Analysis Plan for Digital Mindfulness Project (Fall 2026)

- **Research questions and hypotheses**
    - **Primary research question:** Can an eight-week digital mindfulness-based program (MBP) improve the mental health of college students with mild to severe symptoms of depression and anxiety in China?
        - H1 (alternative hypothesis): Students in the digital MBP condition will show significantly greater improvement in depression symptoms, anxiety symptoms, and perceived stress compared to the waitlist control condition.
        - H0 (null hypothesis): There will be no significant difference in the change in depression symptoms, anxiety symptoms, and perceived stress between the digital MBP condition and the waitlist control condition.
- **Primary variables of interest**
    - **Depression:** PHQ-9 (Patient Health Questionnaire-9). In line with scoring guidelines, we will sum responses to the nine questions, each rated 0 (not at all) to 3 (nearly every day), for a total score of 0-27. We will use this continuous outcome in the primary analyses, with higher scores indicating greater depression severity (e.g., 5-9 mild, 10-14 moderate, 15-19 moderately severe, 20-27 severe). These data will be collected at baseline, biweekly during the intervention, immediately post-intervention, three months post-intervention, six months post-intervention, and post-graduation.
    - **Anxiety:** GAD-7 (Generalized Anxiety Disorder-7). In line with scoring guidelines, we will sum responses to the seven questions, each rated 0 (not at all) to 3 (nearly every day), for a total score of 0-21. We will use this continuous

outcome in the primary analyses, with higher scores indicating greater anxiety severity (e.g., 5-9 mild, 10-14 moderate, 15-21 severe). These data will be collected at baseline, biweekly during the intervention, and immediately post-intervention, three months post-intervention, six months post-intervention, and post-graduation.

- **Perceived stress:** PSS-10 (Perceived stress scale-10). In line with scoring guidelines, we will sum responses to the ten questions, each rated 0 (never) to 4 (very often). We will use this continuous outcome in the primary analyses, with higher scores indicating greater perceived stress. These data will be collected at baseline, biweekly during the intervention, and immediately post-intervention, three months post-intervention, six months post-intervention, and post-graduation.
- **Practice time:** In weekly surveys, we will ask students in the treatment group which days they had practiced and on average how much they practiced on those days. For each participant, we then multiply the number of days practiced by the average practice time to obtain their weekly practice time outside of class for that week. In addition, we also ask whether students in the treatment group had attended the 90-minute class during the previous week, and we also include this as a part of their total weekly practice time. We focus on the treatment arm for within-person dose–response. We will also check whether students in the control group report any mindfulness-like practice during the intervention.

- **Statistical analysis plan:**

Means and standard deviations will be calculated for all continuous variables. Frequencies and percentages will be calculated for all categorical variables. Balance tests

will be performed between the treatment and control group, as well as between attrited and non-attrited students. Since the randomization is at the individual level, we use robust standard errors.

To obtain estimates of the effect of participation in the mindfulness program on the entire sample, we calculate the intention to treat (ITT) effect of the program on those assigned to the treatment, regardless of their take-up or engagement in the program. To do this, we regress the outcome on treatment assignment for the whole sample using analysis of covariance (ANCOVA). The model is specified as follows:

$$Y_{i,\text{post}} = \beta_0 + \beta_1 T_i + \beta_2 Y_{i,\text{pre}} + \mathrm{X}_i'\gamma + \epsilon_i$$

where $Y_{i,\text{post}}$ is the outcome variable for individual *i* measured at post intervention; T_i is the treatment assignment indicator (1=treatment, 0=control); $Y_{i,\text{pre}}$ is the baseline measure of the continuous mental health outcome (depression or anxiety) for individual *i*; X_i' is a vector of other baseline covariates for individual *i*; γ is a vector of coefficients corresponding to the covariates in X_i'; and β_1 is the main coefficient of interest, estimating the average difference in the post-treatment outcome between the treatment and control groups, while holding the baseline outcome and other covariates constant.

In this study, we also seek to understand the effect of the intervention on those with higher levels of compliance to the intervention protocol (i.e., the effect of engaging in the mindfulness program through individual outside of practice as opposed to simple random assignment to it). To do this, we estimate the Local Average Treatment Effect (LATE). To address potential endogeneity, we employ a two-stage least squares (2SLS) instrumental variable (IV) strategy, using the initial random assignment to the treatment group (T_i) as a valid

instrument for the treatment receipt (D_i). Here, we define treatment receipt as completing at least 50% of the weekly modules (four out of eight) and engaging in formal mindfulness practice for at least 25% of the total suggested time (180 minutes per week * 0.25 = 45 minutes per week). The model is specified as follows:

$$D_i = \alpha_0 + \alpha_1 T_i + \alpha_2 Y_{i,\text{pre}} + \mathrm{X}_i'\delta + u_i$$

where D_i is an indicator variable equal to 1 if individual *i* received the treatment and 0 otherwise; T_i is the instrument, equal to 1 if individual *i* was assigned to the treatment group and 0 otherwise; $Y_{i,\text{pre}}$ is the baseline measure of the outcome; X_i' is a vector of other baseline covariates; and α_1 is the key first-stage coefficient, representing the effect of assignment on receipt.

The second stage equation, which regresses the outcome on the predicted values of treatment receipt, is as follows:

$$Y_{i,\text{post}} = \beta_0 + \beta_1^{\text{LATE}} \widehat{D}_i + \beta_2 Y_{i,\text{pre}} + \mathrm{X}_i'\gamma + \epsilon_i$$

where $Y_{i,\text{post}}$ is the outcome variable for individual *i* measured after the intervention, $\widehat{D}_i$ is the *predicted* value of treatment receipt for individual *i*, and β_1^{LATE} is the Local Average Treatment Effect (LATE) (the primary coefficient of interest).

- **Attrition and missing data**

We define attrition as non-participation at the time of the post-intervention survey. For survey attrition, we do not impute missing data. However, we will check whether there is a correlation with treatment status. If so, we will construct robust bounds for the treatment estimates (e.g., Lee bounds).

For item missing data in PHQ-9/GAD-7, we remove the score if more than 20% of the data on that scale are missing. As with attrition, we also check whether there is a correlation between the missing items and treatment status. If 20% or less of the data are missing, we impute the mean score of the other responses for that individual.

- **Multiple outcomes/hypotheses**

To address the testing of multiple outcomes (anxiety and depression), we apply the Bonferroni correction. To do this, we divide the original alpha by the number of comparisons (i.e., 0.05 / 3 tests = 0.0167).

- **Heterogeneity**

We conduct moderation analyses of the treatment effect on depression and anxiety symptoms. We will test for heterogeneous treatment effects by estimating an Ordinary Least Squares (OLS) regression model that includes an interaction term between the treatment indicator and the subgroup variable. The model that we use for this is the following:

$$Y = \beta_0 + \beta_1 * \text{Treatment} + \beta_2 * \text{Subgroup} + \beta_3 * (\text{Treatment} * \text{Subgroup}) + \text{Covariates} + \varepsilon$$

The potential moderators that we investigate in this analysis include the following:

- Baseline anxiety symptom severity: We include this as a continuous mean score on the GAD-7.
- Baseline depression symptom severity: We include this as a continuous mean score on the PHQ-9.
- Gender: We include this as a binary variable (1=female, 0=male)

- Childhood residence (*hukou*): we include this as a binary variable (1=urban, 0=rural)