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Enhancing learning at work. How to combine theoretical and data-driven approaches, and multiple levels of data?

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Abstract. This research plan focuses on learning at work. Our aim is to gather empirical data on multiple factors that can affect learning for work, and to apply computational methods in order to understand the preconditions of effective learning. The design will systematically combine theory- and data-driven approaches to study (i) whether principles of effective learning found in previous studies apply to real life settings, (ii) what interactions between individual and organizational factors are related to learning outcomes, and (iii) new connections and phenomena relevant to enhance learning in real life.

1 Introduction

Research on learning and memory is vast and multidisciplinary. Though reviews of cognitive and learning research have found some basic principles of improving memory and learning [1] it remains unclear how well these theories derived from empirical research apply to learning in complex real-life settings. In order to better understand learning, we should apply a theory-driven approach to study learning in its context. We should also make use of technological innovations that provide big data, and use data-driven approaches that offer new explorative ways to utilize all the data relevant in complex situations.

We are planning a research project to test whether research findings on effective learning techniques apply to occupational settings. There is a need for data that reflect the heterogeneous nature of the population in working life and the complexity of learning tasks and materials, and thus includes relevant individual characteristics and organizational factors.

1.1 Evidence for effective learning techniques

Research on cognitive and educational psychology suggests two main techniques that effectively improve learning on an individual level [1]. Our project will concentrate on these techniques, namely (i) practice testing and (ii) distributed practice (spacing). The term practice testing refers to active testing that students engage in while studying. Distributed practice refers to practice and learning being spaced over time.

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Although there are hundreds of studies showing the effectiveness of these techniques, most of them involve verbal material that is relatively simple [1] and irrelevant to most occupational training contexts. A few previous studies also show the advantages of practice testing with longer text materials, video lectures, spatial locations, symbols, and skills of resuscitation. Distributing practice has similarly been shown to improve performance in a range of domains and skills [2]. However, new data are needed on the applicability of these findings to real occupational contexts.

1.1.1 Factors that affect learning

There are a number of individual characteristics that affect learning and memory, such as age, prior domain knowledge, working memory capacity, motivation, and self-efficacy [e.g. 3, 4]. However, there are few studies on whether these individual factors influence the effectiveness of a given learning technique [1], an issue highly relevant to understanding learning in practice, where the group of learners has a wide range of abilities and attitudes. The few studies on the issue suggest that the testing effect can be found at different knowledge levels, and that the testing and the spacing effects generalize to learners of different age groups [1]. There is therefore a need for more data on other individual characteristics interacting with the testing and the spacing effects, in order to identify whether heterogeneous groups in occupational training benefit from these techniques.

1.2 **Learning safety at work**

In this project, we will concentrate on learning at work. An example of such are training programs to improve occupational safety: the safety of people that are at work, which is tightly coupled with organizational safety. Improving occupational safety encompasses improving the awareness and behaviour of the people at work, but also improving the environment in which they work, in order to make it as safe as possible. Due to the number of aspects involved, improving occupational safety is hard. Training workers is one of the approaches through which organizations aim to contribute to the improvement of occupational safety.

1.2.1 Safety training

Many different training methodologies have been developed with the aim to contribute to safety, specifically to address awareness [e.g. 5] or to address safety related behaviour [see e.g. 6]. One example is the Finnish Occupational Safety Card, an official qualification obtained by completing a standardized one-day course. The training includes information on safety laws and regulations, as well as best practices to avoid incidents. Learning goals are tested with a multiple choice exam which assesses the individual's knowledge and understanding of the issue. Although this training - and many other training programs - are commonly accepted, little is known about their effectiveness in improving workers knowledge and behaviour and safety in the organization.

1.2.2 Improving safety in the organization through learning

Although training addresses the knowledge and behaviour of employees, safety research has shown that some organizational factors, such as safety climate, trust in

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the management, organizational culture, and social aspects, also have an effect on learning [6, 7, 8]. Therefore, when developing training programs, or when studying their effectiveness, it is important to gather background data from the organizations, and to understand what happens before and after training [9, 10].

Another important aspect when improving safety is that not only individual learning outcomes matter. If occupational safety training is effective, not only the behaviour of individual workers, but also the organizational safety performance improves. Organizational learning is a process in which information is acquired and used for continual improvement of weaknesses in the organization, such as the ability of the organization to respond to errors and unwanted situations, and to learn from incidents [for a review see 11]. In our project, we find it important to assess and gather data on organizational learning outcomes as an addition to individual outcomes.

1.3 New technologies provide big data

During the last decade, new technologies have influenced where and how training and learning occurs. Furthermore, technological learning innovations enable automatic collection of information about the process of training and learning, whereas mobile and quantified-self technologies provide information on the wider contexts of learning, and the psychological and physiological state of the individuals. As the amount of data has increased, data-driven analysis methods have developed as well, which is useful for both the theoretical and practical aims of understanding the enhancement of learning.

Our plan is to create new big data on learning at work: a heterogeneous and high-dimensional data set collected with several methods and on multiple levels. We will utilize new technologies to measure various independent variables that are likely to affect learning. By using a theoretical approach and psychometrically sound methods as well as modern data-analysis methods, we expect to minimize the amount of irrelevant, ambiguous, and contradictory data and find novel regularities in the big data created during the project.

The main research question in our multidisciplinary study is whether the two learning techniques - testing and spacing - affect individual and organizational learning when applied in occupational training. We study the influence of both individual-level and organizational factors on the effectiveness of learning techniques.

2 General method and design

The study consists of five stages: two stages before the training session (background and pre-training), the training session (1-3 days), and two stages after the training session (post-training, follow-up). Throughout these stages, we use several methods to create the high-dimensional dataset, including surveys, self-assessments, physiological measurements, computerized tests, and learning applications.

The participants are divided into four different learning condition groups with a between-subject design in which one, both or none of the learning techniques (testing during training and/or distributing practice with pre- and post-training assignments) is used in the training group.

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2.1 Participants

In order to find participants for the study, we are collaborating with institutes that provide occupational training and the organizations that send their workers to these trainings. Participants are people who are participating in the specific occupational safety training (the target group) and their colleagues.

2.2 Questionnaires and measurements

The following section gives a brief overview of the measurements in our research plan. It shows the variety of data that are used throughout the five main stages in the study. Some variables are measured only in one phase (e.g. background measurements at base-line stage), whereas others are repeated two or three times.

2.2.1 Individual-level variables

Individual information is collected through a survey, computerized tasks and through physiological measurements. The survey contains questions on demographic information, on experience (other training lessons in occupational safety, and whether this is a first time attendance or obligatory rehearsal), on cognitive capacities (through computerized cognitive tests and use of 15 items from the Workplace Cognitive Failure Scale [12]), on well-being (through standardized questionnaires on stress, work load, and work engagement) and other individual level variables (through standardized motivation and task engagement scales). The physiological measurements will only be tested in a selected subset of participants in the target group, primarily with EEG and eye activity, to assess brain physiologic state (e.g., vigilance, alertness) during training.

In addition to these measures, several aspects will be measured that are relevant to learning outcomes: knowledge on the subject matter will be tested with to-be-defined tasks, and performance in course assignments and multiple-choice tests are also used as individual level learning outcome variables. Subjective measures on learning and positive change will also be included in the questionnaire.

2.2.2 Organization-level variables

Organization-level variables are studied both in the target group and among other workers of selected organizations in which the participants in the training group work. Organization-level variables are used as background variables but the change between in the initial and post-training measurements is used as organizational outcome measure.

Several instruments are available to measure specific aspects of safety [see for instance 13,14,15]. Specific safety indicators, such as lost time injury rates, percentage of absence caused by illness, and number of safety reports, company specific indicators, and process safety indicators will be used to assess whether training affects safety on organizational level [15]. These indicators will be combined with an organizational background survey, which will include items relevant to learning and occupational safety. Part of the working conditions survey will be included, to assess factors that are likely to disrupt cognitive functioning and learning, such as interruptions, work load, and problems in communication [16].

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2.2.3 Learning environment variables

Since several training groups are studied, there is variation in the learning environment, and several aspects have to be considered as independent or moderating variables. Relevant background variables include learning content, the trainer, and the time and the place of the course, and the type of the e-learning application. Factors related to other participants in the training and their number may also moderate learning effects. As a distal learning environment we use survey items to study support from the organization and opportunities to use what was learned.

2.3 **Data analyses**

We will collect data that offer more information on the learners and conditions than previous research did. We will apply classical modelling techniques and parametric statistics to test the hypothesis that the testing and spacing effects generalize to real life and use descriptive analytics methods to profile in greater detail which factors and what learning activities lead to enhanced learning.

In the data analyses we will construct probabilistic models which are constrained by theories of learning and memory, and we will use the empirical data to fit the models. Individual data points are fitted in the models, rather than aggregate measures. With computational probabilistic models, we can incorporate individual differences and handle datasets with several measurements and variables in a novel way, and explore the rich data set for new connections and phenomena.

3 Conclusions

The main impact of the project will be a new and interdisciplinary understanding of learning and memory in a real-life occupational training context. The design will systematically combine theory- and data-driven approaches and thus allows testing predefined hypotheses, that is, the effect of testing and spacing on learning in real life. The results will also show the interactions between individual and organizational level factors and learning conditions that are related to learning outcomes. The thorough data analyses may lead to unforeseen discoveries; new efficient individually-adjusted training methods would have a major practical impact on occupational training.

Combining different approaches and disciplines will be challenging. However, the era of Big Data provides new opportunities to advance both theoretical and practical understanding also within the psychological sciences [17]. From the theoretical perspective, it is crucial to understand how individual characteristics and environmental factors moderate which techniques enhance learning. From the practical viewpoint, new research-based knowledge is crucial as organizations want to invest in training and development programs that are proven to be effective.

We aim to create the best possible design and opportunities for using new methods of collecting and analysing big data. Your feedback is welcome and you are welcome to contribute and join us in planning a study on enhancing learning for work.

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