)	-.01 (0.05)	-1.64 (0.013)	.101	
Curiosity →rumination → depression	-.06 (0.03)	.42 (0.04)	-.03 (0.03)	-0.00 (0.03)	-.07 (0.06)	.09 (0.08)	.01 (0.05)	-1.96 (0.013)	**.050**	
Decenter → rumination → Stressor	-.05 (0.03)	.14 (0.03)	-.03 (0.01)	-.01 (0.01)	-.04 (0.06)	-.04 (0.05)	-.03 (0.03)	-1.54 (0.004)	.124	0.101
Curiosity → rumination → Stressor	-.06 (0.03)	.20 (0.03)	-.04 (0.01)	-.02 (0.01)	-.07 (0.06)	-.03 (0.05)	-.02 (0.03)	-1.90 (0.006)	.058	0.094
Decenter → rumination → well-being	-.05 (0.03)	-.43 (0.05)	.05 (0.04)	.01 (0.04)	-.04 (0.06)	-.14 (0.11)	.04 (0.08)	1.63 (0.013)	.104	
Curiosity → rumination → well-being	-.06 (0.03)	-.43(0.05)	-.02 (0.04)	-.04 (0.04)	-.07 (0.06)	-.14 (0.11)	.11 (0.08)	1.94 (0.013)	**.053**	

Note. PA= physical activity a = direct effect of predictor (Curiosity or Decentering) on mediator (rumination, exercise, or sleep). b = direct effect of mediator on outcome variable (well-being, depression, or stressor count). c = total effect of predictor on outcome variable. c' = direct effect of predictor on outcome variable accounting for mediator.

Discussion

My main research question was if and how changes in different aspects of psychological functioning occur during a remotely delivered mindfulness intervention. To that aim, I trained 57 college students using the 4-week Koru protocol and compared pre-to-post changes with corresponding time-yoked changes in a group of 55 waitlist controls. I also examined day-to-day changes over the 4-week period between the control and intervention using linear growth models specifying autocorrelation. Additionally, I examined how the variables affect each other using mediation analysis.

Pre-post trait changes

In regard to the pre-post-test changes, the simplest summary of the findings for hypothesis 1 is that the intervention produced significantly larger benefits for mindfulness, rumination, worry, mood, stress, anxiety, three aspects of psychological wellbeing (Autonomy, Environmental Mastery, and Self-acceptance) and physical activity—sixteen of the 21 variables probed.

The effect sizes from these variables ranged from 0.37 to 0.93, with a mean of 0.59. There were non-significant effects for depression (d = 0.33), sleep (d = -0.13), and for three out of six aspects of psychological wellbeing (Personal growth, Personal relations, and Purpose in Life; average d = 0.17). No effects favoring the control group were obtained. Average effect size over all 21 measures was 0.48, which falls just shy of Cohen's 0.5 threshold for a medium effect (Cohen, 1988).

In order to understand what these effect sizes mean, it is crucial to benchmark the findings against the existing literature. One obvious comparison is with the two previous RCTs on in-person Koru interventions. My study has a few variables in common with these, namely mindfulness, stress, and sleep quality with both Greeson et al. (2104) and Weis et al. (2020); Weis et al., like

us, additionally measured anxiety. I replicated the effects of Koru on mindfulness, stress, and anxiety, but did not find effects on sleep quality. The effects obtained on mindfulness (d = 0.64) are smaller than those obtained by both Greeson et al. (d = 0.98) and Weis et al. (d = 1.32). It is important to note that the two extant studies used the CAMS-R, which arguably measures mostly non-judgmental awareness and nonreactivity (Karl & Fischer, 2020). My effect sizes for those two components of the FFMQ were 0.80 and 0.94, respectively, that is, perhaps comparable with Greeson et al., but lower than the effect obtained by Weis et al. The effect on stress observed here (d = 0.61) falls in between that of Greeson et al. (d = 0.47) and Weis et al. (d = 1.11); the effect on anxiety (d = 0.37) is smaller than that of Weis et al. (d = 0.86). Taken together, the results suggest that the effects are somewhat smaller than those obtained in the two existing studies using the same intervention. This most likely could be attributed to the delivery method. Because we were in the height of the pandemic, I administered the Koru intervention remotely. Some caution is in order here because many other differences exist between studies, such as the different dependent measures, the different historical time compared to Greeson et al., the length of isolation in the pandemic compared to Weis et al., the difference between a large public university and a small liberal arts college compared to Weis et al., and so on. From my informal observations, I speculate that one potentially essential difference between my study and the others is that remote learning does not appear to allow for the sense of community that in-person classes provide. Group processes are a crucial ingredient in group interventions for health in general (e.g., Borek et al., 2019) and mindfulness in particular (Cormack, Jones, & Maltby, 2018). Additionally, remote teaching was still relatively new at the time, and this might have impacted the level at which students absorbed the information. Assessing these aspects and their impact on intervention effects would be a fruitful venue for future research.

A second basis for comparison is the larger literature on mindfulness interventions. Eberth and Sedlmeier (2012) report the average effect of mindfulness meditation studies, including traditional MBSR programs. Effects from my study are on par with those for MBSR for mindfulness ($d = 0.64$ vs. 0.62, resp.) and positive affect ($d = 0.72$ vs. 0.60), but lower for negative affect ($d = 0.45$ vs. 0.69), anxiety ($d = 0.37$ vs. 0.64), and wellbeing ($d = 0.37$ vs. 0.80). Note, however, that MBSR programs are eight weeks long, and require about three times as much formal home practice as Koru. On that basis alone, MBSR might be expected to lead to stronger effects. It is also important to note again the differences between the time and historical context in which these studies were done: The semester culminated in a worsening pandemic and a contentious election. These factors could have led to more intervention-resistant negative affect, anxiety, and well-being.

Generally, then, it appears that Koru as implemented here is an effective way to boost mindfulness and positive affect. The intervention loses some of its effectiveness compared to in-person Koru but still yields still significant results in the areas of stress reduction, anxiety/negative affect, and selected aspects of wellbeing, but failed to deliver significant effects on depression, some aspects of psychological wellbeing, and sleep quality. The study also found effects for Koru that were not previously investigated, namely positive effects on both worry and rumination, and on physical activity. The effects on worry and rumination are particularly noteworthy here, because these variables are known to meditate the effects of mindfulness interventions on mental health outcomes (for a meta-analysis, see Gu et al., 2015). I return to this below when discussing mediation in the day-to-day measures.

It is not immediately clear why there are no effects on sleep quality, given that these effects were found in both previous Koru studies. It is possible that the prolonged effect of the pandemic,

where people might have created or slipped into strong habits concerning bedtime and bedtime routines might be to blame.

The limited effects on psychological wellbeing, with three not showing significant effects (viz., Personal growth, Positive relationships, and Purpose in life) are somewhat puzzling. A first reason might simply be time spent in training and/or practice: MBSR increases wellbeing with an average effects size about twice as large as what I obtained here, but it is also a longer and more intensive intervention. Relatedly, it might be the case that effects of mindfulness training are staggered, with some aspects of the psychological system benefitting earlier than others (e.g., changes in mindfulness precede changes in affect; Snippe, Nylíček, Schroevers, & Bos, 2015); perhaps psychological wellbeing, specifically changes in eudemonic well-being seems less likely to occur during such a short intervention or rather they might appear late in the chain of expected effects. A third reason might be the content of the intervention. MBSR has a uniquely large effect of wellbeing compared to other interventions (Eberth & Sedlmeier, 2012). The reason is likely MBSR's explicit emphasis on teaching participants "to take care of [them]selves and flourish, how to relate to [them]selves and others more effectively and what it might be like to nourish behaviors and activities that express [their] innate capacity for wellbeing" (Santorelli, Meleo-Meyer, Koerbel, & Kabat-Zinn, 2017, p. 8). In contrast, Koru does not explicitly stress wellbeing, but rather focuses on the more proximal goal of providing tools to reduce stress and anxiety.

Day-to-day state changes

This study is the first to collect data on day-to-day changes in multiple outcomes over the course of a mindfulness intervention. Remote Koru was an effective way to boost mindfulness and sleep and reduce rumination. These effects were linear, suggesting a simple dose-response relationship in the sequencing of effects. This is important to note because previous research has

found lift-off effects in rates of change over time in contrast to mine (Andreotti et al., 2018; Baer et al., 2012; Bergen-Cico et al., 2013). The intervention, however, did not yield significant day-to-day changes in the areas of stress, depression, wellbeing, and physical activity. Two of these null effects are surprising when compared to the existing literature, specifically for depression and stress since Bergen-Cico et al (2013) did find effects on depression and stress. More importantly this lack of change in depression and stress did not match the effects of my pre-post data. I will return to this point in the section comparing pre-post data to EMA data. One major potential reason for the lack of effects on stress might be due to the instrument of measure used to collect data because I only asked how many stressors they had encountered that day rather than probing for perceived stress. Future research should use perceived stress to evaluate effect on stress and converge results with existing literature (Baer et al., 2012; Bergen-Cico et al., 2013). Alternatively, the results on well-being and physical activity were less surprising and more interesting. Well-being and physical activity have never been research in this kind of intensive longitudinal manner during any mindfulness intervention. What was surprising was the discrepancy between well-being and physical activity's null day-to-day findings in comparison to significant pre-post findings. I will return to this in the next section.

It is important to note that the intervention group exhibited significantly less variability in the number of stressors than the control group day to day as reported by the F-test reported previously. Because the data for both the control and intervention group were collected within the same semester within the same school, it is likely that both groups experienced similar amounts of stressors over the course of the study. The implication is that the mindfulness intervention somehow smoothed out the peaks and valleys of the normal stressor experience. One possibility is that participants have learned to subjectively label their experiences as stressors less often than the

participants in the control group do, thus notably reporting fewer peaks in the number of stressors per day, see Figure 5.

It is also noteworthy that for two of the EMA variables, sleep and physical activity, the autocorrelation model did not fit better than the model without autocorrelation. It is important to note that these variables are the only two physiological and non-psychological variables that I collected data on. One possible reason for these results might be that data on these variables were collected only once a day (morning and evening, respectively), whereas all other variables were collected three times per day. Therefore, if participants missed the particular survey that contained these variables, the data for that day would be missing, possibly decreasing autocorrelation because of the longer delay. To investigate the validity of this possible explanation, I re-analyzed that data, including only participants that had no missing data ($n = 8$). Even in this case, the model specifying autocorrelation fit not better than the model without autocorrelation, but sample size was likely too small to provide sufficient power. A second potential reason could be the reality of the pandemic, where sleep habits and physical activity were more unpredictable across time, due to gyms not being open and students working longer hours and alternating their sleep schedules. It is important to note that significant change still did occur in sleep quantity in the intervention compared to the control group.

Comparison of pre-post and day-to-day findings

In comparing pre-post and EMA data, both analyses found significantly larger improvements in mindfulness measures and rumination in the intervention group compared to the control group. This is important because it is known that rumination is a key maladaptive contributor of depression and anxiety, thus altering rumination by just being mindful of a ruminative thought pattern can help to shield individuals from depression and anxiety (Godfrin &

Heeringen, 2010; Greeson et al., 2014; Gu et al., 2015; Lin & Mai, 2016; Mayer, Polak, & Remmerswall, 2019).

One puzzling discrepancy between the EMA data and pre-post change data concerns the results on sleep, where I found effects in the day-to-day data, but no significant pre-post change on sleep quality. One possible reason is the lack of conceptual overlap in the measures – the Pittsburg Sleep Quality Index (PSQI) measures sleep quality, as opposed to the daily surveys, which only collected number of hours slept. This is unlikely, however, given that there was no group by time interaction for the pre-post data when only the number hours slept is used for the PSQI. Another possible reason is memory lapses: Students might either under or overestimate their time asleep when reflecting back over the course of a month. Thus, it is possible that pre-post data does not show improvements due to memory lapses, so EMA would most likely be the most accurate way to investigate sleep improvements. Note, however, that in the two previous Koru studies sleep quality did produce a significant group by time interaction.

The results on psychological well-being were also puzzling. The daily surveys showed no change in psychological well-being over time, but my pre-post-test analysis show significant effects on three subscales (viz., Environmental Mastery, Autonomy, and Self-Acceptance) while the other three subscales do not show significant effects (viz., Personal growth, Positive relationships, and Purpose in life). The most plausible reason is that the PWB questions in the daily surveys arguably relate mostly to Purpose in Life, Positive Relationships, and Personal Growth, which were the PWB subscales that were not significant in the pre-posttest comparison. To wit, a sample item from the EMA survey is "In the past several hours, I have led a purposeful and meaningful life" while a similar question in the Purpose in Life subscale from PWB is "I have a sense of direction and purpose in life."

A pair of noteworthy null effects in the comparison between EMA results and pre-post-test change results were those for stress and physical activity. The pre-post-test change was significant in these two variables, but the EMA data showed no significant change over time. One possible reason for this for my stress variable is that the EMA survey only probed whether the participant had encountered different kinds of stressors in the past few hours, while the stress variable in the pre-post was probing for levels of perceived stress over a period of a month. A future EMA study should probe perceived stress levels as well as the number of encountered stressors per day. As for physical activity, it is possible that in the pre-post-test participants overestimated the amount of exercise they engaged in over the course of a month, whereas the day-to-day data, which reported over a period of 24 hours might be more accurate than averaging/reflecting over a few weeks.

Another noteworthy null effect, present in both EMA and pre-post data, is on depression. I'll note, first, that the pre-post effect size was positive ($d = 0.33$) and the associated p value (.081) was close to threshold, so this result may simply be due to a lack of statistical power, but when comparing depression scores in the EMA data, the associated p value (.562) was not close to threshold. I'll also note that pretest depression scores were quite elevated in the sample, possibly due to the ongoing pandemic – the average participant scored at the 83rd percentile on the DASS-21 norms for depression (Henry & Crawford, 2005). It is then possible that dysphoria levels in at least some of the participants were too high to be brought down without a more direct, professional, clinical intervention. Compatible with this interpretation, I found a correlation of -.57 between the level of depression at the onset of the program and the pre-post-test change over the five weeks of the intervention, suggesting that participants who started the study at a higher level of depression were more resistant to change. Supporting this, I found a correlation of -0.30 between the level of depression as measured by EMA at the onset of the program and the change over the 4 weeks.

Third, here too the relative short length of the intervention may be partially to blame. I did observe changes in both rumination and worry in pre-post and day-to-day change, variables notably related to depression, suggesting the possibility that effects on depression might either be achievable in a longer intervention or become apparent in follow-up assessments.

The null-effect on depression highlights a broader issue. Generally, with many of the measures of psychological functioning -- PWB, depression, rumination/worry, and stress – the correlations between initial scores and change over time suggest that individuals at the lower levels of functioning benefit less. This, in turn, suggests that Koru is not as effective at the low ends of the distribution, either because mindfulness in general or Koru in particular is less apt at improving possibly clinical levels of depression, stress, and so on, or because four weeks is not enough to engender such change, or both. This is not a rule in general, however: For sleep, physical activity, positive mood, and practice quality, individuals with lower scores at the onset showed greater improvement. This suggests that Koru might be better at building a resilience shield and alleviating mild symptoms than improving severe symptoms. This idea is supported by Galante et al. (2020), who found that a 8-week mindfulness intervention administered to students without mental illness or crisis built resilience to stress for at least one year after the intervention. Future research should perform follow-up studies to further investigate this idea.

Finally, there was no correlation between changes in state mindfulness as measured by EMA and changes in trait mindfulness from pretest to posttest, even though both sets of measures showed significant group by time interactions favoring the intervention. The simplest explanation for this is the low conceptual overlap between the state and trait mindfulness constructs as exemplified by the lack of significant correlations at pretest. A similar lack of correlations between my measure of state mindfulness, the TMS, and two measures of trait mindfulness was found in Thompson and

Waltz (2007) in a group of beginning meditators. The question remains whether this is a substantive finding, that is, whether trait mindfulness is fundamentally different from state mindfulness, or whether it is a matter of the specific wording of items or of the specific concepts probed. Future research should look at potentially using a trait version of the TMS measure or, alternatively, a state measure of the FFMQ (or another trait measure of choice) to investigate if there is a relationship between state and trait mindfulness within the same scaled measure.

Mediation Analysis on Day-to-Day Change

In my investigation of mediators among EMA variables, the simplest summary of my findings is that rumination was a significant mediator between both mindfulness subscales and all three outcome variables, and that exercise was only a significant mediator in the pathways from Curiosity to depression and well-being. Sleep was not a significant mediator for any mindfulness to outcome variable pathway.

Rumination as a mediator

Rumination significantly mediated the relationship between both aspects of mindfulness to stress, well-being, and depression. The percentages of variance explained in the outcomes were significant and substantial, ranging from 25% to 98%, with three of the six analyses showing complete mediation, suggesting that rumination is a powerful explanatory mechanism indeed. The percentage of variance mediated was largest for the number of stressors, then for depression, then for well-being. This is not surprising, as many studies conducting pre-post studies have found that rumination mediates changes in mental health outcomes (stress, well-being, depression; Gu et al., 2015), Those studies, however, have all used pre-post designs; mine is the first to verify these results over the day-to-day course of an intervention.

Interestingly, Curiosity and Decentering did not have a significant total or direct effect on stress. This might be due to the measure of stress included, namely the number of stressors experienced throughout the day, rather than the level of perceived stress. Future studies should integrate the perceived stress scale into the EMA format to make this measure compatible with the usual pre-post measures of stress. Interestingly, group moderated the direct effect pathways from Decentering to well-being and depression. This means that going through the mindfulness intervention increased Decentering's relationship to well-being and depression directly, rather than through rumination. Interestingly the intervention did not alter the mediating pathway, but rather the direct pathway. This suggests that the mediating pathway of rumination is not influenced by the intervention. One possible explanation for the augmentation of the direct path could be that there is a second mediator between Decentering and well-being and depression that was not measured. Some possible variables responsible could be nonspecific intervention factors, such as group processes, teacher trust, or likeability.

The intervention did not create a significant moderating effect for Curiosity on well-being and depression. Interestingly, moderation was significant in the pathways from Decentering to depression and well-being. It is important to note that the analysis using stressor count as the outcome did not yield significant moderation by group. Generally, then, the mindfulness intervention operated through the standard mechanisms that connect mindfulness to the mediators and the outcomes, and in some instances, the direct pathway from mindfulness to outcome was strengthened through the intervention.

Physical Activity as a mediator

Physical activity was a significant mediator only for the relationships between Curiosity and depression and well-being. The percentages of variance explained in the outcomes were

small—4% to 8%. The moderating effect of group was significant for the direct effect pathway for Curiosity on well-being. This means that the mindfulness intervention created a stronger relationship between Curiosity and well-being that was not accounted for by changes in physical activity. Meanwhile, the direct effect of Curiosity on depression was not moderated by group. This might suggest that there is a second meditating variable that accounts for the change in well-being from Curiosity, such as group processes, teacher trust/likability and the like.

One thought as to why Decentering had no effects on well-being and depression via physical activity might be that decentering or dissociating from unpleasant physical or psychological sensations during physical activity helps to prolong and improve exercise, but at higher intensities dissociating becomes much more difficult to maintain. For example, music can be a distractor during lower intensity workouts but at higher intensities physical pain or exertion becomes much harder to ignore. Hutchinson & Karageorghis (2013) and Hutchinson & Sherman (2014) state that an alternative to sustain and improve higher intensity exercise is to be curious and open to the experience, which can override negative associations with physical activity and boost pleasurable experiences thus increasing physical activity. Thus, Curiosity might be a stronger driving force to increase physical activity at all levels of physical activity, at least in this sample. Future research should look to investigate the level of perceived intensity of exercise to see if there is any relationship between Curiosity versus Decentering.

Sleep as a mediator

Sleep was not found to be a significant mediator, simply because it did not correlate with mindfulness. Moreover, changes in sleep did not correlate with changes in well-being, stress, or depression. This finding is important because it rules out sleep as a mediator of change between mindfulness and its outcomes. Additionally, research has found that increasing meditation hours

actually decreases the need for sleep and therefore increasing sleep might not be a viable driving factor for change in outcome variables (Kaul et al., 2010).

Lagged Analysis

In my lagged analysis I found that higher Decentering scores lead to lower rumination scores up to two days later, but the beneficial effects of rumination scores on stressor count, depression, and high well-being only operate within the same day. Curiosity predicted rumination scores up to three days later, but, as for Decentering, the meditation effect of rumination was only significant for well-being as measured on the same day. These results are the first of their kind, and they suggest that the continual buildup of high mindfulness scores leads to continual maintenance of low rumination and thus impacts mental health outcomes. This supports and extends the results in the current literature using EMA, particularly a meta-analysis by Enkema et al (2020) finding that increasing mindfulness decreases rumination and depression and increases positive affect, and a recent RCT by Bai et al (2020) finding that a mindfulness intervention reduced rumination on days with high amounts of stressors. Where this literature shows within-day effects of mindfulness on rumination, and of rumination on mental health outcomes, my study extends these finding by showing that mindfulness can predict across-day rumination as well. Because of the time lag, the present findings provide strong evidence for causality.

One mechanism of this cycle is outlined in an EMA study by Andreotti et al (2018), who report that a 6-week mindfulness intervention requiring 20 minutes of meditation a day showed rapid decreases in rumination during the first week, stabilization of low rumination from days 10-30, and further declines of rumination after 30 days of practice. These changes in rumination were due to increases in mindfulness and steady meditation practice, which then led to beneficial changes in distress. My results, although linear in nature, additionally show that the effects of

mindfulness on rumination and mental health last for a few days. A further implication would be that maintaining high mindfulness every few days could lead to a continual preservation in low rumination and thus result in a continuous effect on mental health outcomes. Future research should investigate the dose of meditation or mindfulness practices needed to maintain beneficial levels of state mindfulness in order to keep rumination low.

In contrast, the Curiosity to physical activity link was more restricted in time, extending only within a day. Additionally, this suggests that physical activity might not be a long-term mediator of change in outcome variables, but rather a more immediate effector of change.

Taken together, the results show that daily mindfulness is a predictor of change in daily rumination. This further supports the idea of rumination as a mediator for mental health outcomes. These results also demonstrate clear within-person day-to-day mechanisms that otherwise are inferred through between-person pre-posttest analyses in previous research. Lastly, as supported by Enkema et al. (2020), this research shows that longitudinal assessment is a more sensitive and valid tool to chart the time course of changes in mindfulness, rumination, and mental health outcomes and to more concretely infer mediation and the time scales at which it operates.

Mediation Analysis of Formal and Informal Practice Quality

The simplest summary of my findings concerning informal or formal practice quality is that self-rated practice quality did not effect changes in either aspect of mindfulness. At first blush this may seem surprising. On the other hand, meditation teachers in general (Thanissaro, 2008), as well as the Koru handbook in particular (Rogers & Maytan, 2019) do not encourage rating and judging one's practice, instead pointing out that practice can be beneficial regardless of the practitioner's own feelings and judgments about it.

Limitations

This study has obvious limitations. It was conducted within a single institution, using a single mindfulness intervention approach. The sample was predominantly White and female. The results are also almost certainly tinged by the reality of the pandemic, and so might not generalize to in-person or remote delivery of the Koru curriculum (or other mindfulness curricula) in more normal circumstances. More specifically, the pandemic might explain some of my null effects, for example for sleep quality the pandemic resulted in less opportunity for social gatherings which might have impacted sleep quality and quantity more positively since on average participants started with around 7.5 hours of sleep a night at pre-test, therefore the pandemic might have created strong sleep habits before the intervention even began. Additionally, physical activity's null effect can also be possibly explained by the pandemic since gyms were not open and the ability to engage in exercise might have impacted how much and how consistently they could exercise. Another limitation was the fact that anxiety was inadvertently left off of the EMA surveys so no conclusion can be made regarding changes in anxiety day-to-day. Stress was also measured in two different and seemingly not conceptually overlapping ways between the pre-post-test and day-to-day change, complicating data analyses on day-to-day change. Also, the state mindfulness measure did not relate to the trait mindfulness measures, limiting the generalizability of the findings. Furthermore, the intervention strengthened the direct pathways from Decentering to well-being and depression, possibly due to changes in a mechanism that was not measured in this study and would be important to research in further studies. Lastly, with any study that relies heavily on self-report questionnaires there is always a concern for demand characteristics that might be at play, but because I found a simple dose-response relationship in the sequencing of effects in the

intervention group and found a mediating pathway that exists regardless of going through the intervention or not this possibility seems like less of a reality.

Summary of findings

Summarized, the findings show that Koru was effective in improving mindfulness, rumination, worry, mood, stress, anxiety, three aspects of psychological wellbeing (Autonomy, Environmental Mastery, and Self-acceptance), and physical activity in my pre-post analysis. It was less effective compared to the two previously published studies on Koru, which most likely can be attributed to the effects of the pandemic. Koru was also effective in improving mindfulness, rumination, and sleep in my EMA analysis. Additionally, rumination was found to be a significant mediator between both mindfulness subscales and all three outcome variables. Furthermore, the effect of Curiosity on rumination was significant with a lag of three days; the effect of Decentering was detectable over two days. The effects of rumination on stressor count, depression, and wellbeing, however, did not extend beyond the same day. Exercise was only a significant mediator in the pathways from Curiosity to depression and well-being and did not extend beyond the same day. Sleep was not a significant mediator for any mindfulness to outcome variable pathway. Lastly, practice quality, both formal and informal, did not drive changes in mindfulness and did not attribute to changes in the pathway proposed. The results thus suggest that rumination is the main driving factor of change in the present intervention. Finally, it is important to note that one of Koru's distinguishing characteristics is the deliberately low length/time commitment, which makes the intervention feasible for use in a college student population. At the same time, this turns the intervention more into a means to provide students with skills to cope with stress and anxiety as they arise, rather than as a treatment for mental health problems (unlike longer, more focused programs such as Mindfulness-Based Cognitive Therapy). Koru seems, at least in this study, to

promote positive change both in state and trait measures but might be less effective at effecting clinical improvement.

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