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Author: Iván García-Magariño Inmaculada Plaza Filippo Neri

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Highlights

- The proper design of mindfulness interventions can help in reducing burnout.
- A novel agent-based simulator allows designing and simulating these interventions.
- It simulates the repercussion of these interventions on the reduction of burnout.
- The experimentation shows the similarity between the real and simulated outcomes.
- The source code is publicly available for reproducibility and other researchers.

ABS-MindBurnout: An agent-based simulator of the effects of mindfulness-based interventions on job burnout

Iván García-Magariño[a,b,*], Inmaculada Plaza[c,b], Filippo Neri[d]

[a] *Department of Software Engineering and Artificial Intelligence, Complutense University of Madrid, Facultad de Informática, c/ Prof. José García Santesmases 9, 28040 Madrid, Spain*

[b] *Instituto de Investigación Sanitaria Aragón. University of Zaragoza. Zaragoza*

[c] *Department of Electronics Engineering and Communications, University of Zaragoza, Escuela Universitaria Politécnica de Teruel, c/ Atarazana 2, 44003 Teruel, Spain*

[d] *Department of Electronics Engineering and Information Technology, University of Napoli Federico II, Corso Umberto I 40, 80138 Napoli, Italy*

Abstract

Some employees suffer from burnout, and most bosses ignore this problem. Job burnout may hinder employees' quality of life, personal accomplishment and satisfaction with life in general. It can also influence negatively the profits of the business or the organization, as the literature reveals. Mindfulness-based interventions have proven to be useful for ameliorating some aspects of burnout. By the same token, some agent-based simulator (ABSs) have been useful for predicting the influence of mindfulness programs on meditators in different aspects such as their emotions and their heart rate variability. In this context, the current work presents a novel ABS application that simulates the effects of mindfulness-based interventions on the job burnout subscales known as emotional exhaustion, depersonalization, personal accomplishment, exhaustion in general, and disengagement from work. This application allows users to define mindfulness programs without needing any computer-science technical knowledge and simulates its influence on a group of practitioners with certain features. The simulator has been tested by sim-

*Corresponding author, Telephone: +34 913947643, Fax: +34 913947547

Email addresses: igarciam@ucm.es (Iván García-Magariño), inmap@unizar.es (Inmaculada Plaza), filippo.neri@unina.it (Filippo Neri)

ulating two mindfulness-based interventions of two scenarios reported in the literature. The ABS received input from the pre-intervention burnout measures, and performed 1,000 simulations for each scenario for avoiding bias from the nondeterministic behavior. The simulated outcomes referring to the post-intervention burnout measures were similar to the real ones. The mean differences, mean squared errors and mean absolute error were below 0.4% in the normalized values of all the burnout subscales reported in the two scenarios. The source code of this ABS is publicly available for guaranteeing reproducibility and allowing other researchers to extend it or reuse some of its components.

Keywords: agent-based simulation, job burnout, mindfulness-based application, mindfulness program, multi-agent system

1. Introduction

Last decades have witnessed an increase of job burnout. The reduction of burnout syndrome means an opportunity for facilitating personal growth of employees (a) increasing their level of enthusiasm (oppositely to cynicism) and (b) decrease the exhaustion, which is a shared dimension in the most relevant burnout inventories (Maslach et al., 1996; Demerouti et al., 2003). Ameliorating the job burnout can also indirectly influence positively on the profits of enterprises and organizations due to the known relation between (1) job burnout and (2) turnover, job performance and absenteeism (Swider and Zimmerman, 2010).

The literature reveals that job burnout can be ameliorated by mindfulness-based interventions (Duarte and Pinto-Gouveia, 2017; Taylor and Millear, 2016). Although most of these works analyze the effects on health professionals (Suyi et al., 2017; Aranda et al., 2018; Duarte and Pinto-Gouveia, 2017), there might be a high number of employees that are not aware of this problem from different disciplines and can benefit from mindfulness practice.

Technology has supported mindfulness practice in many different ways. Mobile applications have supported the individual practice of mindfulness from people that may participate in group-based mindfulness interventions or not. For instance, Mani et al. (2015) reviewed the iPhone apps that supported the practice of mindfulness, while Plaza et al. (2013) had previously reviewed the mindfulness-based mobile applications for Android platform. In addition, the recent "in-the-large" evaluation analysis of Plaza García et al.

(2017) of a Spanish app for training mindfulness shows that users (n=3977) perceived this app as good for the well-being and health.

Nowadays, the design of mindfulness programs is usually done without any decision support system, to the best of the authors' knowledge. The design of new mindfulness programs is usually carried only by experienced mindfulness instructors, like in Mindfulness Based on Buddhist Tradition (MBBT). There are now courses to train meditators in being mindfulness instructors, so these can guide groups of people in training mindfulness. The design of a training plan is usually determined with an Excel file for summing duration hours, or directly written in paper or a Word file. In some mindfulness centers, mindfulness programs are shared through a learning-management systems like Moodle or by means of a mobile application. However, normally only experienced instructors vary the common well-known mindfulness-intervention programs, and they usually ask participants to answer some questionnaires to determine whether the program was appropriate. Thus, agent-based modeling aided program-design can be useful for naive instructors, given the lack of popular decision-support systems on this matter.

Designing a proper mindfulness-based intervention usually requires a high level of expertise in mindfulness. Instructor may also need professional health knowledge about mindfulness repercussions, especially if the interventions are aimed at improving certain facet of participants. In this context, technology may also help naive instructors in defining appropriate mindfulness programs. Agent-based simulators (ABSs) have supported the development of these applications. For instance, ABSEM (an ABS of emotions in mindfulness programs) (García-Magariño and Plaza, 2017b) allows naive instructors to simulate the repercussion of mindfulness programs on certain emotions of practitioners such as anger, anxiety and depression. In addition, ABS-MindHeart (an ABS of the influence of mindfulness programs on heart rate variability) (García-Magariño and Plaza, 2017a) assist naive instructors in designing mindfulness programs by estimating their repercussions on the heart rate variability, which is a widely used health indicator. In this kind of applications, instructors can test different mindfulness programs and simulate the repercussions on the target facet of the intervention, so they can use this information for selecting an appropriate program. However, none of these two ABS applications simulates the repercussion of mindfulness programs on job burnout. These applications provided a programming-based style for the definition of mindfulness programs, which most instructors may find difficult to use for the lack of programming skills.

In this context, the current works presents a novel ABS application for predicting the repercussions of mindfulness-based interventions on the job burnout of participants. This ABS considers the subscales of two well-known burnout scales, including the facets of emotional exhaustion, depersonalization, personal achievement, exhaustion in general, and disengagement from work. This ABS can assist naive instructors in designing and testing new mindfulness programs. It provides a simple user interface (UI) that allows instructors to define mindfulness programs without needing programming skills. This application may also be useful for meditators that may wonder about possible effects of existing mindfulness programs on ameliorating their job burnout symptoms. The dynamic evolution of burnout is part of the scientific contribution. The dynamic of the model is related to the previous work about ABSEM. Both ABSEM and the proposed simulator simulated the repercussions of mindfulness programs on participants, but in the proposed simulator the output features of participants are different (five facets of job burnout instead of just three negative emotions). The evolution of the proposed simulator considers some boundaries of expected maximum impacts achieving a more natural evolution (decreasing the improvement in each step when gaining enough experience) in which both short and long programs are similar to real results. This improves the previous ABSEM model, which was mainly prepared for mindfulness programs with similar durations. In general, the research question is whether agent-based simulation can accurately simulate the repercussions of mindfulness programs on the burnout of a group of employees.

The remainder of this paper is organized as follows. The next section reviews the background concepts of this work such as the existing burnout scales. It also introduces the most related works highlighting the gaps of the literature covered by the current work. Section 3 introduces the novel ABS about the repercussion of mindfulness programs on burnout, which is referred as ABS-MindBurnout from this point forward. This section introduces its specifications, its internal functioning including the evolution rules and its implementation, and its UI. Section 4 describes the experimentation with this ABS showing the accuracy of the application in obtaining simulated outcomes that are similar to the real ones, given some initial pre-intervention conditions. Finally, section 5 mentions the main conclusions of this work, and depicts some future lines of research.

2. Background

2.1. Causes and consequences of burnout

Several works analyze the possible causes that may provoke job burnout. For instance, Hu et al. (2015) studied the influence of hazardous working conditions on nurses' burnout. They found that bodily hazards (e.g. lifting heavy loads), threats of violence (e.g. threats of bullying/harassment in the last 12 months), and physical environment hazards (e.g. extreme temperatures, exposed to smokes, and loud noises) contributed significantly to the burnout dimensions of emotional exhaustion and depersonalization. Swider and Zimmerman (2010) analyzed the relation between (a) the Five-Factor Model personality traits and job burnout dimensions, and (b) absenteeism, turnover and job performance. They found that job burnout partially mediated the relationship between personality traits and turnover and job performance. Enterprise owners may be interested in reducing the job burnout of their employees to increase the turnover and job performance and reduce the absenteeism.

In the field of nursing, Mudallala et al. (2017) analyzed the influence of burnout of nurses on the quality of nursing care. They found a significant correlation between burnout measures and the quality of nursing care. This quality was measured with a validated scale of quality of service taken by surveying the patients about the difference between what they expected and what they perceived to receive. They also found that the timetable (fixed versus rotating) and the level of education significantly influenced on the quality of nursing care. In this line of analysis, the systematic review of Wilkinson et al. (2017) showed that eight out of ten studies had found a direct relationship between burnout and empathy in healthcare. Similar consequences have been observed in other professional fields. For instance, Söderlund (2017) found that the burnout in service encounters negatively influenced customer satisfaction.

In conclusion, job burnout is related with many other relevant factors. For example, the literature shows its high repercussion on the quality of service provided to the customers/patients, and generally on the turnover and job performance. Thus, this motivates the current work about providing support for designing interventions that ameliorate job burnout.

2.2. Validated scales for measuring burnout

The Maslach Burnout Inventory (MBI) (Rafferty et al., 1986) measures (1) the emotional exhaustion (EE), which is the feeling of being overstressed and the emotional and physical depletion, (2) depersonalization (DP) which is the unfeeling and negative attitude towards clients, and (3) personal accomplishment (PA), the feelings of achievement, competence and productive at work. This inventory has been widely used in studies in fields like nursing (Mudallala et al., 2017). It is replied with a seven-point Likert scale.

The Maslach Burnout Inventory-General Survey (MBI-GS) (Maslach et al., 1996) is a refined inventory that departs from its precursor MBI inventory. MBI-GS measures the following three different components of burnout: (a) emotional exhaustion with 5 items like "I feel used up at the end of the workday", (b) cynicism with 5 items such as "I have become less enthusiastic about my work, and (c) professional efficiency with 6 items like "In my opinion, I am good at my job". The questions are answered in a 5-point Likert scale. The validity of MBI-GS was proved by Schutte et al. (2000) with a study that used data from Finnish, Swedish and Dutch employees (n=9055). They proved that this three-component structure was invariant across all occupational groups.

Burnout can also be measured with the Oldenburg Burnout Inventory (OLBI) (Demerouti et al., 2003). This inventory has only two dimensions: (1) exhaustion and (2) disengagement from work. The corresponding version was replied with a 4-point Likert scale. OLBI exhaustion is different from MBI emotional exhaustion, since the former does not only include affective aspects but also physical and cognitive aspects (Demerouti and Bakker, 2008). Reis et al. (2015) validated this inventory by measuring its invariance across different groups (job and academic) and across different countries (Greece and Germany). For their experiments, they adapted this inventory to measure academic burnout, and denoted this adaptation as OLBI-S.

Burnout can also be assessed with the second subscale of the Professional Quality of Life Scale, version 5 (ProQOL-5). For instance, Duarte and Pinto-Gouveia (2016) used this subscale for measuring the effectiveness of a mindfulness intervention on reducing the burnout among other aspects.

In summary, MBI, MBI-GS, OLBI and a dimension of ProQOL-5 are validated inventories for measuring job burnout. Most of these provide its own subscales, but between all of these subscales may be some redundancy. The set of MBI and OLBI provides a set of five subscales that are different without matching any two of them, and covers most of the aspects of burnout.

Hence, the subscales of MBI and OLBI may be relevant for being considered in any simulator that estimates influences of interventions on job burnout, like in the current work.

2.3. The influence of mindfulness interventions on burnout

Mindfulness-based interventions have been widely used for reducing the burnout in the health professionals. In their systematic review and meta-analysis, West et al. (2016) searched for studies of interventions to prevent and reduce physician burnout, up to Jan 15, 2016. Results substantiated that individual-focused interventions, such as mindfulness, stress management, small group discussions, and structural or organizational interventions can be effective approaches to reduce burnout domain scores. In this line, the study of Asuero et al. (2014) supports the use of mindfulness-based programs as part of continuing professional education to reduce and prevent burnout, promote positive attitudes among health professionals, strengthen patient-provider relationships, and enhance well-being. In a similar way, Fuertes Goñi et al. (2016) defended the use of mindfulness and cultivating compassion training to reduce stress and burnout among health professionals.

Aranda et al. (2018) found significant improvement in the burnout variable (n=45 considering the intervention and control groups), but Suyi et al. (2017) did not find significant improvements (n=37 participants). A similar study was conducted for the specific case of oncology nurses with a larger total sample (n=94) (Duarte and Pinto-Gouveia, 2016). They assessed the repercussion of a mindfulness-based intervention for different psychological aspects including burnout. They found significant improvements in burnout. The difference about the significance of the improvement of burnout can be due to the low sample size of the study of Suyi et al. (2017).

Focusing on healthcare providers, Goodman and Schorling (2012) developed a continuing education course based on mindfulness-based stress reduction. A total of 93 healthcare providers participated, including physicians from multiple specialties, nurses, psychologists, and social workers who practiced in both university and community settings. As results, MBI scores improved significantly from before to after the course for both physicians and other healthcare providers for the emotional exhaustion, depersonalization and personal accomplishment scales. Mental well-being measured by the SF12v2 also improved significantly. They concluded that a continuing education course based on mindfulness-based stress reduction was associated with significant improvements in burnout scores and mental well-being for a broad range of healthcare.

Luberto et al. (2017) offered a 4-week mindfulness-based cognitive therapy (MBCT) group program for hospital employees and used a mixed-methods practice-based research approach to explore feasibility, acceptability, and effects on stress and burnout. Participants were 65 hospital employees (social workers, nurses, marketing, health unit coordinator, physicians, dieticians, pastoral services, administration). As results, there were large, statistically significant decreases in stress and medium decreases in burnout, which were supported by qualitative themes of improved self-regulation and mindfulness skills, stress reduction, emotional well-being, and improved work productivity and patient care skills.

Outside the health field, mindfulness-based interventions may be useful in supporting the wellbeing of paraprofessionals from diverse backgrounds working in low-income, urban environments (Jacobs et al., 2017). Testa and Sangganjanavanich (2016) examined the contribution of mindfulness and emotional intelligence to burnout among counseling interns (n = 380). Results indicated that higher scores on mindfulness and emotional intelligence were related to lower burnout scores. Counselor educators and supervisors should be proactive in helping students to cultivate wellness practices during internships. The interdisciplinary study of Taylor and Millear (2016) analyzed the burnout of professionals from different fields, considering a large sample (n=381). Their results showed a significant correlation between mindfulness levels and three different components of burnout.

Other studies focused in specific aspects. For instance, Kaplan et al. (2017) examined the mechanistic role of psychological resilience on burnout. Mindfulness-Based Resilience Training (MBRT) is a preventive intervention tailored for first responders to reduce negative health outcomes, such as burnout. They worked with law enforcement officers (n=47 participants) and firefighters (n=22). Results indicated that changes in resilience partially mediated the relationship between mindfulness and burnout and that increased mindfulness was related to increased resilience, which in turn was related to decreased burnout.

In brief, the literature has proven the relationship between mindfulness and job burnout. Some works show that certain mindfulness-based interventions can be useful for reducing some particular aspects of job burnout. However, there is no tool that assists instructors in defining effective mindfulness interventions for reducing job burnout by estimating the possible repercussions of these interventions.

2.4. Current trends in agent-based simulators

ABSs can be very powerful in the decision-making processes, as argued by Macal and North (2007), who introduced ABSs as a third way of doing science in addition to deductive and inductive reasoning. They showed that a wide range of toolkits and methods could support the development of ABS models.

ABSs have been proposed as solutions for a wide range of domains, such as recently for earthmoving operations (Jabri and Zayed, 2017), real-estate transactions based on different buying and selling strategies (García-Magariño and Lacuesta, 2017), the behavior of hospital emergency departments (Liu et al., 2017), and the air traffic management (Gurtner et al., 2017). In addition, ABSs have been widely used for simulating social media interaction, like in the simulation of viral marketing strategies based on the Twitter social network (Serrano and Iglesias, 2016). ABSs have also been applied for simulating health interactions, in contexts such as the analysis of the place effects on health based on the common interactions among neighbors and epidemiology theories (Auchincloss and Diez Roux, 2008).

Nevertheless, the application of ABSs for simulating certain psychological or physiological variables of people is still much less common for certain challenging issues. Both the complex biological processes and the psychological ones resulting on certain complex behavior are probably almost impossible to model from a pure chemical and biological point of view even for the best experts in the area. Hence, the literature only provides raw solutions for implementing ABSs in this context. Even though, some ABSs have proven to be useful in some psychological areas. For example, some ABSs show the influence of different mindfulness programs on certain aspects. In particular, ABSEM (an ABS of emotions in mindfulness programs) (García-Magariño and Plaza, 2017b) simulates the repercussion of mindfulness programs on certain emotions measured with some validated scales. ABS-MindHeart (an ABS of the influence of mindfulness programs on heart rate variability) (García-Magariño and Plaza, 2017a) simulates the heart rate variability of meditators based on the estimated influences of mindfulness exercises and considering the past simulated history. In a different domain, VoteSim (Serrano et al., 2014) simulates the political choices of people. This ABS uses clustering techniques for associating people with the group of people that represent a certain political party.

Other works used a chemical approach centering on a specific internal process. For instance, Taherian and Mousavi (2017) presented an ABS for simulating the forward osmosis given the effects of various parameters. They used NetLogo platform for representing the movement of particles. In addition, Kang et al. (2017) simulated colorectal tumor with an ABS. Since they needed to simulate a high number of agents, they used parallel computing advanced techniques for increasing its performance.

Recent ABSs now include meaningful visual UIs that allow users to introduce certain inputs and to understand the evolution of the simulations by viewing the visual interface. For example, the ABS for Earthmoving Operations (ABSEMO) (Jabri and Zayed, 2017) allows users to introduce parameters about bulldozers, loaders, trucks and spotters. Then, this ABS simulates some of these agents in a schematic map, with a notation of colors to make users understand their state. In other cases, the simulators evolve their simulations and present a chart with the evolution of all the relevant variables. For example, the work of Liu et al. (2017) shows the evolution of the number of arrived emergencies in a hospital for each day of the weak, as well as the evolution of the stay durations. Gurtner et al. (2017) showed the number of flights for the different simulated hours. Therefore, some current ABSs present the evolutions of simulations showing step-by-step explanations that carry certain final results.

The analysis of the distribution of the results can be relevant in some cases. For example, the ABS about the air traffic management of Gurtner et al. (2017) presented histograms for representing the frequencies of different intervals for respectively the airplane velocity and the flight level occupancy.

On the whole, the application of ABSs for simulating physiological and psychological aspects is still challenging. In this context, some ABSs explored the influence of mindfulness programs on certain aspects, but none of these simulated their effects on job burnout. In addition, the analyzed ABSs did not provide a mechanism for letting users to visually design the behavior of one agent, like for example indicating the mindfulness program that guides an instructor agent. In general, ABSs are improving the way they present the simulated outcomes visually. While there is a common consensus around some visual components such as representing the evolution of agent attributes over the simulation in a chart, there are other other kinds of charts that are not so explored like the starplots to the best of the authors' knowledge. The next section introduces a novel ABS that advances the state of art in these aspects.

3. ABS-MindBurnout

ABS-MindBurnout is an ABS that simulates the influence of mindfulness programs on the different aspects of burnout. This ABS allows naive instructors to design programs of mindfulness-based interventions as a sequence of mindful activities. This ABS includes two kinds of agents. The "instructor" agent represents the mindfulness instructor and incorporates a mindfulness program as its main attribute, represented with a list of mindful activities. The "meditator" agents represent naive mindfulness meditators with their burnout states considering the different subscales. In each step of the mindfulness-based intervention, the instructor agent interacts with each meditator agent for guiding a certain mindful activity, and the later simulates the effects on its burnout subscales. The source code of ABS-MindBurnout is publicly available from a permanent dataset of the Mendeley public research repository [1].

We decided to define a generic instructor agent type to encapsulate the teacher behaviors in training programs. The user can define different instructor agent subtypes to simulate different mindfulness programs. Although this approach has been tested with fixed mindfulness programs, the proposed approach could allow one to define dynamic strategies, in which the instructor would apply different variations of their mindfulness programs regarding the evolution of meditator agents. Other alternatives were considered such as having one instructor and several instructor assistants, but we kept only the instructor agent for the sake of ease of use and because the role of instructor assistants is usually to help participants in doing exercises rather than interfering with mindfulness programs.

The goal of meditator agents was to simulate the repercussion of mindfulness exercises on people that suffered from job burnout. We considered the possibility of having different roles of mindfulness program attendants, such as passive, participant, joker, obstructive and so on like in education literature (Roberts, 2008). However, we found that this role classification was not applicable to our context since meditation was different from common educational activity (e.g. nursing) and this classification would not properly cover the common profiles of people suffering job burnout. Instead, we de-

[1] "ABS-MindBurnout source code for simulating the effects of mindfulness-based interventions on job burnout with an agent-based approach", Mendeley Data, v1 http://dx.doi.org/10.17632/8gzskr4chz.1

cided that meditator agents were characterized with the common facets of job burnout, according to some relevant job burnout scales.

We also evaluated the possibility of defining other agent types for modeling other aspects of the environment, such as music, temperature, and humidity. However, we decided not to define agent types for these aspects, since (1) these aspects did not properly fall into the category of agents according to the common definitions, (2) the influence of these specific environmental factors on burnout reduction were not detailed in the literature for this particular context, and (3) for the sake of simplicity by not combining many different factors.

In this simulator, the key performance indicators are the burnout MBI and OLBI scales, in which the performance of a mindfulness program is its capacity for reducing burnout in meditators. Notice that facets EE, DP, exhaustion and disengagement from work are directly related with burnout, while PA is inversely related with it.

In order to select the appropriate burnout scales, we considered MBI, MBI-GS, OLBI and a dimension of ProQQL-5, because all these scales had been validated. Since MBI and MBI-GS share many aspects, we decided not to include both of them for avoiding redundancy. We discarded the burnout dimension of ProQQL-5, since it did not have several facets. We selected OLBI, since in combination with MBI, they covered five non-overlapping facets of burnout. We corroborated our decision of selecting MBI and OLBI by checking that there were enough available data in the literature to test the current approach and compare simulation outcomes with real-life experiments.

Section 3.1 provides a specification of the application focusing on its inputs and outputs. Section 3.2 introduces the evolution rules that model the internal behavior of agents. Section 3.3 describes the implementation of the ABS mentioning its internal structure. Finally, section 3.4 presents the UI of the application highlighting its most relevant visual components.

3.1. Specification of inputs and outputs

ABS-MindBurnout receives input from the subscales values of MBI and OLBI scales. Hence, this ABS receives input from the values of the subscales EE, DP and PA regarding the MBI scale, and the subscales exhaustion and disengagement from work concerning the OLBI scale. The ABS also receives input from the number of meditators.

Another simulation input is the program of the mindfulness-based intervention defined as a list of mindful activities represented with their literal names assigned in the current approach. Table 1 includes these activities with their names and brief descriptions (Aranda et al., 2018; Suyi et al., 2017). Section 3.4 will describe how the application assists users in defining these programs by selecting the mindful exercises from a list.

After the simulation has been executed, the outputs use the exact same scales of burnout as the input, i.e. EE, DP, PA, exhaustion, and disengagement. The outputs include the values of all the individuals at the simulation end, the final averages, and the evolution of averages through the different steps of the simulation. Section 3.4 further introduces the visual representation of all these simulated outcomes.

3.2. Evolution rules

This ABS followed TABSAOND (a technique for developing agent-based simulation apps and online tools with nondeterministic decisions) (García-Magariño et al., 2017) for defining the nondeterministic decisions to simulate the way of altering the agent burnout attributes during the simulation. TABSAOND was selected because it provides a guide for testing different mechanisms for simulating non-deterministic behaviors as well as how these behaviors could affect in different ways to the evolution of agent features. We needed using nondeterministic behaviors, since mindfulness exercises affect different people in different ways. At the same time, the progress in mindfulness programs follows some specific usual improvement patterns, so TABSAOND allowed us to try different evolution patterns to match these patterns.

TABSAOND provides different ways of setting probabilities for simulating decisions and several formulas for calculating agent attribute variations. It guides ABS designers in selecting an appropriate combination of taking non-deterministic decisions with probabilities and varying agent attributes. Following this guidance, we decided to use fixed probabilities for each burnout subscale. It can simulate both increasing and decreasing trends on different subscales. In particular, $p_{i,b}$ and $p_{d,b}$ respectively denote the probabilities of increasing and decreasing each burnout subscale b. Following TABSAOND, the result can be either to increment (d=1), to decrement (d= –1) or to keep a neutral trend (d=0), with the following formula:

Identifier	Activity name	Description
1	Raisin meditation	The meditator pays attention to a raisin and the whole process of eating it.
2	Body scan	The meditator sequentially draws their flow of awareness to each part of their body.
3	Mindful breathing.	The meditator focuses on nothing but their breathing.
4	Mindful self-compassion	The meditator takes time to be aware of their suffering and painful emotions. Then, they regard these with perspective for their understanding and getting internal peace.
5	Burnout lectures	The instructor explains the main causes and symptoms of burnout, so practitioners can be aware whether they are suffering from burnout. The instructor also mentions possible mechanisms for ameliorating it.
6	Mindful walking	The practitioners are conscious about the moment-to-moment experience while walking.
7	Compassionate hugging	Practitioners hug each other feeling their compassion.
8	Empathetic listening	The practitioners do this practice in pairs. One speaks about their life and the other listens putting themselves on the former one's place. Then, they switch roles.
9	Focusing meditation	The participants look for the connection between the mindful experience and their own principles.
10	Practice 'me in the future'	Meditators focus on discovering what really matters to them, by imagining themselves in the future.
11	Tonglen (give and receive)	The meditator does not avoid negative feelings, but instead they feel them and learn to go through it.
12	Lectures about self-care	The instructor recommends meditators to make themselves conscious about what they actually need and how they can take care of it.
13	Mindfulness introduction	The instructor introduces the bases of the mindfulness experience to practitioners, and tells them how it can improve their lives.
14	Perception and engaging with practice	The meditators are encouraged to perceive their environment and being aware of it, for starting experiencing mindfulness.
15	Awareness of being stuck	The practitioners are recommended to be aware of the obstacles that recursively prevent them from being happy or achieving their personal goals.
16	Mindfulness of feelings/thoughts	Practitioners make themselves aware of their feeling and thoughts with a non-judgmental attitude.
17	Reacting and responding to stress	Practitioners learn to take their time in stressful situations to be fully aware of the circumstances, avoiding to react automatically. In this way, they can take free decisions in this kind of situations.
18	Mindful movement	They meditate while doing physical exercises.
19	Communication in stressful situations	Practitioners learn to communicate truly in the current moment with kindness and compassion even when the situations provoke stress.
20	Kindness meditation	The practitioners try to be kind with themselves and the others.

Table 1: Practical activities for exercising mindfulness according to Aranda et al. (2018) and Suyi et al. (2017)

$$d = \begin{cases} 1, & \text{if } r \leq p_{i,b} \\ -1, & \text{if } p_{i,b} < r \leq (p_{i,b} + p_{d,b}) \\ 0, & \text{otherwise} \end{cases}$$

where r denotes a number randomly generated in the interval from 0 to 1.

Notice that is necessary to have different values for each subscale. For instance, mindfulness-based interventions usually have an increasing repercussion on PA, while these normally have a decreasing influence on EE. It can also simulate non-significant influences.

After the trend is decided to be increasing, decreasing or neutral, the variation of the agent attribute of each burnout subscale is calculated with the following formula:

$$\Delta_k(x) = \begin{cases} E_a * K * (l_{upper,b} - x), & \text{if } d > 0 \\ -E_a * K * (x - l_{lower,b}), & \text{if } d < 0 \\ 0, & \text{otherwise} \end{cases}$$

where E_a is the effect of the corresponding practical activity on the b burnout subscale.

In this occasion, $l_{upper,b}$ and $l_{lower,b}$ are established from the maximum differential limit effects on each burnout scale b. In this manner, the simulator can simulate different effects on the burning subscales. More specifically, the following formulas are applied for this calculation:

$l_{upper,b} = b_0 + Dl_{upper,b}$

$l_{lower,b} = b_0 - Dl_{lower,b}$

where b_0 is the initial value of the burning scale at the beginning of the simulation, and $Dl_{upper,b}$ and $Dl_{lower,b}$ are calibrated for representing the maximum differential effects even for the largest mindfulness programs on each burnout subscale.

This formula was inspired by the formula formally denoted as $\Delta_k(x)$ in TABSAOND and referred as "calculation of variation as portion to the limits", and was adapted for producing realistic results in this domain, in which the repercussions were quite different from one subscale to another.

3.3. Implementation

The presented ABS was developed using the Process for developing Efficient Agent-Based Simulators (PEABS) (García-Magariño et al., 2015). The implementation uses the Unity cross-platform engine in order to obtain a usable interface and to be able to deploy the simulator as both as a mobile app and as a desktop application in the main operative systems, like one can observe in some recent serious games applications (Chittaro, 2016). It uses the C# language because it is one of the available scripting languages in Unity and supports object-oriented programming paradigm, which has been widely used for developing agent-based systems in general, like with PEABS and with the widespread Java Agent DEvelopment framework (JADE) (Bellifemine et al., 2008). We discarded to use Repast and NetLogo because these environment were mainly designed for representing agents in spatial positions (either 2D or 3D), and in our case the physical positions of meditators were not so important, since we were mainly modeling internal psychological repercussions. Although AnyLogic is very powerful to perform agent-based simulations in many industry scenarios, their application in psychological internal processes would be really weird given the available functionalities. Notice that its specific libraries normally support the simulation of either industry or business processes.

Figure 1 shows the main excerpt of the class diagram of the application. As proposed in PEABS, the "Simulation" class contains a list of agents, which are invoked through the "Live" method. This simulator contains two kinds of agents. The instructor agent is the one that guides a mindfulness program represented as a list of practices. This agent guides each practice by sending the practice and the knowledge to each meditator agent.

The instructor agent has a mindfulness intervention, and guides all meditator agents in performing the mindfulness activities of this intervention. In particular, the instructor agent interacts with each meditator agent and sends a mindfulness activity. Each meditator agent simulates the effect of this activity in each of its burnout facets considering (1) the non-deterministic happening of whether the meditator actually deeply followed the activity and this changed the meditator, and (2) if so, the formulas for altering each burnout facet given some calibrated constants associated with the particular mindfulness activity, which were described in section 3.2.

Each meditator agent follows the practice indicated by the instructor agent. Each meditator agent has a list of values that represent its burnout states for the different subscales. Each meditator applies the evolution rules described in the previous section. The "Knowledge" class contains most of the values of the internal parameters necessary for simulating the evolution of burnout. The meditator agents can access to the effects of each practice

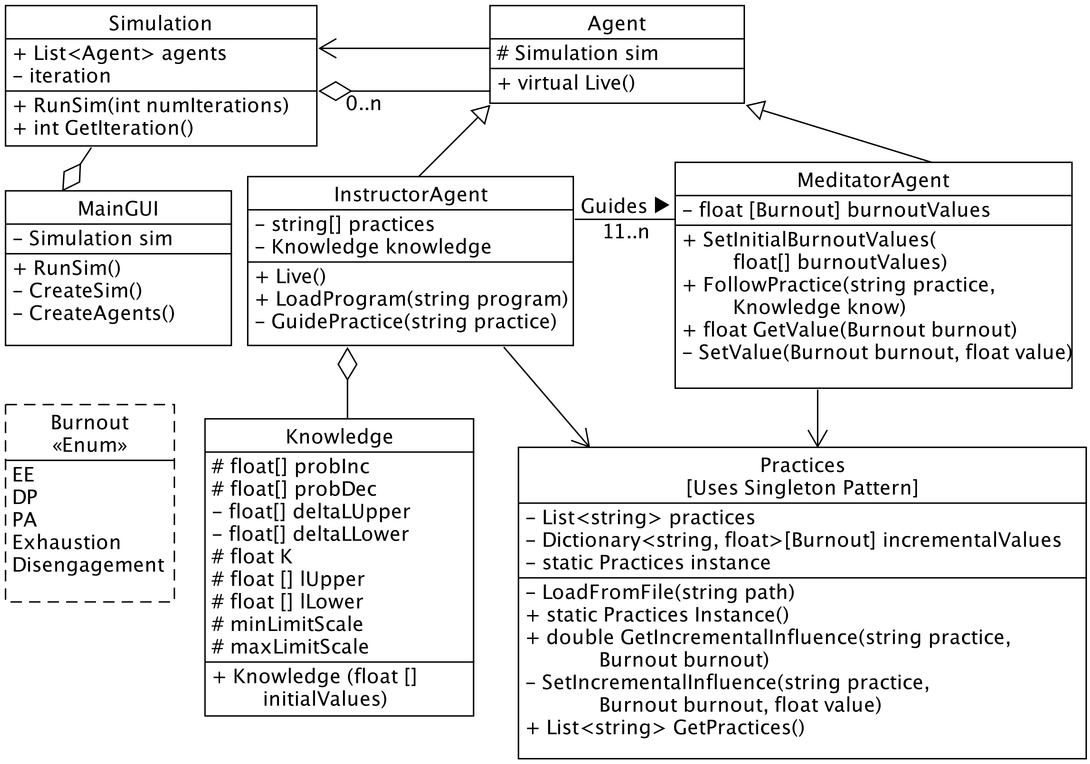


Figure 1: Main excerpt of the class diagram of ABS-MindBurnout

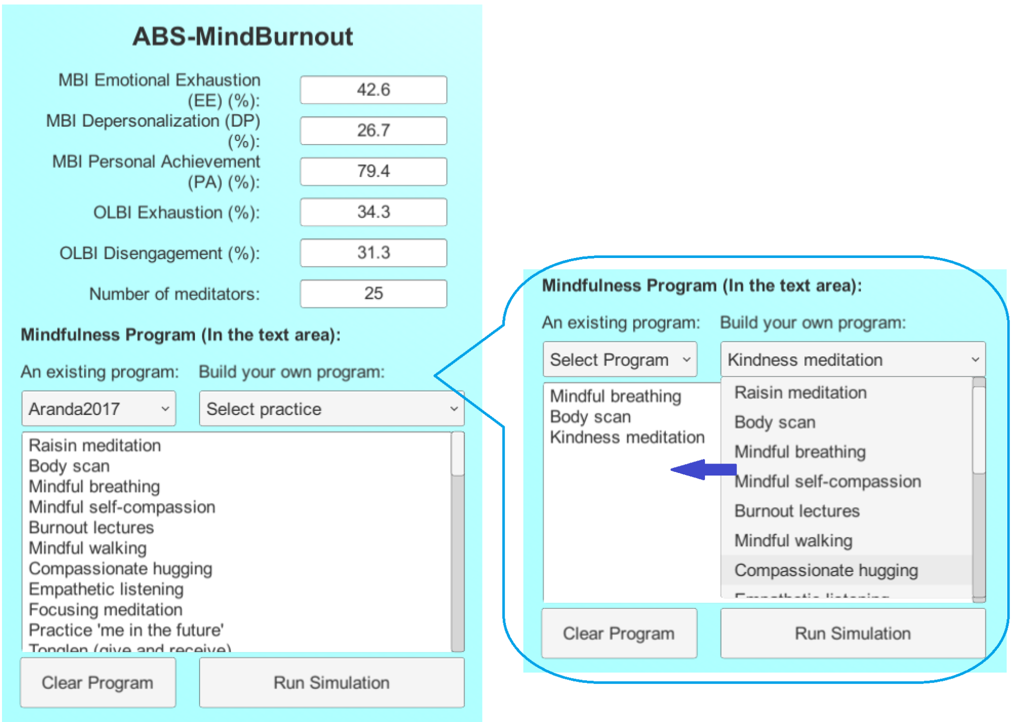


Figure 2: Input introduced in the UI of the app

through the "Practices" class. This class uses a Singleton pattern, so that all the meditators can easily access it. This class loads all the values for all the practices and burnout subscales from an internal text resource on its first use. This has two advantages from the ease of maintenance point of view: (a) more mindful practices can be added to the simulator, and (b) the corresponding effect values can be changed, both of which just by modifying the text resource without altering the programming code.

3.4. User interface

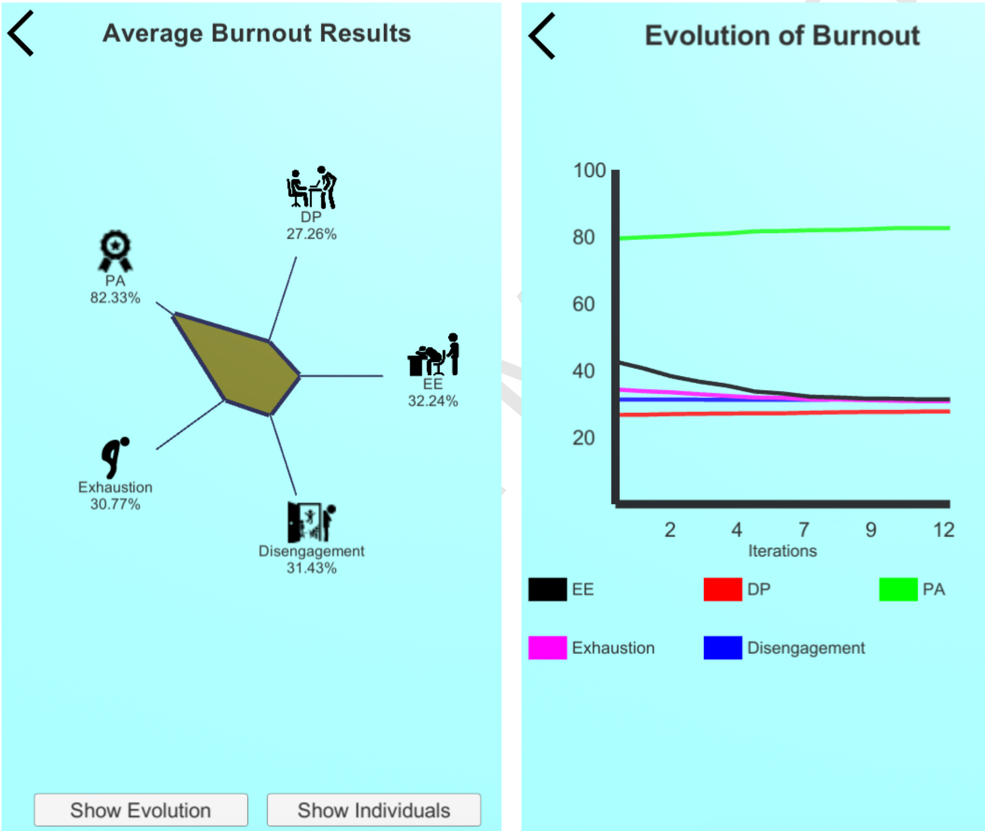
The UI of ABS-MindBurnout allows users to enter the initial pre-intervention circumstances as Figure 2 shows. More concretely, the user can enter the initial averages of the different subscales of both MBI and OLBI in the corresponding input fields shown in the left-side of the figure. The user can also indicate the number of participants. In order to obtain representative results, it is important that the initial baseline population is representative. For this purpose, the real instructor should have some information about the burnout levels of the real participants before the mindfulness program. The initial state of the simulation will be a group that has the same average burnout levels that the average burnout levels of the real group considering each facet of MBI and OLBI scales. In this way the drawn simulation outcomes can be representative of the effect of the simulated mindfulness program.

Regarding the mindfulness program, the user can either (a) select a complete mindfulness program from the existing ones specifically addressed for reducing burnout, or (b) define a new mindfulness program from scratch. They can perform the former operation by selecting a program from the left dropdown list labeled as “An existing program”. In the latter operation, the user can define its own mindfulness program within the application interface without needing specific technical knowledge or programming skills. As one can observe in right-side of the figure, the user can define the mindfulness program by sequentially selecting practical activities from the right dropdown list labeled “Build your own program”. Each of the selected activities is appended to the existing program in a new line. The user can also clear the existing program to start from scratch, or delete any specific practice by deleting the corresponding line. Once the user has introduced all the input, they can start the simulation by pressing the “Run Simulation” button.

When the simulation has been executed, the app shows the results with charts like the ones presented in Figure 3. More specifically, first the app presents the average results with a starplot like the one in Figure 3(a). In this chart, the user can observe the average resulting percentages for the different burnout subscales normalized as percentages in the 0 to 100 interval. This normalization was performed so that all the scales can be presented together in a meaningful way, and non-experts can easily understand their values.

In particular, each end of the starplot will only arrive to the maximum value of the destined area represented with a line, if it gets to 100%. In this manner, the user can compare starplots from different evolutions, as each starplot end is always spatially represented as a proportion of the same maximum limit. The starplot visual representation is enriched with certain images associated with the different subscales, to facilitate their understanding at a glance.

From the starplot screen of Figure 3(a), the user can press the “Show Evolution” button to observe the evolution of the average of burnout subscale values. The user can see this evolution in the app by means of a chart like the one shown in Figure 3(b). In this way, the user can know the evolution



(a) Starplot screen (b) Evolution of average results

Figure 3: Average simulation results presented in the UI of the app

during the different simulation iterations. Each iteration represents a mindful practice of the simulated program. Alternatively, the user can also consult the final burnout values of each individual by pressing "Show Individuals" in the starplot screen. In this case, the app goes to a different screen in which the user can observe all the final simulated burnout subscales values of each simulated participant in a scrollable table of data.

In general, the ABS tool communicates how a group of employees can improve respectively in the burnout facets of emotional exhaustion, depersonalization, personal accomplishment, exhaustion in general, and disengagement from work by following a particular mindfulness-training program. We selected the starplot for representing the final results with the specific values written on the star ends, because it communicates visually the final outcomes, in which the different facets can be easily compared, as well as the numerical data can be known. We selected the evolution plot so that the user can observe the improvement in each of these facets from the beginning of the mindfulness program to the end.

4. Experimentation

In order to obtain a representative experimentation, the proposed ABS-MindBurnout simulator was validated on two different scenarios. The first scenario was in the context of burnout of primary care health professionals, and was described by Aranda et al. (2018). The second scenario was about burnout of mental health professionals, and was introduced by Suyi et al. (2017). It is worth highlighting that the proposed ABS was trained with a different scenario from the ones used for validation, and this training scenario was about burnout of oncology nurses and presented by Duarte and Pinto-Gouveia (2016). The collection of data was performed by people different from authors, as detailed in the corresponding articles. The simulation executions were performed by the authors, which belong to two different countries (i.e. Spain and Italy). In addition, the simulator is publicly available, so potentially any researcher on the world could double-check the simulation results. The starting populations were set with the average pre-intervention values of each burnout facet reported in each article, so the starting populations had the same features as the real ones. Since the proposed ABS is non-deterministic, we executed a high number of simulations for each scenario to avoid bias due to stochastic behaviors. We selected 1000 simulations since this number is higher than the usual number to have a statistical power that detects medium significant differences (between 50 and 100 depending the particular statistical test) and higher than the number of simulations in similar works published in high-impact peer-reviewed articles, e.g. 100 simulations for each condition in a work about an ABS for multi-project scheduling under uncertainty (Song et al., 2018). We also informally tested different numbers of simulations (i.e. 10, 50, 100, 200, 500 and 1000), and we observed that with 1000 simulations we always obtained almost the same average value. Thus, we considered 1000 simulations as an enough high number.

In order to calibrate the ABS-MindBurnout app, we initially assigned some internal values to the effects of practice activities (referred previously as E_a), and some probabilities were assigned for respectively the increasing and decreasing decisions (respectively denoted before as $p_{i,b}$ and $p_{d,b}$), based on the known effects of mindfulness interventions of burnout subscales of the literature (Duarte and Pinto-Gouveia, 2016). Inspired in the literature, we also established some differential limit effects of mindfulness interventions on each b burnout subscale (referred as $Dl_{upper,b}$ and $Dl_{lower,b}$). Then, the values were tuned for obtaining realistic results considering the influences of the internal parameters on the simulated outputs as suggested by ATABS (a technique for Automatically Training ABSs) (García-Magariño and Palacios-Navarro, 2016). After the calibration, the ABS was configured with a K factor (ratio for approaching each subscale limit) of 0.15, and with the internal parameter values shown in table 2 for the different burnout subscales.

Regarding the calibrated values, it is worth mentioning that the practice of the mindfulness of feeling/thoughts was considered to have the highest impact on EE (i.e. E_{16}). The practice of the compassionate hugging (E_7) and empathetic listening (E_8) are the ones that were set to be more related with the decrease of DP. In addition, PA was mostly affected by the practice of "me on the future" (E_{10}) and burnout lectures (E_5). The body scan was the practice most related with the reduction of exhaustion (E_2). The practice about reacting and responding to stress (E_{17}) was mainly related with the amelioration of disengagement.

After this, the simulator was experienced with the work of Aranda et al. (2018) and the one by Suyi et al. (2017). In particular, Aranda et al. (2018) applied a mindfulness-based intervention inspired by the Mindfulness-Based Stress Reduction (MBSR) program and incorporated certain compassion exercises of the Mindfulness Self-Compassion (MSC) program. They applied the program during 8 weeks with a session of 2.5 h per week. They detailed

	EE	DP	PA	Exhaustion	Disengagement
$p_{i,b}$	0.18	0.28	0.70	0.15	0.25
$p_{d,b}$	0.76	0.15	0.16	0.45	0.25
$Dl_{upper,b}$	2.10	2.55	5.10	1.10	1.50
$Dl_{upper,b}$	15.30	1.50	1.60	6.33	1.50
E_1	1.11	0.82	0.78	1.14	0.84
E_2	1.55	1.22	1.14	1.79	1.03
E_3	1.31	1.15	1.07	1.41	1.05
E_4	1.31	1.15	1.07	1.41	1.05
E_5	2.11	1.52	2.02	1.50	1.62
E_6	1.34	0.92	0.95	1.42	0.41
E_7	1.82	2.12	0.61	1.95	0.43
E_8	0.62	2.31	0.44	0.51	0.61
E_9	0.93	0.97	1.02	0.98	1.04
E_{10}	0.95	0.89	2.11	1.35	1.21
E_{11}	0.67	1.98	0.33	1.42	1.02
E_{12}	1.75	0.83	0.79	1.72	0.87
E_{13}	0.43	0.52	0.47	0.39	0.53
E_{14}	0.73	0.82	0.90	0.88	0.79
E_{15}	1.03	1.07	1.36	1.05	0.91
E_{16}	2.24	1.09	1.01	1.70	0.98
E_{17}	1.15	0.75	1.88	1.21	1.84
E_{18}	1.07	1.12	1.02	1.11	0.71
E_{19}	1.03	2.11	1.02	1.09	1.34
E_{20}	1.77	2.05	0.32	1.20	1.42

Table 2: Values of the internal parameters

all the exercises, so the current work was able to simulate the exact same mindfulness program. Among other aspects, they measured the burnout of 25 participants before and after the intervention with the MBI scale, using a validated Spanish translation denominated MBI-HSS. In the MBI emotional exhaustion, they found a decrease from 23.0 (pre-intervention) to 17.2 (post-intervention). In MBI depersonalization, there were no significant changes, 8.0 in pre-intervention and 8.2 in post-intervention. The participants increased the MBI personal achievement from 38.1 to 39.6.

Suyi et al. (2017) conducted a mindfulness intervention based on MBSR shortened to 6 weeks, with a two-hour session per week, and they detailed the exercises. 37 participants attended this program. They measured the burnout before and after intervention with the OLBI scale. The exhaustion scores changed from 2.37 in pre-intervention to 2.25 in post-intervention. The disengagement did not change from pre-intervention (M=2.25) to post-intervention (M=2.25).

The programs of the mindfulness-based interventions of the two aforementioned scenarios were defined with the current approach. Each of these mindfulness programs was defined by indicating a list of the mindful practical

	Pre-intervention		Post-intervention	
	MBI	MBI norm. (%)	MBI	MBI norm. (%)
EE	23.00	42.59	17.20	31.85
DP	8.00	26.67	8.20	27.33
PA	38.10	79.38	39.60	82.50

Table 3: Real pre- and post-intervention results of the scenario of Aranda et al. (2018)

	Real	Simulated	Comparison		
	MBI norm. (%)	MBI norm. (%)	Diff. of Means	MSE	MAE
EE	31.85	32.01 (0.44)	0.156	0.214	0.362
DP	27.33	27.44 (0.14)	0.105	0.030	0.142
PA	82.50	82.51 (0.19)	0.006	0.036	0.152

Table 4: Comparison of real and simulated post-intervention results in the scenario of Aranda et al. (2018)

exercises selected from the dropdown list of the ABS application interface. Appendix A includes the definition of both programs with the current approach.

Table 3 indicates the real pre- and post-intervention results from the scenario of Aranda et al. (2018) using the MBI scale. This table presents these results in the original range MBI scale, and in the normalized (abbreviated as "norm.") range from 0 to 100 for representing percentages.

The current simulator was run receiving input from the same pre-intervention values as in the real scenario. The simulator used the same mindfulness program as in the real case, and used the same number of participants, i.e. 25. In order to avoid bias from the nondeterministic behavior of the simulator, the app was executed 1,000 times to obtain a representative analysis. Table 4 compares the real and the simulated post-intervention outcomes. Each simulated result represents the corresponding average of all the simulations and the standard deviation (SD) between parentheses. The table also includes de differences of means, the mean squared errors (MSEs) and the mean absolute errors (MAEs). As one can observe the mean differences, MSEs and MAEs were below 0.4% for all the MBI subscales considering the normalized range.

Figure 4 shows an example of the simulated evolution of one participant in this scenario of Aranda et al. (2018). The purpose is to show the fluctuations that each individual can suffer during the simulation of the 8-week program. The average burnout values of the whole group of participants evolved more smoothly since these represented the averages of several individuals. This evolution can be observed in Figure 3(b) previously introduced for presenting the UI of the app.

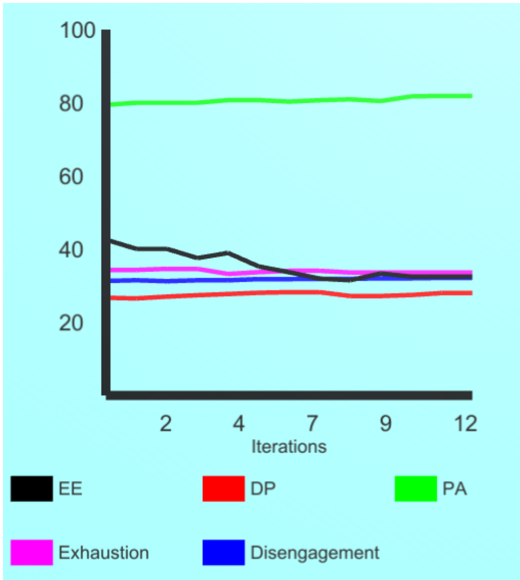


Figure 4: Example of the evolution of one individual in the scenario of Aranda et al. (2018)

	Pre-intervention		Post-intervention	
	OLBI	OLBI norm. (%)	OLBI	OLBI norm. (%)
Exhaustion	2.37	34.3	2.25	31.25
Disengagement	2.25	31.3	2.25	31.25

Table 5: Real pre- and post-intervention values of the scenario of Suyi et al. (2017)

	Real OLBI norm. (%)	Simulated OLBI norm. (%)	Comparison Diff. of Means	MSE	MAE
Exhaustion	31.25	31.25 (0.18)	0.002	0.032	0.144
Disengagement	31.25	31.30 (0.07)	0.047	0.007	0.068

Table 6: Comparison of real and simulated post-intervention outcomes in the scenario of Suyi et al. (2017)

ABS-MindBurnout was experienced in a similar way with the scenario of Suyi et al. (2017). The main differences are that this experiment uses the OLBI scale and a different mindfulness program. The number of participants was 37, which is higher than in the previous scenario. Table 5 shows the real pre- and post- intervention values of this scenario. The simulator was also executed 1,000 times for this scenario. Table 6 compares the real and simulated outcomes. In this scenario, the mean differences, MSEs and MAEs were below 0.2% for the two OLBI subscales considering their normalized ranges.

On the whole, the current simulator has been experienced with two different scenarios reported in the literature. It has been run 1,000 times for each scenario for avoiding bias. Given the same pre-intervention values, the simulator obtained simulated outcomes similar to the real ones, with mean differences, MSEs and MAEs below 0.4% for all the subscales of the analyzed burnout scales.

5. Conclusions and future work

The current work has presented a novel ABS about the repercussion of mindfulness-based interventions on the job burnout aspects identified by the subscales of respectively the MBI and OLBI inventories. This simulator can be useful for both novel mindfulness instructors and practitioners. More concretely, novel instructors can design new programs for mindfulness-based interventions and simulate their repercussions on the burnout of a group of practitioners. The results of the ABS can assist them in selecting the appropriate program. In this ABS, the definition of new mindfulness program does not require programming skills as in some of the previous similar simulators, so most mindfulness instructors may be able to use it. In addition, each meditator can use the simulator to know which can be the repercussion of each existing program on their actual job burnout, in order to select the right mindfulness-based intervention for themselves. The reliability of the ABS has been measured by comparing the real and the simulated outcomes for certain initial conditions. The results advocate that the simulator is quite accurate, since the difference of means, the mean squared errors and the mean absolute errors were under 0.4% in the normalized percentage values of the burnout subscales of the two analyzed scenarios. Thus, the response to the research question is that agent-based simulation can accurately simulate the repercussions of mindfulness programs on the burnout of a group of employees.

The current work is planned to be enhanced by performing a user study of the simulator application with (a) naive mindfulness instructors, (b) experienced mindfulness instructors and (c) naive users without any experience or relation with mindfulness. The results of these three groups will be analyzed separately as each of these may use the tool in a different way. This study will be aimed at detecting design opportunities for respectively increasing more the usability and including more useful functionalities. In addition, we are currently developing another app with a drag-and-drop interface for just the definition of mindfulness programs, and the simulator presented in this paper may be adapted to import these definitions and/or incorporate a similar interface. Furthermore, the current simulator may be extended to become also an app that supports mindfulness practice for ameliorating job burnout. This extended version will guide users in some basic mindful exercises for this purpose. This app will measure burnout of users through the MBI and/or OLBI inventories. The app will track the evolution of burnout subscales of users, so that they will be able to access their history. Finally, the simulator can be extended to simulate the effects of techniques that combine mindfulness with other activities such as physical exercise and yoga, like the technique proposed by De Bruin et al. (2017).

In the standpoint of behavioral sciences, the proposed simulator opens a research line in the context of decision-support systems for planning collective psychological interventions or some collective ludic activities in order to improve the well-being of members and their feeling of being integrated in the group, among others. In this way, some ABSs could be developed to allow enterprise directors to plan all these kinds of activities to improve the general feeling of their employees, and consequently their productivity. School teachers may also benefit from this approach for improving the general feeling of students, and hopefully their academic achievements.

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Appendix A. Definition of the mindfulness programs

This appendix includes the definition of the programs of the mindfulness-based interventions of the experimentation with the current approach. Figure A.5 shows the definition of the mindfulness program of the scenario of Aranda et al. (2018), and Figure A.6 presents the program of the scenario Suyi et al. (2017). In each of these programs, each mindful practical exercise is represented in a different line. Each practice name must match one of the existing practices of the simulator. The application includes a dropdown list, so the user can select each practice from a list, avoiding possible misspellings.

Raisin meditation
Body scan
Mindful breathing
Mindful self-compassion
Burnout lectures
Mindful walking
Compassionate hugging
Empathetic listening
Focusing meditation
Practice 'me in the future'
Tonglen (give and receive)
Lectures self-care

Figure A.5: Definition of the mindfulness program in the scenario of Aranda et al. (2018)

Mindfulness introduction
Body scan
Perception and engaging with practice
Mindful breathing
Awareness of being stuck
Mindfulness of feelings/thoughts
Reacting and responding to stress
Mindful movement
Communication in stressful situations
Kindness meditation

Figure A.6: Definition of the mindfulness program in the scenario of Suyi et al. (2017)

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