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An experimental replication on the effect of the practice of mindfulness in conceptual modeling performance☆

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ABSTRACT

Context: Mindfulness is a meditation technique aimed to increase clearness of mind and awareness. In the 2013–2014 academic year, an experiment was carried out to test whether the practice of mindfulness during 4 weeks improved or not the conceptual modeling performance using UML class diagrams of 32 second–year students of Software Engineering at the University of Seville.

Objective: An internal replication with some changes in the original design was performed in the first semester of the 2014–2015 academic year in order to confirm the insights provided by the original study and increase the confidence in its conclusions. The sample were 53 students with the same profile than in the original study.

Method: Half the students (27 subjects) practiced mindfulness during 6 weeks, while the other half (26 subjects), i.e. the *control group*, received no treatment during that time. All the students developed two conceptual models using UML class diagrams from a transcript of an interview, one before and another after the 6 weeks of mindfulness sessions, and the results were compared in terms of conceptual modeling effectiveness and efficiency.

Results: The results of both experiments were similar, showing that the practice of mindfulness significantly improves conceptual modeling efficiency. Regarding conceptual modeling effectiveness, an improvement is observed in practice, but the analysis shows that such improvement is not statistically significant. After a reanalysis of data, consistent results have also been obtained.

Conclusion: After a replication that leads to the same conclusions as the original study, the adequacy of the original experiment is confirmed and the credibility of its results is increased. Thus, we can state that the practice of mindfulness can improve the efficiency of Software Engineering students in the development of conceptual models, although further experimentation is needed in order to confirm the results in other contexts and other Software Engineering activities different from conceptual modeling.

1. Introduction

Mindfulness is a meditation technique which has demonstrated to be useful for, among other things, educating attention and enhancing mental clarity, thus improving problem–solving capabilities, as described by Davis and Hayes (2011), Tan (2012), and Mrazek et al. (2013), among others. After experimenting the benefits of mindfulness at personal and professional levels for some years, we considered that the students in the degree in software engineering at the University of Seville could also benefit from the practice of mindfulness, especially in a technique such as conceptual modeling in which concentration and clearness of mind is so important. In order to confirm our intuition, an experiment—the *original study*—was carried out during the first semester of the 2013–2014 academic year (Bernárdez et al., 2014). In that experiment, a group of students attended a mindfulness training workshop during four weeks, whereas a second group of students—the *control* group—attended a *placebo* training workshop about public speaking during the same amount of time. Two conceptual modeling exercises using UML class diagrams were performed by all the students (see Appendix A), one before and another after participating in the corresponding training workshop, and their performance were compared.

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The conclusions of the original study were promising. After some weeks of practicing mindfulness, evidence suggested that students have a better performance in conceptual modeling compared to the students not practicing mindfulness; i.e. students practicing mindfulness create models of similar quality faster. However, the results in the original study regarding effectiveness—whether students practicing mindfulness produce better conceptual models or not—were not fully conclusive. Some improvement was observed on average, but the differences were not statistically significant.

Thus, we decided to replicate the experiment following a *same experiment & same objects* approach (Gómez et al., 2014) with a twofold purpose: to check the experiment results in order to increase the validity and reliability of the observed outcomes, i.e. the main goal of replications according to Juristo and Gómez (2012); and to overcome some limitations of the original experimental design.

As described by De Magalhães et al. (2014), the publications about replications in SE either i) present one or more replications of an original study, or ii) contribute some knowledge on replication, i.e. process, guidelines, lessons learned, taxonomies, etc. This article corresponds mainly to the first of De Magalhães et al. categories since it presents an internal replication of an original study previously developed by the authors (Bernárdez et al., 2014). To a lesser extent, it also contributes to the second category by providing some lessons learned during the replication (see Section 7.1).

Considering two of the main problems reported by Da Silva et al. (2014) with respect to replication presentation, i.e. the lack of a widely accepted guideline for reporting an experiment replication in Software Engineering (SE), as Carver (2010) comments; and the unavailability of *lab–packages*, that leads also to an increased difficulty for external replications, this work has been organized based on the proposal by Jedlitschka et al. (2008), following some of the recommendations by Carver (2010), and the corresponding lab–pack is available at https://exemplar.us.es/demo/BernardezJSS2016.

Specifically, the rest of the article is organized as follows: in Section 2, the practice of mindfulness is briefly described; in Section 3, a summary of the original study is presented; in Section 4, the replication is thoroughly described; in Section 5, the outcomes of both experiments are compared; in Section 6, related work is commented; finally, in Section 7, the conclusions, lessons learned about replications and the future work are presented.

2. The practice of mindfulness

The term *mindfulness*—the translation into English of the Pali word *sati*, a Buddhist concept meaning awareness, attention, and remembering (Simón, 2013)—refers to a practice in which a person or a group of people draw away to a quiet place for meditating during at least 10 min. During meditation, the intention of the mindfulness practitioner is keeping her mind calmed and focused only on breathing (the usual meditation support because of its unavoidability), discarding any other thoughts that could come to mind. The usual steps for a mindfulness session, based on the recommendations of Puddicombe (2011) and Simón (2013), are summarized in Table 1.

The goal of mindfulness is to transfer the state of consciousness achieved during meditation to ordinary activities, i.e. being aware and focused in daily life, staying in the present moment rather than rehashing the past or imagining the future. By developing the ability to keep focused through acknowledging and abandoning thoughts without identifying ourselves with them, mindfulness helps us to perceive our environment clearly and to solve problems more efficiently by reducing mental wandering while performing tasks.

Table 1
Usual steps for a mindfulness session.

Step	Description
1	Imagine a thread extending from the top of your head, pulling your back, neck and head straight up towards the ceiling in a straight line. Sit tall.
2	Use a timer to set a time limit.
3	Close your eyes and scan your body, relaxing each body part one at a time.
4	Take three slow, deep breaths.
5	Begin to breathe normally, but focusing on your breathing.
6	If thoughts come to you, simply acknowledge them, set them aside, and return your attention to your breath.
7	Enjoy the rare chance to let your mind simply *be*.
8	When you are ready to end your practice, bring your conscious attention back to your surroundings and open your eyes slowly.

2.1. Neurological effects of mindfulness

At a neurological level, the effects of mindfulness are explained by some changes in brain activity, mainly in the prefrontal cortex, which is the main area involved in problem solving, as described by Seligman (2012). A hyperactivity of the prefrontal cortex has the undesired effects of rumination and wandering that, paradoxically, prevent us from solving problems properly and having a clear vision of reality, as commented by Simón (2013). This hyperactivity is one of the consequences of our current relationship with technology, i.e., the ubiquity of Internet–connected devices and the continuous interruptions they generate from social networks, email systems, etc. making very difficult to focus on only one task at a time (Gordhamer, 2013). Some neuroscientists like Brefczynski-Lewis et al. (2007), Lutz et al. (2009), and Brewer et al. (2011) have demonstrated that a continued practice of mindfulness reduces prefrontal cortex hyperactivity while increases the activity of other areas of the brain which are active when concrete tasks are performed.

2.2. Psychological and social benefits of mindfulness

In 1979, Jon Kabat–Zinn founded the *Stress Reduction Clinic* at the University of Massachusetts Medical School and started to apply mindfulness as a therapeutic treatment in the *Mindfulness–Based Stress Reduction* (MBSR) program[1] (Kabat-Zinn, 2003). Other mindfulness–based therapeutic programs have been also successfully applied to individuals prone to anxiety and other chronic diseases, as reported by Grossman et al. (2004), Shapiro et al. (2005) and Germer et al. (2013). For example, in Riebel et al. (2001), neuro–psychologists studied the effects of mindfulness in 136 heterogeneous patients showing that, after two months of daily 20 min practice, a significant percentage experienced better personal well–being in terms of mental clarity, equanimity, wisdom and self–compassion based on standard health surveys (questionnaires).

The benefits of the practice of mindfulness in students have also been reported. For example, Schure et al. (2008) present a qualitative study examining the influence of mindfulness in a 15–week course with graduate students. Participants reported an increase of their mental clarity, organization, awareness, and acceptance of emotions and personal issues. Mrazek et al. (2013) describe a controlled experiment based on *Graduate Record Examinations* (GRE) assessing verbal, quantitative and analytical skills to measure reading comprehension, concentration, level of mind wandering, and working memory capacity. The outcomes showed a

[1] http://www.umassmed.edu/cfm/stress-reduction/.

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