On the impact and lessons learned from mindfulness practice in a real-world software company

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***Abstract*—*Background*. Mindfulness is a meditation technique whose main goal is educating attention by focusing only on one thing at a time, usually breathing. Mindfulness practices improve concentration and attention, being particularly valuable in demanding and high-stress work settings, such as those found in software companies. A family of five controlled experiments on the impact of mindfulness on future and current software engineers' performance has been carried out in six years, whose participants practiced mindfulness daily for several weeks. *Aims*. This work has a twofold purpose, to present the fifth experiment in the series and to summarize the lessons learned across the family of experiments. The fifth experiment was carried out at INPRO, a public software company in Seville (Spain), in order to evaluate whether software workers improve their performance and some psychological factors, i.e. attention awareness, techno-stress and well–being, compared to a control group. *Method*. Employees of two departments (*Development and Operation*) were recruited to participate in the study. Mindfulness (the treatment) was applied to 24 subjects who attended mindfulness sessions daily for six weeks, while the other 27 subjects were the control group. For all subjects, such psychological factors were measured using questionnaires, whereas performance was measured using INPRO's task management systems. *Results*. Findings have shown significant differences in terms of attention awareness and techno–stress levels between the practitioners who practised mindfulness and those who did not. Benefits on the perceived well-being have also been reported by participants after the continued practise of mindfulness. Regarding the performance, the analysis depicts inconclusive results, probably due to the small size of the sample, a problem which was accentuated by significant variability in the kinds of tasks performed in both departments. *Conclusions*. Mindfulness practice has yielded significant benefits in the series of experiments, such as performance in the academy and psychological factors in the industry. Nevertheless, its impact on performance in software companies requires further research, since the limited data availability on subjects' performance has led to a small sample size, ultimately posing challenges in drawing dependable conclusions.**

***Index Terms*—Mindfulness, Software Psychology, Field Experiment, Human factor, Family of experiments**

I. Introduction

Empirical research in Software Engineering aims to study the impact of new methods, practices, and tools to understand and improve the software development process [1]. To carry out such research, several empirical strategies have been applied, which vary in their objective that could be exploratory, inferential, predictive, causal, or mechanistic [2].

Each of these strategies presents specific weaknesses and strengths and is applicable or not depending on the context of the research [3]. For example, conducting controlled experiments is common in academia to seek cause–effect relationships, the level of control that can be exerted is high, but generalizability is low, i.e., it can not sometimes be ensured that the same would happen in a real-world environment [4].

Therefore, after conducting several controlled experiments in academia, similar empirical research is recommended in the software industry with realistic subjects and tasks to increase the generalizability of the results [5].

Once the empirical study is taken into the industry, (i) the level of control decreases drastically [2], [6], (ii) the amount of resources for the study increases [4], and (iii) the experimental setting must be adapted not only to avoid being invasive in the organization, but also to adapt the study to the culture of the company and its organizational structure [7].

Following such an approach of first conducting experiments in academia and then in the industry, we have carried out a series of experiments to study the effect of continued mindfulness[1] practice on the performance of future and current software engineers [8]–[10]. Figure 1 illustrates the five experiments conducted, three controlled experiments at the University of Seville –the original experiment and two internal replications– and two field experiments at software companies, in particular Accenture and INPRO (an Andalusian public company). The baseline experiment has evolved throughout the series to overcome some limitations and has been adapted to both software companies, looking for realism and noninvasive procedures, as recommended in [4], [11].

All experiments belonging to the family share the same basic research question as a core that is *Can the continuous practice of mindfulness improve the performance*[2] *in the soft-*

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[1]For the sake of brevity, we used sometimes the term mindfulness to refer to mindfulness meditation, which is a mental training practice of attention focused on breathing and without religious connotations.

[2]Performance has been operationalized in a different manner across the series of experiments.

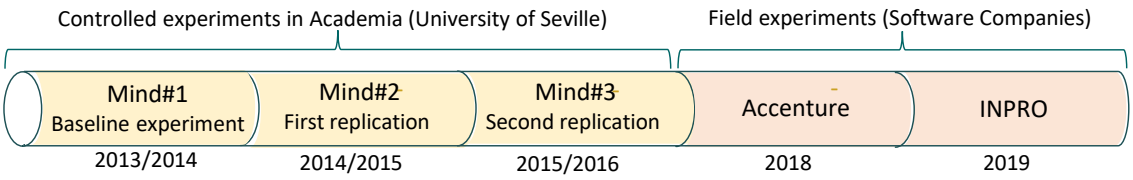


Figure 1: Series of experiments conducted to evaluate the impact of mindfulness in Software Engineering Practises

ware engineering process? We hypothesize that mindfulness can have positive effects on the Software Engineering process because mindfulness meditation decreases stress [12] and improves attention [13], concentration [14], problem resolution [15] and work–related well–being [16], [17] which is a key factor in professional performance [18].

Aware of those effects, several organizations such as Google, Cisco, P&G, Facebook or Deloitte –to name a few in the ICT sector– have integrated mindfulness in the workplace to promote creativity and innovation, as well as emotional intelligence and well–being in their employees [19], [20].

In this paper, we present the last field experiment in the series conducted in INPRO, a company that develops software for local councils in the province of Seville. Encouraged by the initiative to implement mindfulness in nearby organizations, one of the INPRO managers, who was familiar with mindfulness practice, wanted to study whether the benefits observed on a personal level after the continued practice of mindfulness would reflect on staff's attention awareness[3], techno–stress[4], work performance and well–being. To check this intuition in INPRO, the following research questions were stated.

- RQ_1 *Does the practice of mindfulness impact attention awareness and techno–stress INPRO employees?*
- RQ_2 *Does the practice of mindfulness impact performance INPRO employees?*
- RQ_3 *Does the practice of mindfulness impact perceived well-being INPRO employees?*

In this study, we address our *RQs* and provide a comprehensive overview of the insights gained from the family of experiments as lessons learned.

The rest of the paper is organized as follows. A brief overview of mindfulness and its effects, a summary of the findings of previous experiments, and a description of the context of the current study are presented in Section II. Experimental planning and Execution are described in Section III and IV, respectively. The results of the statistical analysis are detailed in Section V. The threats to the validity are commented in Section VI. Related work is presented in Section VII. The discussions and lessons learned from the entire family of experiments are compiled in Section VIII and, finally, the conclusions and future work are presented in Section IX.

[3]The ability to pay attention non–judgmentally to what is happening at the present moment and stay calmed and focused [21]. Attention awareness status plays an important and broad role in self–regulation and emotional experience, which also affects work and productivity [22].

[4]Phenomenon characterized by a state of heightened mental and physiological arousal, due to the pressure experienced by employees who rely on technology in their work [23].

II. Background

A. Mindfulness: A Synopsis

Being mindful is a personal state in which the mind is aware and attentive to the experience of living in each moment. The mindful person displays an increased awareness of the contents of her mind such as thoughts, sensations, and emotions. This is an inherent human ability, although infrequent in everyday life [24]. Failing that, thoughts and feelings operate outside of consciousness, and the subject has difficulty managing them, whereas being mindful is an opportunity to pause and observe before evaluating, making a decision, and acting. To enhance the mindful status of human beings, in years 70' mindfulness meditation was born inspired by ancestral meditation methods [25]. Mindfulness meditation is an attentional technique that consists of being for a while in silence, completely unmoved, and focusing the attention on a unique *anchor*, usually breathing. When thoughts come to mind, the subject puts them aside and returns the focus to her breathing.

Mindfulness involves training practitioners since it enables them to apply the state of consciousness achieved during meditation to daily activities, promoting present–moment awareness and focus while reducing rumination about the past or future, even in our hyper-connected world full of interruptions.

From the point of view of neuroscience [26], mindfulness can transform the brain structure and functionality through *neuroplasticity*, i.e. the continuous modification of our brain by synaptic connections in response to our everyday experiences.

Due to the aforementioned changes in the brain, the continuous practice of mindfulness meditation has been revealed positive to reduce stress symptoms [27], well–being [28], emotional intelligence [29], sustained attention [30], concentration and working memory capacity [14]. As a result, mindfulness has entered the mainstream media, attracting the attention of schools [31], several universities [32], [33], psychologists' practices [27] and companies from different sectors [16], [34].

B. The series of experiments

As commented in Section I, we conducted a 3–year series of experiments at the University of Seville to assess whether second-year students in Software Engineering improved their performance in conceptual modelling (UML class diagram development) after the daily practice of mindfulness meditation

for several weeks, comparing their results with those of a control group receiving a placebo treatment.

The results of the individual experiments revealed that the efficiency (number of UML class diagram elements correctly identified per unit of time) of students who practiced mindfulness was significantly better than those of the control group. Concerning the effectiveness (the rate of correctly identified model elements per unit time), i) increases were observed in the baseline experiment (Mind#1) [8] and the first replication (Mind#2) [9], but were not statistically significant and ii) In Mind#3, a small decrease was observed, but it was not statistically significant [10].

Once the individual experiments finished, a joint analysis of pooled and aggregated data meta–analyses from three experiments is also carried out [10]. Consistently showed that students who practiced mindfulness performed significantly better on the task (small effect size) and were more efficient, arriving at solutions more quickly (high effect size). The joint analysis revealed that mindfulness practice not only improves efficiency, but also effectiveness. The increase in sample size with the aggregated data allowed us to uncover subtle effects that were not observable in isolated experiments [10].

Encouraged by the results in the academy, a first field experiment was carried out in an Accenture helpdesk, where agents worked answering phone calls to solve problems with the software system of the Andalusian Health Service. In this field experiment, we preserved the same goal, experimental setting, and design as the University of Seville experiments. However, some changes were introduced not only to adapt the experiment to Accenture and its way of working but also to study the impact of mindfulness meditation on attention awareness, well-being and some key performance indicators (KPIs). In particular, we introduced questionnaires to measure attention awareness (MAAS[5]) and Perceived Benefits of Mindfulness in Well-being (PBMW), after the mindfulness continued practice for six weeks. Additionally, employee performance was measured using several KPIs used in Accenture on a daily basis.

The findings show that the employees who received treatment with mindfulness significantly improved their attention awareness and perceived well-being with respect to the control group. Regarding organizational KPIs, in general, no evidence of significant differences between groups was detected. However, the KPI *number of answered phone calls* was significantly lower in the mindfulness group, probably due to a longer call duration caused by better customer care, but without damaging any other KPI [35].

C. Research Context: INPRO

The Provincial Society of Informatics (INPRO) of the Seville Provincial Council provides ICT services to 104 municipalities and 40 local public entities. With a team of over 90 employees, INPRO is also responsible for developing and maintaining the software required to provide these services.

[5]Mindfulness Attention Awareness Scale

In Spain's public administration sector, city councils are responsible for implementing digital transformation and engaging with citizens, with INPRO providing ICT support. However, this work can lead to stress and burnout among INPRO employees due to challenges such as attending meetings, finding technological solutions, and making decisions. To promote employee well-being, INPRO managers have introduced mindfulness practices within the company.

The study focuses on two departments within the organization that have tools to objectively measure employee activity. The *Development* department is responsible for developing software solutions for internal management needs and offers SaaS solutions for citizens and companies to conduct procedures online. They use REDMINE for project and task management. The *Operation* department manages the operation of the organization's systems and resolves incidents in a timely manner. They use GLPI [36] as an incident handler and task management tool.

III. Experiment Planning

This section reports the experimental process following the Jedlitschka *et al.*'s guidelines [37] with minor changes. The purpose of the experiment is defined below using GQM [38].

Analyse *the daily practice of mindfulness for six weeks* **for the purpose of** *evaluating its effects* **with respect to** *the attention awareness, techno-stress, performance and well–being of software workers* **from the point of view of** *the experimenters and company managers* **in the context of** INPRO*, a public software company.*

A. Participants

The sample was drawn from INPRO's *Development* and *Operation* departments. Table I shows the demographics of the sample which consists of 51 subjects with an average age of 46.6 years, most of whom were men. The sample was randomly divided into 24 subjects in the experimental group (*Exp*) and 27 in the control group (*Ctrl*). Two subjects in the *Ctrl* group were withdrawn from the study as they did not provide their consent to participate. The average number of mindfulness sessions attended by each participant is 18.8 in the *Exp* group and 15.8 in the *Ctrl* group, with 5 subjects of the *Ctrl* group not attending the mindfulness training. The most common educational level was associate degree (37.3%) and the most common professional profile was developer (45.8%) with an average of 23.5 years of experience, 16.3 of them in the company. Both groups are balanced, among others, in terms of professional profile, experience, and department.

Regarding the experimental material, a structured *labpack* is available on Zenodo platform [39]. For the sake of reproducibility and transparency [6], [40], the *labpack* includes experimental material, datasets, the statistical analysis scripts, and the raw results of script execution, including plots. In addition, in such results, a full report of the sphericity and homoscedasticity tests is also available in the labpack for studying the applicability of parametric tests.

Table I: Demographics of the experimental subjects

		Missing	By group		
			Overall	Exp	Ctrl
n			51	24	27
group, n (%)	Exp		24 (47.1)	24	
	Ctrl		27 (52.9)		27
attendance, mean (SD)		5	17.4 (8.0)	18.8 (7.7)	15.8 (8.2)
age		3	46.6 (7.2)	46.7 (6.6)	46.5 (7.8)
gender n(%)	female	3	19 (39.6)	12 (52.2)	7 (28.0)
	male		29 (60.4)	11 (47.8)	18 (72.0)
experience		4	23.5 (8.0)	23.1 (7.8)	23.9 (8.5)
experience in INPRO		4	16.3 (9.9)	16.6 (9.1)	16.1 (10.8)
Dept., n (%)	Development	2	25 (51.0)	12 (50.0)	13 (52.0)
	Operation		24 (49.0)	12 (50.0)	12 (48.0)

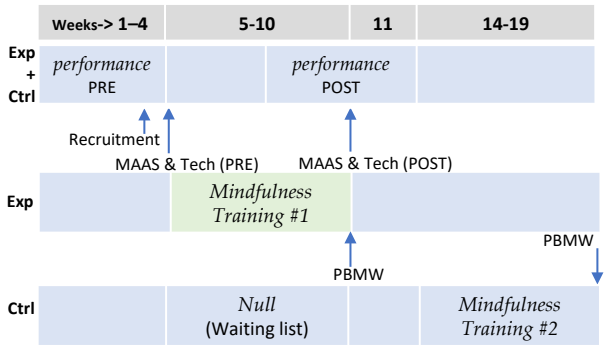


Figure 2: Experiment schedule organized by weeks

B. Tasks

During the conduction of the field experiment, the subjects were tasked with performing the following activities (see Figure 2): (i) attending a brief introduction about mindfulness and filling out the interest questionnaire after providing consent to participate in the study (labeled as Recruitment in Figure 2); (ii) filling in the first MAAS and Techno–stress questionnaires (labeled as PRE in Figure 2); (iii) attending a talk about the practice of mindfulness and the sessions on mindfulness, i.e mindfulness training, during six weeks, four days a week at the beginning of the working day (only the *Exp* group, see *Mindfulness Training #1* in Figure 2); (iv) filling in the second MAAS and Techno–stress questionnaires (labeled as POST in Figure 2); and (v) The *Exp* group also completed a PBMW questionnaire after the practise of mindfulness for six weeks.

After the field experiment conduction, (weeks 14–19 in Figure 2), the *Ctrl* group (i) attended a talk about the practise of mindfulness and the equivalent daily sessions on mindfulness at the beginning of the working day (labeled as *Mindfulness Training #2* in Figure 2); and (ii) filled in a PBMW questionnaire.

Notice the period of data collection (from both the *Exp* and *Ctrl* groups) comprised from week 1 until week 11, except the PBMW questionnaire. Nevertheless, since employees in the *Ctrl* group showed their interest in learning mindfulness, they attended to an equivalent mindfulness training after the conduction of the experiment, being part of a waiting list in the meantime. Thus, we not only promote *Ctrl* group participation and prevent dropout, but also can ensure that the *Ctrl* group remains in its control status during experimental conduction.

C. Independent variables

The two independent variables, i.e. factors, in the current field experiment are the following:

1) group: It represents the main factor under study, i.e. the *group* the employees were assigned during the intervention. This variable is on a nominal scale and has two levels, mindfulness which was the treatment administered to the *Exp* group and a *null* intervention in the *Ctrl* group.

2) moment: It represents the *moment* in time when employees were measured using questionnaires or internal measures provided by INPR0. This variable is also on a nominal scale and has two levels *pre–treatment* and *post–treatment* (in the figures, these levels are labeled as PRE and POST).

D. Response Variables and Metrics

To study the impact of the mindfulness practise in INPRO employees, multiple data collection methods were used, in order to obtain a more comprehensive understanding of such a complex phenomena as human behavior [41]. Specifically, four different data sources were used, three related to psychological factors: i) *attention awareness*; ii) the perceived *techno–stress*; and iii) the perceived benefits of mindfulness in *well–being* after its continued practice; and one related to the iv) *performance* which data could be extracted from the logs of REDMINE and GLPI.

1) Attention Awareness: MAAS is a 6–point Likert scale that measures a natural level of mindful *attention awareness* i.e., the dispositional capacity of an individual to be attentive and aware of the experience of the present moment in daily life. Several works [42], [43] have revealed that higher levels of mindful *attention awareness* may be associated not only with lower levels of perceived stress but also with higher subjective *well–being* levels. We decided to use MAAS because the psychometric analysis of the Spanish version of such a scale shows good properties, both in terms of validity and reliability [44].

2) Techno–stress: Techno–stress is increasingly recognized as a modern-day affliction that makes it difficult to adapt to new technologies in a healthy and effective manner, since the presence of Internet–connected devices and their disruptive nature is constant, in our daily lives.

Recent work has revealed that being in a mindful state can mitigate the negative consequences of *techno–stress* within workplace settings and its negative consequences [45]. Encouraged by INPRO managers, we included the study of *techno–stress* in the present study which was measured at the same time as *attention awareness* (see Figure 2), so participants completed a single questionnaire measuring both response variables. To avoid changing the scale within the

same questionnaire, the seven *techno–stress* questions (Table II) were written on a 6-point Likert scale, and each item is labeled in the same way as in the MAAS scale i.e. from *1-Almost always* to *6-Rarely*.

Table II: Techno–stress Questionnaire

ID	QUESTION
Q1	I require time outside of my working hours to complete tasks that require greater concentration.
Q2	I unlock my phone more than 5 times for a one-hour period even realizing it.
Q3	I often unlock my phone unconsciously, without being aware of it.
Q4	I am unaware that I am cringing or clenching my jaw.
Q5	When faced with external interruptions, I struggle to prioritize which ones require immediate attention and which ones can be postponed.
Q6	I am not aware that I am experiencing stress.
Q7	I tend to give impulsive answers without giving much thought when responding to someone.

3) Performance: Based on previous experiments in the academy showing a significant positive impact of mindfulness on conceptual modeling performance, it was logical to study its impact on performance for this experiment. To measure performance, we calculated the number of *Task Closed* (TC) by each experimental subject using the data extracted from the REDMINE and GLPI logs. Although other metrics, such as Total Time to Resolution (TTR) or cycle time, are also commonly used to measure performance, in this case, TC is considered the most appropriate metric due to GLPI log data does not provide information about the instant when the subject started working on the task, making the use of cycle time unfeasible. Furthermore, TTR could be affected not only by the kind of tasks performed in each department (which also affects TC), but also by the own nature of each specific task, generating additional noise on the data which, given the small sample available, could hinder the drawing of meaningful conclusions.

Table III: Perceived benefits of mindfulness on *well–being* Questionnaire

ID	QUESTION
A	Introductory talk on mindfulness was interesting.
B	I felt comfortable with the room and job during daily sessions.
C	I did not manage to calm my mind at all and found it impossible to pay attention to breathing during the first week.
D	As days went by, my mind wandered less during the sessions.
E	The body sweep at the beginning makes it easier for me to focus on breathing later.
F	I intend to continue with the daily practice of mindfulness.
G	I have learned a tool that can be useful to improve my quality of life.
H	I am learning to observe my mind and avoid racing thoughts.
I	It is easier for me to focus on a single task after practice.
J	I sleep better or wake up more rested.
K	It is easier for me to focus on the present, enjoy nature or be more aware of reality.

4) Well–being: After attending the corresponding mindfulness training, the subjects completed the questionnaire shown in Table III, a 5-point Likert scale (from *1-Not at all agree* to *5-Strongly agree*). This survey addresses the experience during the mindfulness training itself (A–E questions), the joy of mindfulness practice (F–H), and the perceived benefits observed after six weeks of continued practice (I–K). This questionnaire aims to assess the mindfulness training impact on the participants' *well–being*.

Notice that a participant completed the PBMW only once, after finishing the corresponding edition of the mindfulness training, whereas the rest of the response variables defined above were measured twice, i.e. once before the *Exp* group attended *Mindfulness Training #1* and once after it (Figure 2).

E. Confounding and Context Variables

The confounding and context variables and how they were controlled are defined next.

1) Dept: This confounding variable represents the department in which each employee works. It has two levels *Development* and *Operation*. Both departments are facing similar situations of overwork and work pressure. However, there are differences in the kind and workflow of the tasks they perform. Operational tasks tend to have a shorter life cycle, which affects the *performance* response variable. To address this concern, we have considered *Dept* as a covariate in the data analysis of *performance*.

2) Company: This context variable represents the particular characteristics that INPRO presents as a company. As described in Section II-C, INPRO is a public company whose experimental subjects are software workers.

F. Hypotheses

The response variables *attention awareness* and *techno–stress*, as well as *performance*, were analyzed using hypothesis testing since they follow a repeated measured design with a *Ctrl* group. However, the variable *well–being* has been studied by descriptive statistics and narrative synthesis [46], since the PBMW form is filled in by both groups after its corresponding mindfulness training, when subjects can assess satisfaction after practicing mindfulness (see PBMW in Figure 2).

As a consequence, in this section, we define groups two of hypotheses for the *Attention Awareness*, *Techno-stress*, and *Performance* variables.

Attention Awareness Hypotheses

$H_{0,1}$ There is no difference in *attention awareness* between subjects practicing mindfulness and subjects with *null* treatment.

$H_{0,2}$ There is no difference in *attention awareness* of subjects at different moments of time.

Techno-stress Hypotheses

$H_{0,3}$ There is no difference in *techno–stress* between subjects practicing mindfulness and those subjects with *null* treatment.

$H_{0,4}$ There is no difference in the *techno–stress* of subjects at different moments of time.

Performance Hypotheses

$H_{0,5}$ There is no difference in *performance* between the subjects practising mindfulness and those subjects with *null* treatment.

$H_{0,6}$ There is no difference in the *performance* of those subjects at different moments of time.

G. Design

In the current field experiment, as we did in the previous experiments in the family, we used a 2 (*moment*) *x* 2 (*group*) *mixed factorial* design [47], i.e., (i) the *moment* factor is a within–subjects variable since all the subjects were measured before and after treatment, which is commonly known as repeated measured design, having two levels of *moment* (PRE and POST mindfulness), whereas (ii) the *group* factor is a between–subjects variable with two levels, the *Exp* and the *Ctrl* groups, and each subject only belongs to one group.

It is noticeable that while the *Exp* group received de treatment (labeled as *Mindfulness Training #1* in figure 2), the *Ctrl* group was placed on a waiting list with *null* treatment, as detailed in Section III-B.

IV. Execution

Several days before starting the field experiment conduction, the employees were invited to a 30–minute meeting in which the researchers presented the ongoing research and explained how mindfulness could improve their attention, mood, and professional activity while reducing stress. After the presentation, the employees were given an interest questionnaire to fill in.

Once the answers were analyzed by the experimenters, the employees were split randomly into two groups, except two employees who showed no interest in participating and were therefore kept aside from the sample. The rest of employees filled the MAAS and *techno–stress* questionnaires manually.

Next, the developers assigned to the *Exp* group were given an introductory seminar about mindfulness which took about one hour. In this opening session of the mindfulness training, employees' attendance was controlled using of a sign–in sheet.

Then, for six weeks, the *Exp* group attended to a 15–minute guided mindfulness session before the start of their workday, four days a week. Being in silence and motionless, a session comprises a *body scan*[6] and an attentional exercise consisting of an invitation to observe breathing, discarding thoughts, emotions, or other interruptions. The sessions were carried out always in the same room and attendance was also controlled by means of a sign–in sheet. Some chairs were left empty near the door in case employees arrived some minutes late.

Once the mindfulness training was finished, both the *Exp* and *Ctrl* groups filled out the second MAAS and *techno–stress* questionnaire manually. Notice all the activities described above were delivered during the ordinary working day.

A. Data Collection

For each subject, the following data was collected: responses to the interest questionnaire and both MAAS and *Techno–stress* questionnaires. For subjects in the *Exp* group, the number of sessions in the mindfulness training and the responses to the perceived benefits of mindfulness in their *well–being* were also collected by the PBMW questionnaire.

In addition to the questionaries mentioned above, the *performance* measures were collected in the form of CSV files generated by the execution of several queries to the corresponding INPRO *task management systems* where the employee's daily activity is recorded, such as REDMINE or GLPI. To avoid the influence of day-to-day work-load variability on the results, we collected data for eight weeks. To gather subjects' *performance* for the time period related to *pre–treatment*, data was collected four weeks prior to the mindfulness intervention (weeks 1–4 in Figure 2). On the other hand, to gather subjects' *performance* on the *post–treatment*, the last three weeks of mindfulness training (weeks 8–10 in Figure 2) plus one week after the intervention (week 11 in Figure 2) were considered. We refrained from collecting data during the first three weeks of mindfulness practice based on prior research [48] indicating that effects do not emerge until after this initial period. To obtain a balanced dataset, we collected data for four weeks in each time period.

Given a new edition of mindfulness training for employees in the *Ctrl* group was held (*Mindfulness Training #2* in Figure 2), the corresponding responses to the PBMW were incorporated to the dataset, closing the process of data collection.

[6]A brief review of each part of the body at a time, to be conscious of this part and try to remove tension, if any.

V. Analysis

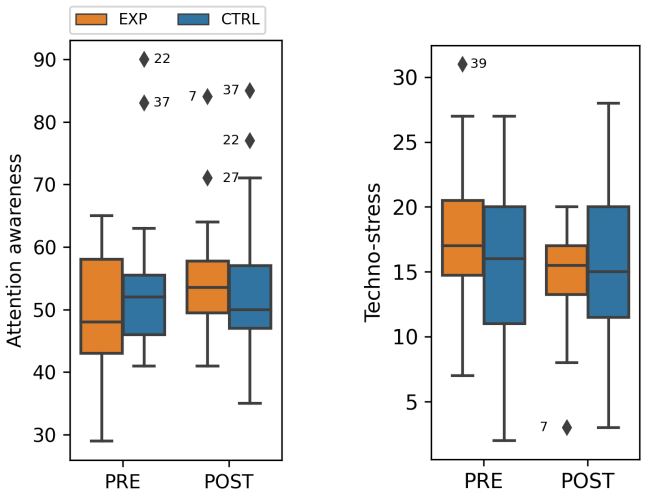
A. Descriptive Statistics and Dataset Preparation

The data analysis was carried out only for those employees considered valid according to the criteria selection depicted in Table IV. As a result, of the 24 participants in the *Exp* group and 27 in the *Ctrl* group that we had at the beginning of the study (as shown in the first row of Table I), we have a sample of 19 participants per group, except for the case of *performance*, where the total sample size is 18 participants.

Table IV: Inclusion criteria and flow of participants per group

Criteria Selection Items	*Exp*	*Ctrl*
To give consent while completing the interest questionnaire	24	25
To have attended at least at 60% of sessions of the *Mindfulness Training #1*	20	–
To have completed both questionnaires (PRE and POST)	19	19
To have available metrics for *performance* resp. variable	8	10

Once the sample is determined, in order to prepare the dataset some actions have been performed. On the one hand, to provide a clear depiction of the effects of mindfulness on *techno–stress* we have computed the values shown in the figures of techno-stress as the maximum possible value to be assessed by the questionnaire (7*6=42) minus the sum of the scores provided by the users according to the Likert scale, this provides a scale where the higher the value, the higher the affliction by techno-stress, which is easier to interpret. On the other hand, to prepare the *performance* data, we extracted the records from REDMINE and GLPI and calculated the TC as the main *performance* metric used in the study. To do so, we considered each task-closing event generated by each experimental subject. Depending on the specific date on which the closing event occurred, we either accumulated it into the TC measurement for the *pre-* or *post-treatment* phase (*performance* PRE and *performance* POST in Figure 2), or we discarded it altogether if it did not fall within either period.



(a) MAAS (b) Techno–stress

Figure 3: Boxplots by group and *moment*

Table V: Mixed model ANOVA table for Attention Awareness

	DF	MS	F	p	η_p^2	Pow
moment	33	48.057	1.776	0.191	0.051	0.771
*group *moment*	33	136.353	5.041	0.031	0.132	0.721

B. Attention Awareness and Techno–stress (RQ_1)

Due to the effect of the mindfulness intervention, we expect the *Exp* group to have higher scores in *attention awareness* and lower scores in *techno–stress* than the *Ctrl* group, after the *Mindfulness Training #1* (as stated by $H_{0,1}$ and $H_{0,3}$).

The boxplots displayed in Figures 3(a) and 3(b) show differences between the evolution of employees practising mindfulness and those in the *Ctrl* group for *attention awareness* and *techno–stress* respectively. After conducting a thorough analysis of the outliers depicted in the boxplots, we concluded that they were natural outliers, and they were retained as part of the sample used in this study.

To analyze the hypotheses, we first confirmed that the groups satisfied the assumption of normality and homoscedasticity. We then conducted a mixed-model ANOVA, for both between-group and within-group factors as outlined in the experimental design described in Section III-G. The effect sizes of the variables were computed using η_p^2.

As we hypothesized, the mixed-model ANOVA conducted on the *attention awareness* test (Table V) found that employees in the *Exp* group achieved significantly higher levels of *attention awareness* after the intervention compared to the *Ctrl* group, as described by the *moment* **group* interaction (p = 0.031), with a moderate effect size (η_p^2 = 0.132). In a similar way, the test (Table VI) revealed a significant decrease (p=0.016) in the levels of *techno–stress* expericenced by employees in the *Exp* group compared to those in the *Ctrl* group, with a large effect size (η_p^2 = 0.150) at the $\alpha = 0.05$. Consequently, we reject the null hypotheses $H_{0,1}$ and $H_{0,3}$.

Table VI: Mixed model ANOVA table for Techno–stress

	DF	MS	F	p	η_p^2	Pow
moment	35	66.216	7.301	0.011	0.173	0.99
*group *moment*	35	62.333	6.872	0.013	0.164	0.99

Table VII: Mixed model ANOVA table for Tasks Closed (TC)

Source	DF	MS	F	p
moment	15	3.182	0.002	0.966
*group *moment*	15	558.41	0.326	0.576

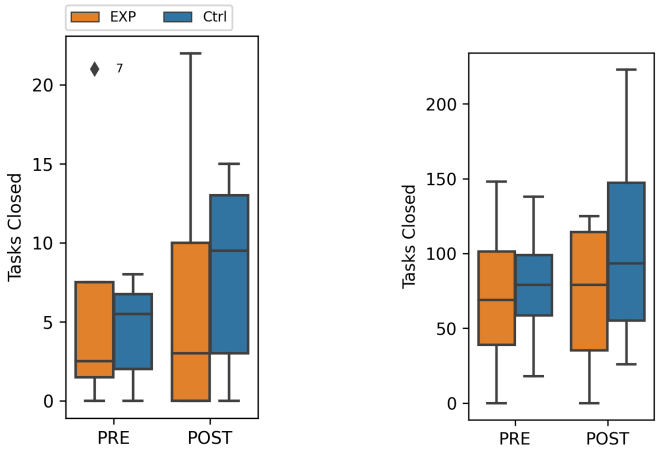
With respect to hypotheses $H_{0,2}$ and $H_{0,4}$ (Tables V and VI), there is not enough evidence as to reject $H_{0,2}$ (p = 0.242) at $\alpha = 0.05$. However, we can reject $H_{0,4}$ (p=0.011) with a moderate effect size (η_p^2 = 0.109). This indicates that although the observed improvement in *techno–stress* is an effect of the mindfulness intervention, the *moment* (*pre* or *post–treatment* phase) of the measurement could have also impacted the perceived *techno–stress* of the experimental subjects. We have determined that the statistical power for all factors related to *attention awareness* is above 0.7, and for *techno–stress*, it is above 0.99. This suggests that the likelihood of detecting a true effect using the tests is high, considering it acceptable.

C. Performance (RQ_2)

Unfortunately, although most subjects participated in the surveys on psychological factors, only 18 subjects provided data about their *performance*. Figures 4a and 4b show the tasks closed by the subjects in the Development and Operation departments respectively. The figures indicate an increase in the number of tasks closed on POST in general, with a more notable increase in the *Ctrl* group, particularly in the Development department. As discussed in Section III-E and illustrated in the boxplots (Figure 4), the type of tasks performed in each department under study has a significant impact on results. Therefore, we performed an ANOVA mixed model analysis with the *Dept* as a covariate. The use of such covariate allows us to study the effect of the treatment while controlling for the effect of the kind of tasks performed in each department.

After ensuring that the assumptions of the ANOVA test are fulfilled for the data, we obtained the results shown in Table VII; the differences were not statistically significant for neither *group* (p =0.576) nor for *moment* (p =0.9666). Based on the results presented in Table VII, we can conclude that there were no statistically significant differences between the *Exp* and *Ctrl* groups, nor between the PRE and POST moments in terms of the number of tasks closed.

Contrary to our intuition, we can not reject the hypotheses $H_{0,5}$ and $H_{0,6}$. Therefore, there is not evidence as to conclude that the practice of mindfulness has impact on the *performance* of the experimental subjects. Further research focusing on the *performance* of each department separately with a larger sample size could be a suitable direction for future work.



(a) Development (b) Operation

Figure 4: Tasks done by department

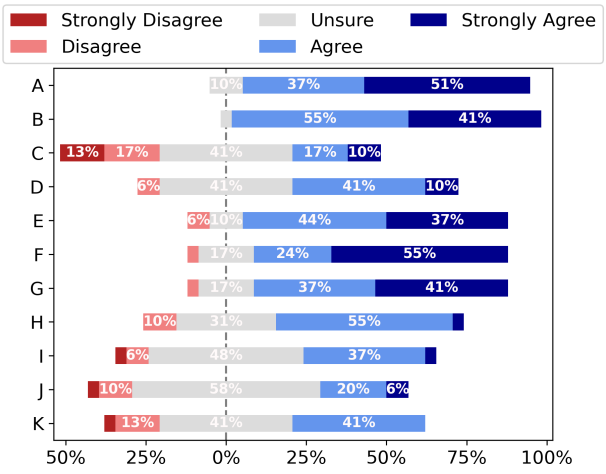


Figure 5: Stacked divergent bar chart for PBMW questionnaire

D. Well–being (RQ_3)

As mentioned in Section III-B, after attending their respective mindfulness training, participants filled in the questionnaire shown in Table III (Section III-D). As shown in Figure 5, in terms of the participants' experience during the mindfulness training (A–E), the results indicated a high level of satisfaction overall. However, question C shows the worst results, it is possible that the wording of the question could have influenced participants' responses, as it included strong statements such as *at all* and *impossible*.

Regarding the joy of mindfulness practice (F–H), the majority of participants (79%) indicated that they either *Agree* or *Strongly agree*, revealing a high level of satisfaction.

Finally, regarding the perceived benefits observed after six weeks of continued mindfulness practice (I–K) in terms of concentration, being in the present and improving sleep quality, almost half of the responses fall into the *Agree* category, except for the responses to question J, which clearly leans to the left. It is plausible that an increased proportion of employees would have been recipients of such benefits had the duration of the practice been prolonged more than six weeks, as observed in long–term practitioners [49].

VI. Threats to Validity

In this section, threats to validity and the actions performed to mitigate them are described, in accordance with the guidelines established in [1].

Conclusion validity is concerned with the statistical relationship between the treatment and the outcome. The main threat to conclusion validity in this study was the limited sample size. Although 38 subjects completed the experiment, only 18 employees comprised the sample for *performance* due to the reluctance of the participants to be monitored. Nevertheless, we considered conducting a best–effort experiment, as it would provide baseline results for further experiments.

Internal validity is concerned with influences that can affect the independent variable with respect to causality, without the researcher's knowledge. Next, several potential threats to internal validity are analyzed.

(i) History appears when different treatments are applied to subjects at different times. We mitigated this threat by including the *moment* in time when employees were measured as a factor in our design in order to analyze possible differences before and after applying the treatment.

(ii) Maturation appears when subjects react differently as time passes. Including the *moment* in time as a factor in our experimental design helps us to identify whether our results can be affected.

(iii) Mortality appears when subjects drop out of the experiment. To increase motivation, all subjects received mindfulness training; the *Ctrl* group received it at the end of the experiment. Despite this, some subjects have not completed the last MAAS and *techno–stress* questionnaires.

(iv) Selection appears when the subject assignment produces non-equivalent groups. Subjects were volunteers interested in learning mindfulness and the assignment to groups was random, which neutralises this threat.

Construct validity This validity is concerned with the degree to which the operationalization actually reflects what is to be investigated.

(i) Inadequate construct definition occurs when constructs are not clearly defined before they are translated into measures or treatments. In our case, this issue is mitigated for the treatment since the underlying theory of mindfulness is well-established and has been described in the literature, including previous works from the authors.

(ii) Mono-operation bias occurs when the experiment only includes one independent variable, potentially resulting in an incomplete representation of the construct. We mitigated this threat by including the *moment* of time as a factor.

(iii) Mono–method bias appears when hypotheses depend on a specific metric. We mitigated this threat by considering multiple data collection methods and variables.

External Validity. External validity refers to the extent to which research findings can be generalized to other contexts

beyond the original study. There are two main types of interactions with the treatment that may limit such generalization.

(i) Interaction of setting and treatment appears when the experimental setting or material is not representative of the context under study. Regarding material, while MAAS is a validated scale, *Techno–stress* questionnaire was proposed by INPRO managers once the researchers provided them some related *techno–stress* references and *Performance* was measured using a task management system, we are aware that the PBMW questionnaire is an *ad–hoc* resource, thus it could yield different results in other contexts.

(ii) Interaction of history and treatment occurs when the experiment is conducted at a special date or on a special time, or on subjects with a specific previous experience which affects the results. To avoid the influence of one-off workloads when measuring performance, we collected data for eight weeks (four for PRE and four for POST).

VII. Related Work

The influence of psychophysiological factors on software process improvement is an emerging field [50]. Software development is the most extensively studied software engineering activity, and several empirical studies have highlighted that: (i) improved situational awareness can help software developers reduce human errors while programming [51]; (ii) high levels of calmness and attentiveness on developer lead to less time for team managers to review their source code [52]; or (iii) happiness and personality traits positively have an impact on developers' productivity [53], [54].

As a particular psychophysiological factor, the mindful state, may have a positive impact in software engineering practices such as (i) responsiveness during requirement elicitation, in stressful situations, when system requirements are incomplete or unstable [55]; (ii) openness to explore a wider variety of perspectives contributing to a better design [56]; and (iii) willingness to reuse software components developed by other departments avoiding *no–invented–here* bias [57].

Nevertheless, the aforementioned studies present a substantial difference from our current work, since across the series of experiments, we study the effect of the daily mindfulness practice in Software Engineering practitioners. Next, we focus on two related works that are closely related to the family of experiments we carried out.

(i) A controlled experiment was carried out involving 8 agile teams who had been utilizing the Scrum agile methodology for at least three years. The goal was to assess the perceived benefits of mindfulness in agile stand-up meetings after 3-minute mindfulness practise. After gathering data by questionnaires regarding listening skills, decision-making, meeting effectiveness, and emotional responses, the results have shown a positive impact on both skills of the mindfulness group [58].

(ii) A recent longitudinal study was conducted involving participants both students and software workers from various universities and companies in the ICT sector. The goal was to evaluate the effect of a mindfulness programme on outcomes such as attention awareness, perceived productivity and self-efficacy measured by questionnaires. The mindfulness programme consisted of a weekly talk about some topics related to mindfulness and a guided session. The results show subjects experienced positive moods, resilience and calm [22].

VIII. Lessons learned

This section presents the main lessons learned from the whole family of experiments. A discussion of the experiments and their results is summarized for a better understanding.

Table VIII reports the basic experimental setting of each experiment in the series, showing some aspects of Mind#1 that were modified across the series due to previous experimental results and the lessons learned from each experiment. Table VIII shows also the results of each experiment in the series in terms of the interaction *group *moment*.

A. Operationalization of Performance

As outlined in Section I, the primary objective of the series was to investigate performance. To this end, conceptual modeling was chosen as the domain of inquiry for experiments in the University of Seville. This choice was considered appropriate given the established mindfulness benefits of enhanced mental clarity [59], a quality that facilitates the abstraction capacity required for generating high-quality conceptual models [60].

Following a repeated measures design, two conceptual modeling exercises were selected with comparable complexity and problem domains to reduce the influence of these factors on the results. However, the outcomes of Mind#1 and Mind#2 raised suspicions that the exercises employed had a considerable impact on the results. In response, the *order of the exercises* was swapped for Mind#3, and it was observed that the results on effectiveness were inverted compared to the previous experiments (as illustrated in the last column of Table VIII). Subsequently, several statistical corrections were applied to the meta–analysis to mitigate the impact of this circumstance, including the introduction of *the order of exercises* as a covariate. Once this issue was addressed and a larger sample size was used (130 subjects, see Table VIII), the joint analysis of the data revealed slight significant improvements in effectiveness and substantial gains in efficiency. Tips to refine the experimental design in academia are presented in [10].

In the context of the industry (Accenture and INPRO field experiments), using real, objective metrics provided by companies to measure performance was considered a potential solution to the problem of conceptual modeling exercises. By employing general–purpose metrics for performance, we reasoned that improvements in attention awareness, working memory capacity [14], and well–being would result in enhanced performance [17].

However, the results of both field experiments did not align with our initial assumptions about performance (see the last column in Table VIII). Possible causes of this outcome could be (i) the small sample sizes of the studies; or (ii) unmeasured factors in the field experiments, such as intuition or expertise, act as a moderate factor, masking or improving the effect of

Table VIII: Overview of the family of experiments on mindfulness and software engineering.

Study (Sample)	*Performance measures*	*Psychological measures*	*Control condition*	*Findings*
Mind#1 (32)	Effectiveness and Efficiency on conceptual modelling task	Intentionally the blank	Public speaking	+Effectiveness **++**Efficiency
Mind#2 (53)			Waiting list *(Null)*	**+**Effectiveness **++**Efficiency
Mind#3 (45)				−Effectiveness **++**Efficiency
Meta-analysis (130)				**++**Effectiveness **++**Efficiency
Accenture (56)	KPIs such as *Answered phone calls*, *Resolution* or *Errors*	Attention awareness (AA), Well-being		**++**AA **+**Well-being −−Answered phone calls ˜ the rest of KPIs
This study (38/18)	Tasks closed	AA, Techno–stress, Well-being		**++**AA −−Techno-stress ˜ Tasks closed **+**Well-being

Legend: **++** significant increase; **+** improvement in practise (not sign.); ˜ no evidences of impact; − not significant decrease; −− significant decrease

mindfulness on performance [61]. On the other hand, some adjustments that could enhance the conclusions drawn from future experiments could be (i) focusing on specific software development tasks (requirement elicitation, conceptual modeling, code review, etc.), as did some of the works reported in Section VII; and (ii) using more specific performance metrics, which was difficult in our field experiment due to the limited control that we could exert.

B. Control Condition

As depicted in *Control condition* column of Table VIII, in Mind#1 a *public speaking* workshop was given to the control group, at the same time as the experimental group attended the mindfulness workshop. Our intention was to provide a placebo treatment to the control group while offering an interesting activity to prevent dropout. However, during the presentation of Mind#1 at ESEM 2014 [8], some researchers in the audience warned us that public speaking could not be a real placebo. Therefore, inspired by other experiments with mindfulness in the area of psychology [62], [63], we decided to address this threat of internal validity in subsequent replications. As Table VIII shows from Mind#2 onwards, the control group was constituted as a waiting list with *null* intervention during the experimental execution. Regarding this decision, the meta–analysis [28] classified mindfulness controlled experiments into those that compared mindfulness groups with conventional controls (CC), active controls (AC), and inactive controls (IC). The study found that more differences were detected when using CC/IC compared to AC, likely due to the potential effect of the alternative treatment in the AC groups. Note that in psychology, it is common to compare mindfulness with other attentional techniques to determine which is better, but this is not the case in the current series of experiments.

C. Response Variables Accross the Series

Through conversations with students following mindfulness workshops, we became aware of the reported benefits of mindfulness practice. After reviewing the relevant literature, we were encouraged to include additional non-performance-based response variables. In selecting these variables, we considered not only the existing evidence supporting the potential effects of mindfulness, but also the specific organizational challenges faced by INPRO employees, such as the presence of *techno–stress*. Collaborating with managers to schedule and design field experiments, as well as engaging with subjects through conversations after the mindfulness workshops, has been critical to refining our experimental processes. This approach has been emphasized in prior literature [7] as an important element of experimental design. Reporting these insights in our articles serves to avoid tacit understanding and facilitate replications [5], [64].

IX. Conclusions and Future Work

This paper reports on the fifth experiment in a series investigating the impact of mindfulness practice on software workers, conducted in collaboration with INPRO. Specifically, we conducted a field experiment to examine the effects of six weeks of mindfulness practice on employees' *attention awareness*, *techno–stress*, and *well–being*. Our findings suggest that mindfulness practice led to significant improvements in these outcomes for the mindfulness group, when compared with the control group. Performance was also studied, which showed no significant improvement in the experimental group compared to the control group, possibly because the performance measures used were too broad in scope, the sample size was small, or the duration of the mindfulness training was too short.

In addition to the description of the fifth experiment, the lessons learned from the entire family are also summarized in this work. The iterative process of knowledge acquisition across the series of experiments has allowed us to improve aspects of the experimental setting such as the operationalization of response variables, refining the treatment administered to the control group, and identifying additional factors that mindfulness practice may influence.

Our plan for future work involves the creation of a mindfulness programme that will be disseminated both in academia and industry. This programme will include a framework to analyze the impact of mindfulness using soft theory techniques like grounded theory [2], as well as various data collection techniques such as diary studies. This approach will be similar to how other disciplines like psychology study the effects of mindfulness on health practitioners.

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