

# Get Your Head Together: Designing an Adaptive Digital Intervention to Improve Students' Emotion Regulation.

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## Abstract

This project aims to design an AI-based intervention that improves students' ability to regulate their emotions, and adapts to their personality and experienced stressors. Students increasingly suffer from stress, anxiety, depression and burnout. Therapy waiting times have increased, which may discourage help-seeking. Additional support can be provided by digital interventions during waiting times, but also to prevent mental health issues from developing. Our planned intervention will use mindfulness practices, which are known to reduce stress and prevent the development of mental illnesses. This paper describes studies to inform the intervention's design. First, common stressors among students were collected and stressor categories validated. Second, a user-as-wizard study was performed with a mindfulness expert and students investigating how to adapt the choice of mindfulness exercises to stressors and personality. Finally, the perceived effectiveness of the adaptive exercise selection was evaluated with students, and a final adaptive algorithm proposed based on the results.

## Keywords

Personalization, Mindfulness, Emotion regulation, Personality, Stress

## 1. Introduction

As has become increasingly apparent in the media, students are struggling with mental health issues [4,17,22]. An increasing number of students report suffering from stress, anxiety, depression and burn-out, increasing the workload of mental health professionals [60,47]. Stress often derives from the lifestyle changes a student goes through, such as new sleeping and eating habits, increased class workload, financial difficulties, or new social activities [51]. Poor stress management and long-term stress exposure have a major impact on physical and mental wellbeing, influencing brain development [3,49,35,36], cardiovascular activity [63,14,31,30], the reproductive system [39,12], bodyweight [48] and sleep rhythms [52,1]. Additionally, stress can be a significant factor in developing mental illnesses [45,34,18,27,7]. The conventional solution to tackle stress-related mental health issues is to contact a therapist. However, the average waiting time for a therapist in the Netherlands is currently between six to eight weeks (GGZ Nederland, 2018). The decision to seek help from a therapist is often a challenge for people in distress; a long waiting time could further discourage them from even trying. Technology may provide a possible solution to this problem.

An adaptive e-coach could support students in this new phase of their life, helping to lessen the problems students encounter, providing extra support during the waiting time, or even preventing issues from developing. Several digital interventions have already been proposed, but they often focus on providing therapy exercises via a digital medium without adapting to an individual's unique characteristics and stress response. This paper aims to design an artificial intelligence (AI) intervention to support students in need by providing personalized advice on dealing with stress through mindfulness exercises. We envisage that this intervention will base its adaptive suggestions on the user's personality traits and the source of stress experienced.

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## 2. Related Work

Digital interventions have been shown to effectively support people suffering from mental health issues [66,64]. Examples of evidence-based digital interventions include IntelliCare Hub, an app suite containing 14 apps focused on treating depression and anxiety [41], and SPARX, a game-based intervention that uses cognitive behavioural therapy practices to treat stress, anxiety, and depression [40]. Both interventions effectively reduced symptoms of depression and anxiety in users [41,40]. However, these examples focus on providing therapy exercises through a digital medium, but do not adapt to user personality or stressors experienced. A digital intervention that automatically adapts to the person using it - just like a therapist would adapt to their patient - is something that has become a topic of interest only recently. Such an intervention could automatically provide customized advice based on the user characteristics and context (cf. adaptive systems [6]).

An example of an adaptive system for mental well-being can be found in the work of [8–10], who designed a serious game for improving students' well-being by promoting positive activities such as showing kindness and promoting gratitude. In particular, they investigated in [9] how persuasive messages should be adapted to personality types to influence engagement in positive activities, and in [10] the actual effectiveness of adapting persuasive messages to personality.

In a similar fashion, we aim to create an AI intervention that adapts to students' personalities and stressors to provide the best mindfulness advice. We envisage that it is fundamental to consider the individual's unique response to stress and the characteristics of the situation to provide the best advice. The individual's response to stress is indeed closely related to one's personality: different types of personalities use different coping strategies when experiencing stress [65,13,38,65,43]. Most personality-related research uses the Big Five: a model consisting of five personality dimensions that a person belongs to a greater or lesser extent: Neuroticism, Extraversion, Agreeableness, Openness, and Conscientiousness [38,43]. This research will focus on Neuroticism and Conscientiousness, since these are the strongest predictors of stress coping styles [65,33].

Next to personality, the intervention will adapt based on the source of stress that students experience. What activates the process and feeling of stress can be defined as a stressor [53]. Stressors can vary in type and demands according to the environment: they can be specific to an occupation, a climate, or the social and cultural environment. A general way to categorize them is by assigning them to a certain type of physical and psychological demands. An example of this categorization is the NASA-TLX, a scale that measures task workload by dividing the task demands into six workload components: physical demand, temporal demand, mental demand, effort, frustration, and performance [19]. [29] investigated how a virtual agent can alleviate stress for community first aid responders by adapting emotional support messages to the stressors they encounter. Similarly, [56] investigated how a virtual agent can alleviate stress for informal carers, by adapting emotional support messages to the carer's personality and stressors experienced. Their validation of stressors resulted in seven stressor categories [58], that will be used in this paper to categorize stressors experienced by students<sup>1</sup>:

- *Physical demand*: any physical activity that is demanded of a person. This can become a stressor if, for example, one must cycle to work but it is very slippery outside due to sudden snowfall.
- *Mental demand*: any kind of mental activity that demands a lot of thinking. This can become a stressor if, for example, a student is partaking in a difficult test for which they must think very hard about the questions.
- *Temporal demand*: any kind of time-related demand. An example of a stressor related to this demand could be time pressure.

- *Emotional demand*: any kind of emotion that is demanded in a certain situation. For example, if a student partakes in a social activity with friends, it is demanded (or expected) of them to be happy and excited.
- *Frustration*: the feeling of frustration or annoyance that happens due to an activity. For example, planning to visit a specific restaurant, which turns out to be closed.
- *Isolation*: the feeling of being alone and isolated from other people. For example, one can visit a party but still feel alone among all those people, because they do not know anyone.
- *Interruption*: when an interruption causes stress during an activity. For example, while concentrating hard on an exam, someone's phone rings which interrupts your concentration.

Once exposed to a stressor, a person's cognitive and behavioral efforts to manage the stressful situation are defined as coping strategies. Coping strategies aim at practically resolving the stressful situation (problem-focused coping) and dealing with the deriving negative emotions (emotion-focused coping or emotion regulation) [13]. Stress and emotion are indeed interdependent concepts: stressful situations can lead to anger, sadness, shame, guilt, jealousy, anxiety, envy, and fright [32]. These emotions tend to linger much longer, even after the practical resolution of the stressful situation [15], requiring emotion regulation processes. Emotion regulation strategies modify the emotional arousal, affecting the intensity and duration of the emotion, and they may require the intervention of others to help [62]. Many emotion regulation techniques exist [15,67,24,23,2]; some aim at preventing the emotional response linked to the stressful situation, while others are used when the emotional response is already activated [15,67]. Most cognitive and behavioral therapies focus on emotion regulation techniques that proved to have a positive impact on the mood and stress level of a person. In this research, we focus on the emotion regulation strategy of acceptance. Acceptance means to accept the emotions one experiences, without being judgemental about them. This approach is known to benefit a person's mood and stress levels [21,20], while low levels of acceptance show a higher probability of developing a mental illness [20]. A well-known and well-researched acceptance technique is mindfulness. Mindfulness represents the core of Buddhist meditation [26], and can be defined as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment"[26]. In the same way, one can observe their own emotions as an "external", non-judgemental observer, accepting them as a simple phenomenon of the mind and body. Many societies in Asia have been practising some form of mindfulness as part of their culture, but it was only around the 90s that was implemented into therapy with the therapy program Mindfulness-based Stress Reduction (MBSR) [26]. MBSR has proven to help regulate emotions, reduce stress symptoms and prevent the development of mental illnesses [5,44,59,50,16,54,55].

Our research aims to create an adaptive<sup>2</sup> intervention that recommends the right mindfulness exercise to students based on their personality and stressor experienced. The paper presents four studies to inform this intervention.

### 3. Studies to inform the selection of mindfulness exercises

To create the adaptive intervention, four studies were performed. Study 1 investigated the stressors experienced by Dutch students through focus groups. Study 2 validated the stressor categorization. Study 3 investigated how people adapt the selection of mindfulness exercises to personality and stressor experienced, and Study 4 the perceived effectiveness of the adaptive exercise selection.

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<sup>1</sup> Stressor descriptions have already been adapted here to the student domain, as the original authors' descriptions related to first responders and carers.

### 3.1. Study 1: Collecting stressors

To know what stressors Dutch students specifically experience and how to portray them, the most common stressors were collected through focus groups.

**Participants** 10 students participated, equally divided over two focus groups. All were aged 20-25 and identified themselves as female. They came from a wide range of different majors, such as Veterinary Science, Psychology, Creative Business, Sustainable Business, Social Work, Medical Science and so on.

**Method** The focus groups took place at the university and lasted about 30 minutes. Before starting, participants provided informed consent and answered demographic questions. The focus groups were recorded. The researcher shortly explained the stressor categories by [29], encouraging participants to come up with stressors that belonged to one of the categories, when possible. Seven titled sticky notes, one per category, were prepared and placed on the table with sufficient space in between; participants wrote down stressors and placed each next to the category it belonged to.

**Results** 60 stressors were collected: examples are shown in Table 1.

**Table 1**

**Study 1: Example of stressors collected in focus groups per category.**

Category	Stressors
Mental Demands	The feeling of not being good enough (either academically or personally), and thus trying harder to better myself.
Physical Demands	Feeling sick but still having to go to work or lectures, because you have to be able to pay for everything and get good grades.
Social-Emotional Demands	Having to act normally during the day while I had a fight with a friend/boyfriend that is bothering me.
Frustration	Receiving a bad grade, when you were expecting a good one.
Temporal Demands	The time pressure of deadlines.
Isolation	I sometimes feel more pressure because of my studies than other students seem to feel. That makes me feel lonely.
Interruption	If someone calls me when I am studying, it is very hard to get back to studying.

### 3.2. Study 2: Validation of Stressor Categories

The 60 stressors collected in Study 1 were assigned to the seven categories by the participants. In Study 2, this categorization was validated. The validation is needed to ensure that a stressor clearly represents one category only.

**Participants** 22 participants (5 were male, 17 female, mean age=24) were recruited from SurveySwap.io, a platform where users can post surveys to be completed, and complete surveys for others in return.

**Method** The stressors collected<sup>3</sup> in Study 1 were converted into a suitable writing style using the validation design of [29]. All stressors were converted into stories about a student named "John"<sup>2</sup>,

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<sup>2</sup> A male name was used as we will later combine the stressor stories with personality stories that had been validated with male names [57]. Whilst the stressors used originated from focus groups with female participants, they seem gender neutral.

in order to facilitate participants' feelings of empathy and relatedness with the story. Words that clearly portrayed to which category a stressor belongs were also eliminated and the category "emotional demand" was changed into "social-emotional demand", because of the social connotation of the stressors. The survey was made using Qualtrics. It started with general instructions about the task, followed by information about the different types of categories and by questions about age and gender (among "male", "female", "other", "prefer not to say"). Then, the 60 stressors were presented one at a time, and participants chose the category to which they thought the stressor belonged. An additional "Other" category was added, in case participants judged the stressor as not belonging to any category.

**Results** The Free-Marginal Kappa ( $\kappa$ ) was used to measure the agreement between participants who distribute cases across categories [46]. 17 stressors had an acceptable  $\kappa \geq 0.40$  (the value normally used [57]), meaning that participants mostly agreed upon the category to which these stressors belong. Only these stressors were used in the next part of the research. Every category had one or multiple stressors with a  $\kappa$  of 0.40 or above, except for Frustration; for this reason, Frustration was removed for the remainder of the research.

### 3.3. Study 3: How humans adapt mindfulness exercise selection

A user-as-wizard study [37,42] was conducted, in which a therapist and students decided which mindfulness exercise to recommend given the personality and stressor of a fictional student. A user-as-wizard method is particularly suitable when participants are good at the task normally performed by the system, here providing tailored advice. First, an expert opinion was obtained by interviewing a therapist. Next, a survey was done with students to determine what exercises they would advise for personality and stressor combinations. While students are typically not mindfulness experts, they are the intended recipients of the advice: any advice provided needs to be acceptable to them to increase adherence. Therefore, we decided to investigate the advice they felt appropriate in each situation to complement the therapist's views.

**Participants** We contacted many therapists to obtain expert interview participants. However, therapists are extremely busy, with very long waiting lists (which is actually one reason for our work). Ultimately, we obtained one in-depth interview with a therapist who had experience with both students and mindfulness. In addition, we recruited 40 students between 18 and 30 years old through SurveySwap.io, 20 for each personality trait.

**Method** A therapist with experience with students and MBSR mindfulness exercises was interviewed. The interview was planned as follows: explanation of the research and its goal; provision of informed consent; start of the actual interview, where stressors and personality traits would be presented in different combinations; collection of the therapist's advice for each combination. We planned that each personality would be paired with each stressor before moving on to the next personality, in order to let the therapist really "get to know the person in the story". Next to the personalities and stressors, a paper-based list of mindfulness exercises was provided. The therapist was asked to choose one of those exercises or propose another one that was not on the list. The main question was: "This student is experiencing the presented stressful situation. Which mindfulness exercise would you advise to this student, and why?".

For the study with students, a survey was created. It started with an introduction about the research, followed by an explanation of the mindfulness exercises and lastly by the actual survey questions. In each question, a personality story was displayed, followed by a stressful situation and by the question: "What mindfulness exercise would you advise [person] in this situation?"; the mindfulness exercises were displayed underneath the question. It was possible to choose only one exercise per question. Two versions were created, one for Neuroticism and one for Conscientiousness. In both cases the participants started with the six stressor stories combined with the low level of the trait, followed by the stressor stories combined with the high level, for a total of 12 stories.

**Stimuli** As mentioned above, we investigated the personality traits Neuroticism and Conscientiousness as they account for 40% and 29% of the variance of coping styles, respectively [65,33]. Neuroticism includes a tendency to experience anxiety, self-pity, tension, self-consciousness, irrational thinking, impulsivity, and hostility; Conscientiousness includes a tendency to be organized, reliable, selfdisciplined, efficient, rational, and deliberate [25]. Each personality trait was presented in a similar manner as the stressors in Study 2, following the methodology of [57]. Two stories were used for each personality trait, each containing a fictional character and describing an extreme of the personality trait (based on the ones validated in [57]). Table 2 shows the personality stories used<sup>3</sup>. In addition to personality traits, we used the highest-scoring stressors in each category from the 17 stressors validated in Study 2 (see Table 3).

The mindfulness exercises for this study were taken from the MBSR program [26], as presented in the workbook made by [61] in cooperation with Kabat-Zinn (see Table 4). Whilst all exercises were used as material in the interview of the therapist, a subset was selected for use in the student survey (the ones with abbreviations in Table 4). This choice was made to have a diverse exercise set and based on the interaction with the therapist, who noted the overlap between certain exercises (e.g. the "Mindful Check-In" and "STOP" exercises are essentially the same because they are both about taking a moment to reflect on the current state of mind and understanding the choices one has).

**Table 2**  
**Personality stories used in Studies 3 and 4 for Neuroticism (Neu) and Conscientiousness (Con), adapted from [57]**

Trait	Story
Neu	High James often feels sad and dislikes the way he is. He is often down in the dumps and suffers from frequent mood swings He is often filled with doubts about things and is easily threatened. He gets stressed out easily, fearing the worst. He panics easily and worries about things. James is quite a nice person who tends to enjoy talking with people and tends to do his work.
	Low Eric seldom feels sad and is comfortable with himself. He rarely gets irritated, is not easily bothered by things and he is relaxed most of the time. He is not easily frustrated and seldom gets angry with himself. He remains calm under pressure and rarely loses his composure.
Con	High Martin is always prepared. He gets tasks done right away, paying attention to detail. He makes plans and sticks to them and carries them out. He completes tasks successfully, doing things according to a plan. He is exacting in his work; he finishes what he starts. Martin is quite a nice person, tends to enjoy talking with people, and quite likes exploring new ideas.
	Low Martin is always prepared. He gets tasks done right away, paying attention to detail. He makes plans and sticks to them and carries them out. He completes tasks successfully, doing things according to a plan. He is exacting in his work; he finishes what he starts. Martin is quite a nice person, tends to enjoy talking with people, and quite likes exploring new ideas.

**Results:** Therapist's interview The interview took around 1.5 hours. The therapist first read through the list of mindfulness exercises, and then the first personality and stressor combination was presented. The first personality story described James, who scored high on Neuroticism. The therapist felt he needed help, regardless of the stressor. For this reason, the researcher presented also Eric's story, who scored low on Neuroticism, to encourage the therapist to easily distinguish between personalities and focus also on the stressors. The stressors were presented in the

<sup>3</sup> The students depicted are male as the stories were validated in [57] with male names. Whilst the stressors used came from focus groups with female participants, they seem gender neutral and were validated with male names into stressor categories.

following order: So-Em, Te, In, Me, isolation, Phy. Next, the two personality stories for Conscientiousness were presented next to each other, followed by the stressors in this order: So-Em, isolation, Te, Me. Due to time constraints, Phy and In were not presented; in both cases, the therapist had already noted that personality does not matter for the advice, so their advice for the neuroticism cases was used. The exercises advised are in Table 6.

The therapist provided detailed explanations about why a particular exercise may be particularly useful for a certain stressor or personality trait. For example, the therapist noted that for Temporal demand, Conscientiousness mattered, as this stressor is much related to procrastination and planning. The highly conscientious person is likely a perfectionist and much up in his head, especially with temporal demands. A BS would help by leading attention away from the brain towards the body. In contrast, for the lowly conscientious person HT may help to make him aware of his thoughts and (bad) habits.

**Table 3**  
**Stressors used in Studies 3 and 4, with abbreviation used later.**

Abbr.	Category	Stressor
Lo	Loneliness*	Because of the different courses every period, there are different people every time in lectures. That makes it really hard for John to get to know his fellow students, and makes him feel alone, even during lectures.
Phy	Physical demand	John is an intern at the hospital; he has to run around helping patients.
Me	Mental demand	John is going through difficult study material that is very hard to understand.
In	Interruption	While John is studying for his exam, his mother calls.
So-Em	Social-emotional demand	John feels he has to put up a nice smile and be cheer-ful during activities at his student association, even though he does not feel like it.
Te	Temporal demand	While John is studying for his exam, his mother calls.

\*Isolation was called Loneliness in later studies to better describe the related feelings.

For Social-emotional demand, the therapist felt a CI would be good independently of the Neuroticism level, as this stressor is related to ignoring one's true feelings. The CI takes one off the automated pilot (in this case still going to a party and acting all smiles whilst one feels bad) and makes them aware of their feelings and options (e.g. not going, going and showing how you truly feel, going and pretending to be happy). For the low neurotic person that would suffice, whilst for the highly neurotic person this could be followed by HT, to become aware of habits and thoughts and distance oneself from them.

Both examples illustrate that the therapist saw the need for adaptation to both stressors and personality traits. This was not always the case, as the therapist noted that personality wouldn't matter for the advice in Physical demand and Interruption. For example, an Interruption may make it hard to concentrate on the task again, so ML may help practice refocusing but may also help to become less irritated with what has interrupted your concentration (e.g. ML makes one aware of noises, yet also that they are just noises). Another exercise that might help is LK, allowing processing the interruption that just happened, what it does to you, and returning attention back to yourself and your task. Either one or both of these exercises can be done regardless of the student's personality.

<sup>4</sup> Though this is based on the opinion of just one therapist, it is backed up to some extent by a lack of interaction effect in the student data.

**Results:** Students' survey Figures 1 and 2 show how often each exercise was selected for the Neuroticism and Conscientiousness stories respectively, per stressor and personality level combination (a-f), per personality level over stressors combined (g), and per stressor over personality levels combined (h). Both for Neuroticism and Conscientiousness, a MANOVA was performed with "Stressor" and "Personality level" as independent variables and "Exercise" as dependent.

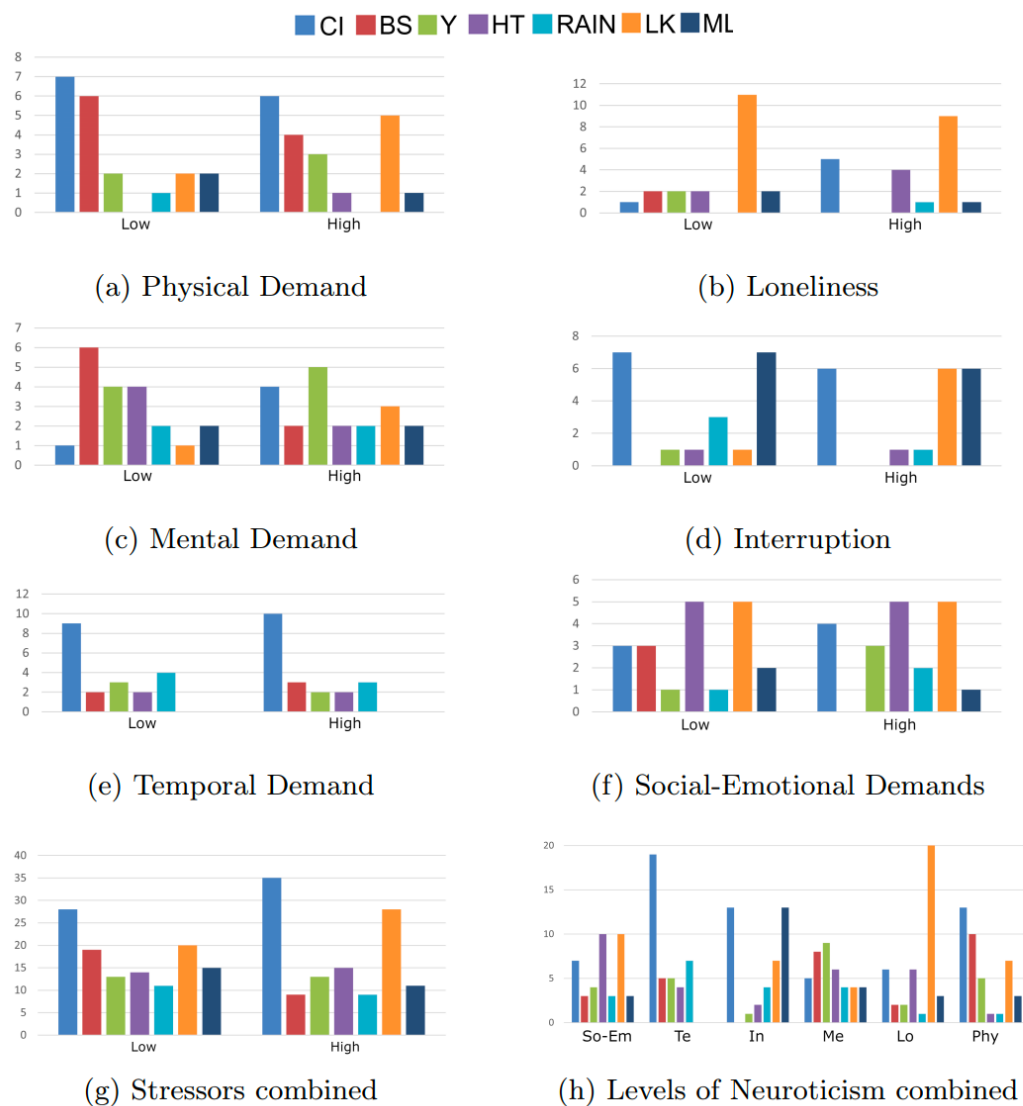
**Table 4**  
**Mindfulness exercises, adapted from [61], used in Study 3 with the therapist. Subset with abbreviations is used in Studies 3 and 4.**

Abbr.	Exercise	Description
	Mindful walking meditation	Not about getting from A to B, but focusing on the walking itself. Focusing on every step, breathing and your surroundings.
CI	Mindful check-in	A short, powerful practice that allows you to recognize how you are feeling physically, mentally, and emotionally and will help you recenter yourself in the present moment.
	STOP-exercise	Useful if you feel tense or upset to check in with yourself and notice thoughts and the body. S = Stop, T = Take a breath, O = Observe, P = Proceed.
BS	Body Scan	An exercise to become aware of the body and how it harbors stress and emotions. One 'scans' every part of the body separately.
	Sitting meditation	Becoming mindful of breathing, sensations, hearing, thoughts and emotions. Increases overall awareness of the present. Meditation can be done in either 15 minutes, 30 minutes or 45 minutes.
Y	Mindful yoga	While John is studying for his exam, his mother calls.
HT	Being mindful of habits and thoughts*	Writing down habits and thoughts to become mindful of them and whether they benefit your or not. This shows you literally the choices you have.
RAIN	RAIN-exercise	Specifically meant for sudden anxiety (or anxiety attack) and stress. R: recognize the strong emotion that is present. A: Allow or acknowledge that it is there. I: Investigate the body, emotions and thoughts. N: Nonidentify whatever is there (understand that these strong emotions are just another passing mind state and not a definition of who you are).
LK	Loving-kindness meditation	Opening the heart to love, compassion and empathy. First bring this love and compassion to yourself. After directing love and compassion toward yourself, you extend it outward, first to those who are easy to love, such as benefactors, mentors, teachers, and others who have guided or inspired you.
ML	Mindful listening	When someone is speaking to you, see if you can pay attention and not interrupt until the other person is completely finished speaking. Notice when your mind begins to wander off, thinking about what you need to do later that day, some grievance from the past, the brilliant counterargument that you want to make, or wherever else it may go. When this happens, just become aware of it, then intentionally bring your attention back to listening.
	Identify habitual patterns in	This helps to become aware of the way we behave in certain relationships. For example, if you notice yourself falling into victim

current relationships	behavior frequently with a specific person, write about how those interactions happen.
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\*Changed to include thoughts as well as habits on the therapist's advice.

Impact of stressor. Figures 1h and 2h clearly show an impact of stressor on the exercises selected. There were statistically significant differences in the use of CI, HT, LK, and ML exercises for the Conscientiousness stories<sup>5</sup>, and for all except RAIN for the Neuroticism stories<sup>6</sup>.



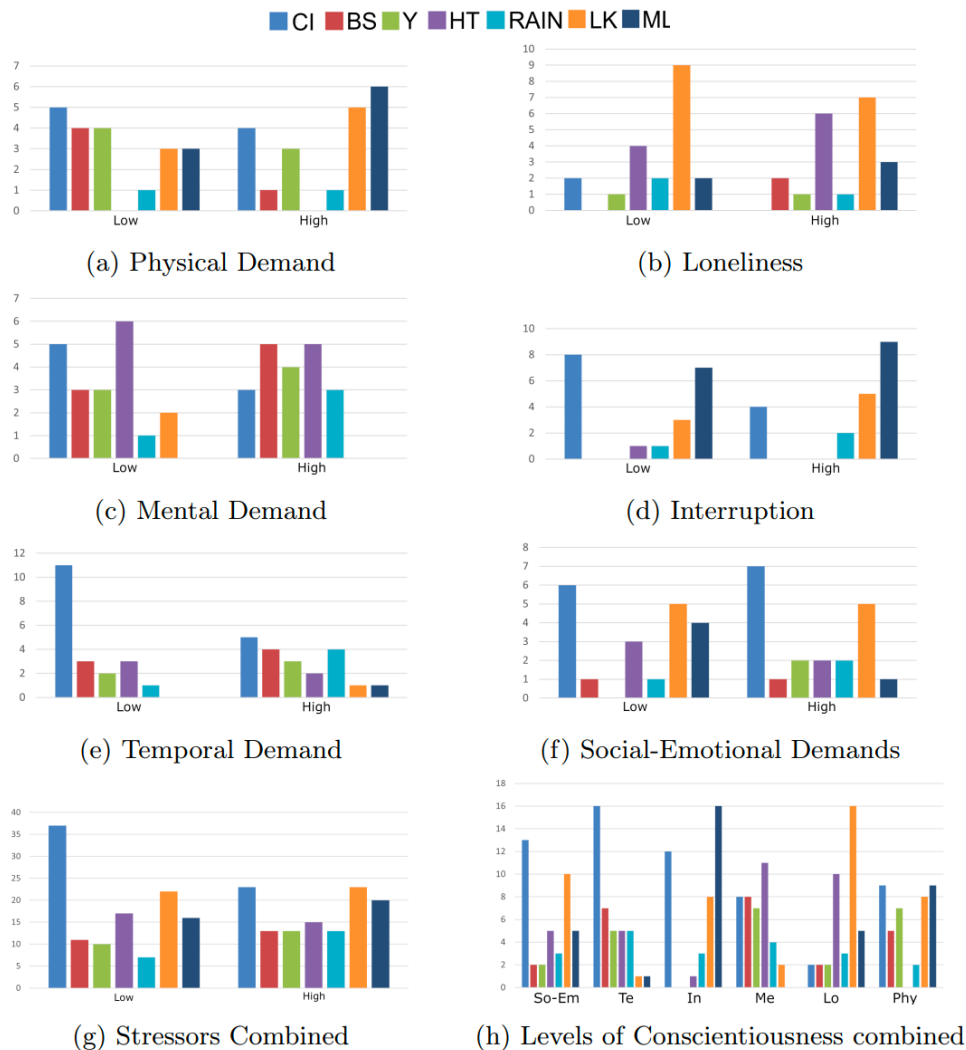
**Figure 1:** Study 3: How often each exercise was selected for the Neuroticism stories. The highest bars in Figure 1h are used in Method 1.

A Tukey Post-hoc test was performed to determine for each exercise for which stressors it was chosen more or less often. Table 5 shows the resulting 'homogeneous subsets' per exercise groups of stressors for which the exercise selection frequency did not significantly differ

<sup>5</sup> CI:  $F(5) = 2.66, p < .05$ ; HT:  $F(5) = 4.57, p < .01$ ; LK:  $F(5) = 4.75, p < .01$ ; ML:  $F(5) = 5.95, p < .01$

<sup>6</sup> CI:  $F(5) = 4.00, p < .01$ ; BS:  $F(5) = 3.24, p < .01$ ; Y:  $F(5) = 3.04, p < .05$ ; HT:  $F(5) = 2.52, p < .05$ ; LK:  $F(5) = 8.30, p < .01$ ; ML:  $F(5) = 6.46, p < .01$

compared to other stressors within their subset, but did differ significantly from other subsets. For example, Table 5 shows that for neuroticism ML is used significantly more for In than for any other stressor, given In is in a subset by itself with a higher mean. Similarly, CI is best used for Te, HT for Me, and LK for Loneliness. The table also shows subsets per trait level. In all cases, the best stressor for an exercise (if found) was the same for the trait level as for overall. Nevertheless, the results are interesting as they provide some evidence that how suitable an exercise is for a stressor can depend on the trait level. For example, in Table 5, for Conscientiousness overall In is a significantly better stressor than So-Em to use ML for, and this still holds for high but not low Conscientiousness.



**Figure 2:** Study 3: How often each exercise was selected for the Conscientiousness stories. The highest bars in Figure 2h are used in Method 1.

To investigate the relationship between stressors and exercise choice further (in particular whether certain exercises were chosen more often), a Bonferroni-corrected analysis of Chi-Square standardized adjusted residuals was performed (the results of this are used for Method 3 below). For the Conscientiousness stories, there were significant positive relationships between ML and interruption, HT and mental demand, and LK and loneliness, whilst for the Neuroticism stories, there were significant positive relationships between CI and temporal demand, ML and interruption, LK and loneliness, and Y and mental demand<sup>7</sup>. Investigating those relationships per

personality level, there were also significant positive relationships between ML and interruption for Neuroticism Low, Neuroticism High, and Conscientiousness High, and between LK and loneliness for Neuroticism Low and Conscientiousness Low<sup>8</sup>.

**Impact of Personality.** There was no significant effect of Neuroticism level on how often any exercise was chosen. However, as shown in Figure 1g, there is a trend for CI and LK to be used more often for high Neuroticism, and BS more often for low. There was a significant effect of Conscientiousness level on how often CI was used ( $F(1) = 4.22, p < .05$ ), with it being used more often for low.

**Interaction effects.** There were no significant interactions of Stressor x Conscientiousness Level and Stressor x Neuroticism Level. This suggests that stressor was most influential on the exercise decision, regardless of personality type.

**Decisions on which exercises students advised.** Figures 1 and 2 show which exercises were preferred by students. However, a bar being slightly higher does not necessarily mean a significant difference. Given the strong effect of stressor, the lack of an effect of personality level, and the lack of an interaction effect, we decided to choose the exercises per stressor based on the student data independent of personality level. The above provides three methods of doing this, using (1) the highest bars in Figures 1h and 2h, (2) the exercise for which the stressor was best based on the homogeneous subsets analysis (bolded in Table 5), (3) the exercise with a significantly positive relationship with the stressor based on the outcome of the Chi-Square residuals analysis. Table 6 shows the decisions made. The methods had the same outcome in most cases.

- When Methods 2 and 3 had no outcome, the other method(s)' was used.
- For Neuroticism for In, CI and ML were equally placed by Method 1; ML was chosen as it was preferred by Methods 2 and 3.
- For Neuroticism for Phy, BS was chosen, as it was chosen by Method 2, a close runner-up to CI in Method 1, and the statistical method took precedence.
- For Conscientiousness for Phy, Method 1 equally placed CI and ML, closely followed by others. Methods 2 and 3 had no results. No choice was made.

### 3.4. Study 4: Perceived effectiveness of the advised exercises

This study investigated the perceived effectiveness of the tailored advice produced by the three methods. We studied perceived rather than actual effectiveness, for the following reason. Actual effectiveness can be studied in two ways. First, participants may be stressed on purpose, using a validated method to stress them (as in [28]). However, it is hard to recreate all stressor categories in this way, and there are large ethical considerations. Also, as found by [28], the ethical considerations. Also, as found by [28], anticipatory stress experienced when told that stress will be induced (because of informed consent) can confound. Second, a longitudinal study could be done, in which participants are supported with the actual stressors they encounter over a long period. The issue then is that providing sub-optimal advice could cause harm. Additionally, it would be hard to study all different stressor types and trait combinations in a controlled manner in this way. In both cases, it makes sense to first study the perceived effectiveness of advice options, and how these ought to be tailored to stressors and traits, and only perform the more intrusive and risky studies once we have gained insights on the best options to pursue.

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<sup>7</sup> Residuals 4.5, 3.4, 3.3 and 3.3, 5.2, 3.2, 5.2 respectively.

<sup>8</sup> Residuals 3.8, 3.5, 3.5, and 5, 3.3 respectively.

Table 5

**Study 3: Tukey Post-Hoc results for Neuroticism and Conscientiousness for each mindfulness exercise (Ex). \* indicates stressors in one subset only, Bold best stressor for exercise according to the statistics (used in Method 2).**

	Ex	Overall		High		Low	
		Stressors in subset	Mean	Stressors in subset	Mean	Stressors in Subset	Mean
Neuroticism	CI	Me*, Lo*, So-Em*, In, Phy	.22			Me*, Lo*, So-Em, Phy, In	.19
		In, Phy, <b>Te*</b>	.38			So-Em, Phy, In, <b>Te*</b>	.33
	BS	In*, Lo, So-Em, Te, Me	.07				
		Lo, So-Em, Te, Me, <b>Phy*</b>	.69				
	Y	In*, Lo*, So-Em, Te, Phy	.08				
		So-Em, Te, Phy, <b>Me*</b>	.15				
	HT	Phy*, In, Te, Me, Lo	.10				
		In, Te, Me, Lo, <b>So-Em*</b>	.14				
	LK	Te*, Me, Phy, In	.12	Te*, Me, So-Em, Phy, In	.19	Te*, Me*, In*, Phy*, So-Em	.09
		Me, Phy, In, So-Em*	.18	Me, So-Em, Phy, In, <b>Lo*</b>	.28	So-Em, <b>Lo*</b>	.40
Conscientiousness	ML	Te, So-Em, Me, Lo, Phy	.08	Te*, Lo, Phy, So-Em, Me	.05	Te*, Me*, So-Em*, Lo*, Phy	.08
		<b>In*</b>	.35	Lo, Phy, So-Em, Me, <b>In*</b>	.11	Phy, <b>In*</b>	.28
	CI	Lo*, Phy, Me, In, So-Em	.20				
		Phy, Me, In, So-Em, <b>Te*</b>	.27				
	HT	Phy*, In, So-Em, Te	.06			Phy*, In, So-Em, Lo, Te	.09
		In, So-Em, Te, Lo	.11			In, So-Em, Lo, Te, <b>Me*</b>	.15
	LK	Te, Lo, <b>Me*</b>	.20				
		Te*, Me*, Phy, In, So-Em	.14			Te*, Me*, In, Phy, So-Em	.11
	ML	Phy, In, So-Em, <b>Lo*</b>	.25			In, Phy, So-Em, <b>Lo*</b>	.23
		Me*, Te*, So-Em*, Lo*, Phy	.09	Me*, Te*, So-Em*, Lo, Phy	.10	Te*, Me*, Lo, Phy, So-Em	.08
		Phy, <b>In*</b>	.25	Lo, Phy, <b>In*</b>	.27	Lo, Phy, So-Em, <b>In*</b>	.18

**Participants** 38 students were recruited from the website SurveySwap.io. 20 filled in the Neuroticism survey and 18 the Conscientiousness survey.

**Method** Two surveys were created, one for each trait. Students were presented with a combination of a personality story and a stressor, followed by one or more mindfulness exercises, and asked to rate the effectiveness of each exercise on a scale from 1 (not effective) to 8 (very effective). The mindfulness exercises shown were all those advised by the therapist and students in Study 3 (see Table 6), with the exception of the RAIN exercise for high Neuroticism, which was left out to reduce the number of exercises per case to a maximum of 3.

**Results** Table 7 shows the exercises' perceived effectiveness. To investigate if an exercise was perceived as significantly effective, first a one-sample one-tailed T-test was performed using a comparison value of 4.5 (the exact middle of the 8point Likert scale). Second, the proportion of participants who rated the exercise as effective ( $\geq 5$ ) was calculated. Table 7 shows the results of this analysis and the decisions based on it. Algorithm 1 reflects these decisions.

Table 6

**Study 3: Exercises advised by therapist (Ther.) and students (Stu.). Numbers in [] indicate methods on which the student decision is based. If no indication is provided, all three methods resulted in the same outcome.**

Stressor	Low Neu		High Neu		Low Con		High Con	
	Ther.	Stu.	Ther.	Stu.	Ther.	Stu.	Ther.	Stu.
So-Em	CI	HT [2]	CI/HT	HT [2]	CI/Y	CI [1]	CI	CI [1]
Te	CI	CI	CI	CI	HT	CI [1,2]	BS	CI [1,2]
In	ML/LK	ML	ML/LK	ML	<i>ML/LK</i>	ML	<i>ML/LK</i>	ML
Me	HT	Y	HT/LK/RAIN	Y	HT	HT	HT/LK	HT
Lo	CI	LK	LK	LK	LK	LK	LK	LK
Phy	HT	BS [2]	HT	BS [2]	<i>HT</i>	-	<i>HT</i>	-

Note: Italic is advice inferred for the therapist for cases where she had said personality did not matter and her advice for Neuroticism was used.

In general, effectiveness was good: all exercises had a mean score >4 and were found effective by ≥50% of the participants. However, effectiveness was better for some stressors than others, and for some combinations of stressors and personality traits than others. This may be explained by certain stressors being harder to cope with using mindfulness exercises than others, such as Interruptions and Mental demands. Also, people low in Neuroticism will (by nature) be less easily stressed, so exercises may be perceived as less needed and effective. Of the 11 exercises rated for low Neuroticism, only 2 were deemed significantly effective and only for 2 stressors. In comparison, 6 from 11 exercises rated for high Neuroticism were significantly effective and for all stressors except Me. Exercise selection decisions for the final algorithm Alg. 1 were made as follows:

- Soc-EM. CI, as it was rated significantly effective for three cases and had the best mean effectiveness for the remaining one, with most finding it effective.
- Te. CI, as it was rated significantly effective for all cases. For low Conscientiousness, HT also was an option, but for simplicity, CI was chosen.
- In. ML for high Neuroticism was the only exercise rated significantly effective. ML was chosen for all cases, for simplicity of the algorithm and because both therapist and students had advised it.
- Me. HT for high Conscientiousness was the only exercise rated significantly effective. HT was chosen for all cases, for simplicity of the algorithm and in line with the therapist's recommendation.
- Lo. LK was rated significantly effective for three out of four cases, and had good mean effectiveness for the remaining case as well, with a clear majority finding it effective. LK was chosen for all cases.
- Phy. HT was rated significantly effective for both Conscientiousness stories, and BS for high Neuroticism. Low Neuroticism did not have a significantly effective exercise (likely for the reasons provided above). We decided to use

**Table 7**

**Study 4: Perceived effectiveness of exercises (Ex), Mean (M), Standard deviation (SD), % participants who rated the exercise effective, results of one sample one-tailed T-tests compared to scale midpoint 4.5. \*= $p < .05$ , \*\*= $p < .01$ .**

Stressor Level	Neuroticism		Conscientiousness		Decision
	Ex	M (SD) %	Ex	M (SD) %	
Soc-Emo	High	HT 5.85 (1.42)** 80 CI 5.55 (1.57)** 75	CI 6.33 (1.46)**	94	CI for all
	Low	HT 4.70 (1.78) 60 CI 5.00 (1.59) 60	CI 6.22 (1.31)** Y 4.61 (2.03) 67	89	
Te	High	CI 5.40 (1.31)** 80	CI 6.44 (1.34)** BS 5.17 (1.82) 61	94	CI for all
	Low	CI 5.15 (1.63)* 70	CI 5.44 (1.54)** HT 5.61 (1.91)* 83	78	
In	High	ML 5.30 (1.56)* 70 LK 4.95 (1.67) 65	ML 4.72 (2.14) 56 LK 4.33 (1.91) 67	56	ML for all
	Low	ML 4.15 (1.69) 50 LK 4.70 (1.75) 55	ML 5.06 (2.01) 61 LK 4.94 (2.13) 61	61	
Me	High	Y 4.80 (1.96) 55 HT 4.90 (1.29) 60 LK 4.50 (2.21) 50	HT 5.61 (1.98)* 72 LK 4.33 (1.91) 67	72	HT for all
	Low	Y 4.90 (1.94) 60 HT 4.55 (1.67) 60	HT 4.28 (1.81) 50	50	

Lo	<i>High</i>	LK 5.65 (1.31)** 80	LK 5.72 (1.97)** 83	LK for all
	<i>Low</i>	LK 5.50 (1.76)* 75 CI 4.95 (1.43) 65	LK 4.89 (2.19) 67	
Phy	<i>High</i>	BS 5.15 (1.63)* 65 HT 4.85 (1.76) 65	HT 5.39 (1.61)* 72	BS for High Neu
	<i>Low</i>	BS 5.00 (1.75) 70 HT 4.50 (1.50) 50	HT 5.56 (1.54)** 72	HT for others

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#### Algorithm 1 Final algorithm

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```

switch stressor do
  case Soc-Emo, Te: Advice (CI)
  case In: Advice (ML)
  case Me: Advice (HT)
  case Lo: Advice (LK)
  case Phy: if Neuroticism = High then Advice (BS) else Advice (HT)

```

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HT in this case, despite its lower mean and proportion, given people with Low Neuroticism may well be high or low in Conscientiousness, and this simplifies the algorithm. So, we use BS for high Neuroticism, and HT otherwise.

## 4. Conclusion

We investigated how an AI-based intervention that helps students regulate emotions by recommending mindfulness exercises can be adapted to personality and stressors experienced. First, we investigated the stressors students experience and how to portray them. We collected 60 stressors in focus groups and validated their categorization. These can be used in future studies which may go beyond mindfulness exercise recommendations, e.g. studies on emotional support.

Next, we studied how a therapist and students adapt mindfulness exercises selection to personality (Neuroticism and Conscientiousness) and stressor experienced. Often the students and therapist agreed on the exercises (e.g. for loneliness, LK, regardless of personality). Sometimes, their advice differed, such as for Physical Demand: the therapist suggested HT, the students BS. Finally, we studied the perceived effectiveness of the exercise options advised by the therapist and students. An algorithm was designed based on the results, which mainly adapts exercise selection to stressors, with a minor role for personality. There is overwhelming evidence that adaptation to stressors is needed. There is also some evidence that exercises' effectiveness may depend on personality, even though it was in most cases possible to pick exercises that are appropriate independent of personality (the studies helped select the exercises). The results can be used to design an AI intervention. Also, the method used to obtain the algorithm may be useful to others who study the adaptation of other support types to stressors and/or personality. Future research may combine our results with emotion-aware systems, which detect the user's emotions and adapt support accordingly [11].

This research has several limitations. Firstly, convenience sampling led to only female students in Study 1's focus groups, though of varied disciplinary backgrounds. Though the stressors we used in future studies seem gender-neutral, and the categories used are based on earlier studies, additional studies could investigate the generalizability of the stressors across genders. Secondly, sample sizes could have been larger. We particularly hope to involve more therapists in future studies, also as they would be better placed to judge effectiveness. Thirdly, we only considered recommendations of individual exercises, whilst sometimes a sequence could

be more appropriate (as also shown by some therapist comments). Finally, only perceived effectiveness was tested. Implementing the algorithm in an app and testing it with users may shed light on its actual efficacy. Research is also needed on longitudinal effects and how to deal with stressor sequences.

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