International Journal of Industrial Ergonomics 67 (2018) 123–134

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Can cued recall by means of gaze guiding replace refresher training? An experimental study addressing complex cognitive skill retrieval

Barbara Frank*, Annette Kluge

Ruhr-University Bochum, Business Psychology, Department of Work, Organisational and Business Psychology, Faculty of Psychology, Building GAFO 04/273, Universitätsstr. 150, 44801 Bochum, Germany

ARTICLE INFO

Keywords:
Refresher training
Visual cueing
Attention guidance
Complex task
Retrieval

ABSTRACT

Skills required for non-routine situations are learned in initial training but are rarely applied during work. Such skills decay if they are not rehearsed repeatedly, e.g. in refresher interventions. A promising concept to counteract skill decay is gaze guiding, which has the potential to reduce the consequences of skill decay by means of cued recall. The present study explores whether gaze guiding can be used as an alternative to refresher interventions. Fifty-five participants learned a complex cognitive skill required for a production task. After two weeks, they recalled the initially learned skill either with support of the gaze-guiding tool (Gaze-Guiding group) or without support (Practice-refresher intervention group or Control group). The participants of the Practice-refresher intervention group repeated the initially learned skill in week 2. The results show that gaze guiding supports the precise execution of a task and is a promising technical tool for cued recall and retrieval support. *Relevance to industry:* Refresher interventions are popular methods for skill retention. A resource-saving alternative is an adaptive computer-based job aid which supports the operator's skill retrieval in the recall situation. It is a further development of step-by-step guidance with computer-based procedures and appears only when the operator fails to remember the task operation.

1. Introduction

Over the past decades, automation has led to technological advances in industry.

The use of automated manufacturing processes (such as in refineries, power plants or chemical plants) means that operators are located in the process control room and handle, control and monitor the machines and processes from a safe distance. This work requires the execution of complex tasks. Such tasks consist of multiple elements that have to be executed successfully, e.g. monitor various parts of the plant, anticipate upcoming events, make decisions, communicate decisions and execute decisions (Proctor and Vu, 2006; van Merriënboer, 1997). The operators acquire these relevant skills for handling complex tasks during skill acquisition in initial vocational training. After the initial vocational training, some skills are only applied very rarely. For instance, operators do not usually handle the plant manually, but in the case of technical faults, incidents or break-downs, they have to be able to recall once-learned skills on how to handle upcoming events manually. Such rare situations are called non-routine situations (Kluge, 2014). As skills that are necessary for handling non-routine situations can decay over time, a lack of initially learned skills after a period of non-use can result in incorrect execution, low performance and (increased) errors. This is termed skill decay (the opposite of skill decay is termed skill retention; Arthur et al., 1998).

The "New Theory of Disuse" (Bjork & Bjork, 1992, 2006) explains the decay of skills in terms of storage strength and retrieval strength. The former describes how well information is acquired and stored in memory, while the latter describes the extent to which stored information is accessible. Accordingly, well-designed initial vocational training should create high storage strength, and continuous repetition maintains retrieval strength. Therefore, in addition to storage strength, high retrieval strength is necessary for skill retrieval. With regard to the aforementioned occupational setting of longer periods of non-use, this means that retaining seldom-used skills is challenging because the lack of retrieval activities during periods of non-use leads to a loss of retrieval strength (Arthur et al., 2013).

The currently existing common methods used for counteracting skill decay basically support the retrieval strength *before* the recall of a skill is necessary (Wang et al., 2013). This means that operators are continuously preparing themselves for rarely occurring non-routine situations, without knowing when learned skills will be required or even whether they will be required at all. Refresher interventions are an

* Corresponding author.
E-mail address: barbara.frank@rub.de (B. Frank).

https://doi.org/10.1016/j.ergon.2018.05.007
Received 24 August 2016; Received in revised form 14 April 2018; Accepted 17 May 2018

effective and popular but resource-consuming method for maintaining the retrieval strength of acquired skills before the recall situation occurs. With reference to the New Theory of Disuse, refresher interventions aim at providing constantly high retrieval strength. Such interventions take the form of preventive training activities that occur with predefined frequencies after initial training (e.g. every quarter, once a year etc.). In some industries, for example in aviation or nuclear power plants, the predefined frequencies of such recurrent trainings or refresher trainings are regulated by law (e.g. EASA, 2012; BfS, 2013). However, in many other industries, no such regulations exist and refresher interventions are not applied due to the resources required in terms of time, personnel and equipment, even though research has found that practical repetitions or practical relearning are especially effective for recalling and executing skills after a period of non-use and for reducing errors (e.g. Kluge and Frank, 2014).

The lack of effort to implement refresher interventions in non-regulated industries has led to the conclusion that an alternative to refresher interventions, with comparable retrieval support, might be preferable. Such an alternative can be implemented by the enhancement of computer-based procedures which were designed and analysed for the operation in control rooms in the past (Fink et al., 2009; Xu et al., 2008). A further development of computer-based procedures and new solution analysed in the present study is the support of skill retrieval *after* a period of non-use with gaze guiding that supports cued recall and compensates for low retrieval strength. This means that instead of rehearsing initially learned skills in the time between skill acquisition and skill recall, retrieval is directly supported in the recall situation (and not at some point before). Gaze guiding is less resource-consuming for an operator than attending a refresher intervention. It belongs to the family of adaptive computer-based job aids and is a human-machine interface that guides an operator's attention to significant areas on the screen, enabling her/him to find relevant information for the next step efficiently (Kluge et al., 2014). With reference to the New Theory of Disuse, gaze guiding is created to compensate for low retrieval strength after periods of non-use and support the retrieval in the recall situation.

The present paper investigates whether a gaze-guiding tool can compensate for low retrieval strength and support retrieval in a recall situation after a period of non-use (to achieve a comparable performance to that at the end of skill acquisition). Further, it explores whether the gaze-guiding tool could potentially be used as an alternative to refresher interventions for skill retrieval in a simulated process control task.

1.1. Non-routine situations and complex cognitive skills

Complex tasks are performed in routine and non-routine situations. Non-routine situations are situations in which operators are required to recall once-learned skills after a period of non-use. Examples of such situations include starting up a plant, solving issues or taking corrective actions after incidents. For handling non-routine situations, operators learn and use “standard operating procedures” (SOPs, Kluge, 2014). SOPs are predefined procedures that describe how and what the operator has to do on upcoming occasions (Wickens and Hollands, 2000). They form part of the complex cognitive skills which are necessary to handle a complex task. Complex cognitive skills are a combination of cognitive and motor skills, although most of the required skills fall under the cognitive category (van Merriënboer, 1997). Such complex cognitive skills are required, for example, in process control, air traffic and computer programming (van Merriënboer, 1997). Operators have to know what to do and how to execute the steps of the procedure at the right time and in the right sequence (interface interaction, timing, sequence of steps, rules).

In the present paper, the start-up procedure of simulated waste water treatment is used as a non-routine situation which requires complex cognitive skills (below in Methods).

1.2. Cued recall

Cued recall is the recall of elements from memory triggered by cues (Moult, 2011). An example of cued recall is remembering words with the support of word categories (Carrier and Pashler, 1992). Research on memory and retrieval shows that cued recall is less difficult than free recall (Tulving and Thompson, 1973; Watkins and Tulving, 1975). Job aids constitute a method for applying cued recall for complex cognitive skills, and are used to process, store and extend information (Kluge et al., 2013; Swezey, 1987). Job aids support skills that are used infrequently, consist of sequences, and/or contain a great amount of information, or skills that can cause serious consequences if performed incorrectly (Rossett and Gautier-Downes, 1991). A classical procedural job aid is designed to guide users through the procedure step by step by means of written checklists (Salas et al., 2006; Swezey, 1987). However, in a computerised environment, e.g. process control, this aid has its shortcomings: It is a paper-based method, meaning that operators have to search extensively through a number of checklists to find the right one, and then apply it step by step, switching between their desktop and the checklist. Moreover, written checklists are not able to support the user's timing of actions and do not show dependencies (this has to be interpreted and understood by the user). A paper-based method can be improved by digitisation, as recent research shows the positive impact and improvement potential of digitisation in control rooms of many industries e.g. in refineries or (nuclear) power plants (e.g. Lin et al., 2016). In the present paper, the advantages of cued recall and the advantages of computer-based technology are combined to further develop the principles of job aids to support the retrieval of once-learned skills.

1.3. Attention guidance with job aids

It is argued that the impact of classical job aids can be enhanced by computer-based technology suitable for computerised jobs, e.g. process control. This is why the shortcomings of paper-based classical procedural job aids has led to the development of computer-based procedures which are e.g. used to guide the operator step-by-step through the procedure with e.g. flow charts, graphics and further information implemented within the interface (O'Hara et al., 2000; Xu et al., 2008). A further improvement of computer-based procedures can be implemented with an adaptive computer-based job aid. The advantage of this kind of job aid is that it is implemented within the task and interface: It shows operators the relevant next steps without explicit searching, it appears dynamically and only when needed, it guides operators' attention and it supports the timing of actions. Adaptive computer-based job aids seem to be particularly promising as a cued recall tool for complex cognitive skills that is able to support retrieval even if retrieval strength is low after periods of non-use. An adaptive job aid “jumps in” by adaptively presenting relevant visual cues and information about what to do next if the operator fails to remember the next step and stops interacting with the system. In the best case scenario, this means that such an aid provides guidance by highlighting relevant cues during the task to support the user's needs directly (Groen and Noyes, 2010). Adaptive computer-based job aids have already been used for skill acquisition and can be applied through various methods, such as “attention guidance " and “visual cueing”. These methods guide learners in understanding complex material, from which it may be challenging to select relevant information and perceive relevant cues (Mayer and Moreno, 1998):

- Attention guidance: The attention guidance technique facilitates the search for relevant information and problem solving by lighting up salient and critical information and by darkening irrelevant information. It has been applied in medical skill training to learn the human body system (De Koning et al., 2007, 2010).
- Visual cueing: Visual cueing highlights, for example, tasks, graphics