ENHANCING RESILIENCE BY INTRODUCING A HUMAN PERFORMANCE PROGRAM

Kaupo Viitanen[1], Christer Axelsson[2], Rossella Bisio[3], Pia Oedewald[1] and Ann Britt Skjerve[3]

[1] VTT Technical Research Centre of Finland, P.O. Box 1000, FI-02044 VTT, Espoo, Finland

[2] Vattenfall AB, Sweden

[3] Institute for Energy Technology, Norway

kaupo.viitanen@vtt.fi

+358 40 845 7618

www.vtt.fi

Abstract

In nuclear industry, human performance programs (HPPs) are commonly used to provide practical solutions for addressing human and organisational issues at nuclear facilities. Human performance programs are implemented by formalizing a selection of working practices called human performance tools (HPTs). In this paper we discuss the insights from our case studies carried out in Nordic nuclear power plants and the input received from human performance experts around the world, and reflect the relation of HPPs to system resilience.

Based on the results of our studies we argue that HPPs have the potential to enhance resilience through various mechanisms. These are i.a. improving organisational learning and monitoring, enhancing staff's understanding of the sociotechnical system of a nuclear power plant, developing practices that help managing the unexpected or providing means of training. The HPPs may, however, also have the potential to be detrimental to resilience. If improperly implemented, HPPs may lead to rigidity and "robotic" ways of performing work, which can even cause safety deteoriration. Therefore, an implementatation process that properly considers the role of HPTs in everyday work and is developed in participation with shop-floor staff is crucial for a successful human performance program.

1 INTRODUCTION

Managing human and organisational factors is a key ingredient in maintaining and improving safety in nuclear power plants. Several approaches are used to provide practical solutions for this issue. In recent years, one of the more popular means to address human and organisational factors has been to introduce a human performance program (HPP). HPPs are typically promoted by various umbrella and peer organisations as development programs that improve safety by reducing active errors and strengthening controls (DoE, 2009a). It is proposed that errors can be reduced through anticipation, prevention, catching and recovering, and controls can be strengthened by means such as eliminating latent weaknesses, removing hazards, engineering barriers, developing instructions or procedures and furthering error-prevention through cultural norms (DoE, 2009a). In practice HPPs are introduced by formalizing a selection of various working practices called human performance tools (HPTs; see Table 1) (DoE, 2009b). Even though HPPs also include examples of practices for management, usually HPPs are targeted solely at the sharp end staff.

The validity of the human-error-focused strategy on safety improvement that also serves as a theoretical background for HPPs has been under debate in the scientific community. It has been argued that rigid control and increased amount of limitations complicate or hinder the execution work, sometimes even causing deterioration of safety (Dekker, 2003). A complementary approach to the error-focused strategy has been proposed by the Resilience Engineering tradition. This approach suggests that instead of focusing on minimizing errors and mistakes, one should switch focus to ensuring that activities result in successes under varying conditions (Hollnagel, 2013). In practice this could mean creating and supporting the preconditions that help various actors in an organisation to perform their work in such a way that results in safety. The aim of this paper is to discuss the relation of HPPs and resilience and provide insights based on the material obtained from our previous studies (Oedewald et al., 2014; Oedewald, Skjerve, Axelsson, Viitanen, & Bisio, 2015; Skjerve & Axelsson, 2014). Our main argument is that even though the explicit rationale underlying HPPs follows a rather error-focused view of safety, due to the adaptive and contextual nature of the HPTs ranging from prescriptive to sensitizing to unexpected situations, HPPs may in practice function as positive, resilience-enhancing programs for working practices.

Table 1. *Commonly adopted HPTs grouped by the level of prescription (Skjerve & Axelsson, 2014)*

Human performance tool	Description
Promoting adherence to procedures or instructions	
Procedure use and adherence	reducing unwanted events by using and adhering to procedures
Catching errors	
Clear communication techniques (e.g. three-way communication and phonetic alphabet)	means of avoiding misunderstanding in communication
Peer-checking	a pair work technique where one worker observes while another performs the task
Independent verification	an independent worker verifies the task result after completion
Sharing insights and experiences	
Pre-job briefing	a meeting during which all involved prepare for the work task
Post-job review	a meeting during which a completed task is discussed
Task observation	reviewing the quality and effectiveness of tasks by management
Use of operating experience	improving the way in which work is conducted by implementing operating experience programs
Sensitizing to unexpected states or events	
Self-checking (a.k.a. STAR-principle)	a method of boosting attention while performing a task (includes steps of Stop-Think-Act-Review)
Questioning attitude	fostering of uncertainty awareness

HPTs are a heterogeneous variety of working practices that range from simple aids used by an individual to resource-heavy meetings held by a group of people. Even though HPP programs are typically promoted with an error-prevention focus, HPTs may also address several other functions. Four general groups of HPT functions have been identified based on their level of prescription (Skjerve & Axelsson, 2014). The four groups are promoting adherence to procedures or instructions, catching errors, sharing insights and experiences, and sensitizing to unexpected states or events (Table 1). These functions can be further elaborated by considering how they relate to balancing flexibility and rule-based control of work (Grote, 2006; Grote, Weichbrodt, Günter, Zala-Mezö, & Künzle, 2009). Tools at the prescriptive end of the continuum are more geared towards minimizing uncertainty and promoting rigid, non-adaptive working practices. The other end on the other hand can be seen to support coping with uncertainty. Some HPTs fall in between of these extremes (e.g. pre-job briefing and post-job review) and can be seen to have the potential to have aspects of both coping with and minimizing uncertainty. It is argued that both minimizing and coping with uncertainty approaches are required for sustaining resilience (Grote, 2006), which suggests that depending on their contextual application, HTPs from all categories may be beneficial for resilience. HPTs may also contribute to system resilience by addressing Resilience Engineering cornerstones (Pariès, Hollnagel, Wreathall, & Woods, 2012). For example, pre-job briefing may provide support for anticipation and responding, and post-job review can have the function of furthering organisational learning (i.e. the change in organisation's knowledge as a function of experience; Argote, 2013). We argue that the most relevant HPTs to system resilience are those that have the potential of furthering sharing of insights and sensitizing to unexpected events, but also that the use of the more prescriptive HPTs may be beneficial for system resilience when a situation calls for such approaches. The role of the HPP in enhancing resilience would thus be implementing the HPTs in such a manner that the real use of the tools is suitable in a given context and would contribute to reaching desirable goals such as safety.

2 METHODS

The study included three case studies in Nordic nuclear power plant organisations and an international, self-administered web survey (Oedewald et al., 2014, 2015). The case studies were mainly focused on maintenance

activities and the international survey was targeted at human performance experts in nuclear industry. The original goal of the studies wasn't to specifically capture or discuss the resilience-enhancing effects of HPPs, but rather to provide general knowledge regarding the impacts and implementation of HPPs.

In two of the three nuclear power plants involved in the case studies a human performance program (HPP) was already implemented. At the third plant there were plans to introduce a HPP, but it hadn't yet been implemented at the time of the study. They were, however, already using some working practices similar to HPTs at the third plant. A total of 47 semi-structured interviews were carried out at the three NPPs. The interviewees represented various levels of management from a variety of different NPP disciplines. This included, for example, maintenance supervisors, technicians, managers and control room operators. The interview questions focused on identifying the expected and experienced benefits and disadvantages of HPPs and what was perceived as important during implementation. In addition to the interviews, in those two plants where a HPP was already implemented, surveys were used to assess personnel opinions regarding the HPP. Data collected from the interviews and the surveys was analysed using a thematic analysis approach (Braun & Clarke, 2006) to identify common patterns and themes.

The international survey was a web questionnaire that was sent to human performance experts in nuclear industry. The individuals were chosen through mailing lists of various human-performance-related seminars and networks. The survey received a total of 87 responses from practitioners at operational plants. All responses were considered in qualitative analyses, and in quantitative analyses only complete responses (n=67) were analysed. Respondents were from at least 47 organisations in at least 13 different countries. Some respondents didn't indicate their organisation or country. The majority of the respondents were from Northern America and the rest were from Europe. The international survey included both open-ended questions and multiple-choice questions. The former were analysed using thematic approach, and the latter were analysed using basic quantitative methods such as statistical means and counts. Open-ended questions concerned expected and experienced benefits and disadvantages of HPPs. Multiple-choice questions concerned the HPTs used, factors driving the introduction of HPPs, indicators used to assess the efficiency of HPPs and key success factors in implementation.

3 RESULTS

Generally the respondents in case study organisations had a positive opinion of the HPPs. They saw that most of the techniques suggested by HPTs have always to some extent been either part of their existing working practices or otherwise desirable good practices. The HPTs were seen useful for i.a. avoiding mistakes, minimizing rework, and making the task smoother and easier to perform. Indirect benefits such as knowledge sharing, organisational learning and safety culture improvements were also mentioned. Many of the respondents didn't find human error a major issue in their work, but instead they discussed problems on practical level such as coordination, preparation or misunderstandings in communication. The human performance expert respondents of the international survey tended consider the error-reduction effects more often than staff at case organisations when discussing the benefits of HPPs. The error reduction paradigm promoted by human performance guidebooks and manuals was clearly reflected in their responses.

Negative responses were mostly related to extra work, cost and time required by some HPTs, relabelling of existing working practices as HPTs or forcefully changing established practices. Many of the respondents also expressed their concern that some HPTs are often used in a rigid way that limits their degrees of freedom in the field and that this may sometimes lead to undesirable outcomes such as causing "robotic" ways of executing tasks or concentrating on executing the tool itself instead of the work task. Respectively, some respondents pointed out the difficulty of deciding how much freedom should be allowed when adapting the HPTs to a particular situation: if too much adaptation by the workers is allowed, HPTs may not be used to the extent expected or in intended ways, and thus the aspect of formalising good working practices may weaken and the HPTs won't be useful anymore.

Pre-job briefing was the most commonly used HPT in all organisations studied. It was implemented in all case organisations (either as a HPT or as a practice) and in all organisations of the international survey. The respondents saw a multitude of benefits to using pre-job briefing: better preparation for work, making sure everyone understands what to do and when to do it, familiarization with the task, coordination between teams and tasks, better understanding of the plant and its functions, education, understanding the connection to other tasks, getting to know all involved etc. The respondents saw that having a pre-job briefing has the potential to both reduce the probability of human error, but also to improve the smoothness of execution, and making the task easier and faster to perform.

Post-job review was usually implemented but it wasn't considered very usable in practice by many respondents. In many cases the respondents perceived it difficult to return back to a completed job tasks to discuss it further unless a clear mistake had been made. Some respondents implied that it could be a cultural issue that a successfully finished task isn't discussed afterwards anymore. Often post-job review was omitted due to practical reasons such as involved workers or contractors having already left the plant after job completion. However, many respondents did acknowledge the potential of post-job review as a learning tool that could facilitate learning and communicating experiences further. Both experiences of errors made and successes identified were considered as something that post-job reviews could help explicate and document.

Self-checking was also one of the most popular tools. This HPT was seen useful by the respondents to identify unexpected situations and to generally avoid engaging in any activities routinely without first considering the specific situation at hand. Unlike the potentially resource-heavy meetings carried out during pre-job briefings and post-job reviews, self-checking was largely perceived as an integrated part of a task's process instead of additional work.

The study revealed that the way HPPs are implemented is critical for the success and usefulness of the program. Such preconditions as proper training, ensuring sufficient resources and integration to existing ways of working and organisational culture emerged. In many responses the negative outcomes were related to a lack of training and integration: the shop-floor personnel were confused on how to use the HPT or why it was important. In addition, the tools were sometimes seen as extraneous or conflicting with their existing work practices or it was unclear whether HTPs are intended to be always used the same way or should they be adapted to the situation. The responses from supervisors pointed out a fundamental issue: there was a degree of confusion or indecision in the management regarding the extent to which the HPTs are allowed to be contextually adapted. Most of the shop-floor staff found that the HPTs can't always be used as such and thus require adaptation. Further confusion and frustration in the shop-floor staff was caused by the mixed messages from management that on one hand required the use HPTs, yet didn't provide sufficient resources for learning or using them. The human performance experts considered that management commitment, training, and managers' activity are the most important key success factors in the implementation of a human performance program.

4 DISCUSSION

HPTs are most often targeted at reducing error of the shop-floor personnel and their potentially system-wide, resilience-enhancing effect isn't usually explicitly discussed. Some of the results of our study imply that HPTs may also have effects on system resilience instead of only affecting sharp-end behaviour. One of these effects is the furthering of organisational learning. The HPTs most obviously related to organisational learning are post-job review and the use of operating experience which can be seen as tools that make the knowledge transfer from the field to the system more efficient. By focusing on those lessons learned that help the system and other sharp-end staff members better face uncertain conditions, these learning tools may be beneficial for sustaining system resilience. Another HTP that has potential to be useful for learning is self-checking, which, if used to sensitize the staff to detect and analyse the unexpected and then bring this knowledge to system level, may enhance resilience through better monitoring of the system state. These HPTs may backfire from resilience point of view if they are used mechanistically or in a simplified manner. For example, if only errors are discussed in post-job reviews, a lot of information (e.g. successful adaptations) that could have the potential to enhance resilience is missed. Error-focused post-job reviews may also foster proceduralization and accumulation of rigid rules. The popular response in the case studies that personnel find it unnecessary to have post-job reviews if everything went according to plans suggests that the post-job reviews in the case organisations were implemented rather as error-collection devices than more general tools for learning. This approach may also reflect the case organisations' cultures in which returning to reflect successful performances aren't seen as beneficial. Similarly, the practical implementation of self-checking usually emphasized boosting the attention of the shop-floor worker to detect errors in their behaviour, rather than furthering learning through identification of good practices or improving monitoring by detecting unknown system deficiencies and then reporting them further. There were, however, examples of cases where an individual staff member successfully handled an unexpected situation due to the use of self-checking.

Another important resilience-related effect that emerged in the studies is the development of an understanding of the system and its sociotechnical components. This is especially related to the pre-job briefing tool. Discussing the related social and technical actors with everyone involved in the task beforehand provides the staff a better understanding of the interconnections of their work to others' and also better understanding of the whole system. In case local adaptations are done, this understanding may help actors

make more informed decisions that lead to successful adaptations and thus to more desirable outcomes.

Some human performance experts and top managers related HPPs to improvements of safety culture and general improvements in awareness of human factors in complex sociotechnical systems. These can be interpreted as aggregate effects of all the HPTs and the implementation of the HPP itself. Most often such cultural characteristics as rigour and discipline were mentioned in the responses. However, if the implementation of the HPP is focused on error-reduction and rule-based control, and the implementation process is top-down, it may result in cultural characteristics that are not desirable. Behaviour characterized as "robotic" or staff shifting focus on performing the tools instead of the task may result from improper implementation process. In such case HPTs are used for the sake of compliance without real understanding of their benefits or usefulness and thus the potential positive effect will be reduced.

Finally, the semantics and logics used in the promotional material (incl. training) of HPPs may have an effect on how they are received in practice. Typically HPPs are presented as methods that result in better safety through error reduction. This argument was popular among the human performance experts. However, when HPTs were applied in the field, the shop-floor staff considered the human error reduction effect rather secondary and emphasized effects such as better understanding of work, improved coordination, smoother and faster execution of work etc. HPTs were perceived as "good, professional working practices" instead of merely error-reduction methods. This may suggest that the shop-floor staff may in fact readily have a better systemic understanding of the relevance and significance of HPPs than human performance experts and management. Shop-floor staff sees the HPTs as more integrated and applicable to other purposes than error reduction as assumed by human performance experts and management. Furthermore, this suggests that if error-reduction is the primary argument used in promotional materials of HPPs or by the top management, the shop-floor staff may find that their expert judgement and experience is not valued or understood which may result in a lack of motivation to use them or in a confrontation between the shop-floor staff and top management. There were strong opinions from some of the shop-floor interviewees that the top management and human performance experts lacked the understanding of the real issues in everyday shop-floor work. This confrontation indicates a problem in communication between the levels of organisation and may also suggest that the management hasn't understood how the HPTs are used in practice or how they will be used in practice. This is especially problematic with experienced workers that are already using practices similar to HPTs because the introduction of HPTs may contradict with their existing practices. This issue further emphasizes that HPPs should be integrated to the organisation as part of continuous work practice and process development, developed in collaboration with the staff, and providing guidance and recommendations for the staff instead of rigidly prescribing their behaviour. Conversely, when viewed from newcomer's perspective, a HPP was seen useful as a training tool. By implementing a HPP, the newcomers are provided a quick and easily understandable reference of how work at a given facility should be performed. Such effect may further organisation's resilience by facilitating the promotion of desirable safety culture.

Based on the insights from our studies, HPPs can be seen to have resilience-enhancing effects under certain conditions. It appears that HPPs have the potential to promote both prescriptive and limiting ways of working but also resilience-enhancing ways of working. The prescriptive effect was reflected in the multitude of responses where concern of limiting staff freedom to adapt locally was expressed – HPTs were perceived as something that inhibit personnel's own judgement or use of professional experience. However, a common response also was that HPTs have had the effect of supporting the work and that better training, use and understanding of such practices during the implementation of a HPP would further improve this effect. This suggests that the manner in which the HPP is implemented plays a crucial role in the resilience-enhancing effect: if the HPP is implemented mainly with a top-down, rule-enforcing control in mind, the HPTs used in a mechanistic way and not much thought is put in making sure the end user understands the actual function of each of the tools, the result might not improve the organisation's resilience, but rather decrease it. On the other hand, if the implementation process acknowledges the role of HPTs as means to improve working practices by supporting workers instead of using prescription to control them, the HPPs may have the potential to enhance resilience.

In summary, three main factors relate to how useful HPPs are to enhancing resilience at nuclear power plants. First, the selection of the HPTs to be implemented needs to be such that resilience-enhancing effects are plausible. The tools that most probably enhance resilience help the end users face the uncertainty at individual level but also carry this ability further to the system level. Examples of such are well-implemented pre-job briefings and post-job reviews. The selection of HPTs shouldn't be limited to the most non-prescriptive ones because depending on context, both prescriptive and non-prescriptive HPTs may be beneficial for resilience.

Second, the implementation process needs to be designed in a way that it supports enhancing resilience. If the HPTs are implemented to provide top-down control, add restrictive procedures and limit local adaptations, the beneficial effect of the workers' professional input on task performance may be eliminated. This may lead to instrumental use of HPTs and possibly reduced system resilience. It is to be noted, however, that all variance is not desirable. For example, as discussed by some of the respondents, allowing too much freedom on adopting the HPTs may lead to staff using them incorrectly or not using them all, both of which have the potential to result in negative outcomes. Emphasizing the actual function of the tool and making sure everyone (incl. top management and human performance experts) understands how, when and for what purpose the tools are beneficial are some of the preconditions that need to be met in order for the tools to result in increased resilience. Third, the way in which the HPTs are actually used at shop-floor level needs to be considered. For example, if a HPT, or a similar pre-existing practice is considered helpful in multiple ways depending on the context, the (re)introduction of the HPT as merely an error-reduction method may lead to confusion, a lack of motivation to use the tools, or in worst cases, conflicts between various parties within the organisation. The integration to existing work practices is therefore essential.

5 CONCLUSIONS

Human performance programmes provide a concrete set of tools that are widely applied in real-life situations. They also appear to have potential to be beneficial for creating or sustaining resilience. However, our study also showed that there are a variety of practical issues involved in implementing a successful human performance program. This has implications for enhancing resilience at an organisation - contextual and systemic factors and the implementation process have an important role and need to be considered. Merely developing a variety of methods that in some conditions may enhance resilience doesn't guarantee that the practical implementation of those methods is at all beneficial for resilience. Using HPTs in a rigid and mechanistic may in some cases even result in safety deterioration. Therefore, in addition to choosing well-developed practices, proper implementation process and close collaboration with those who use those methods are crucial in ensuring that the resilience-enhancing effect actually takes place.

REFERENCES

Argote, L. (2013). *Organizational Learning*. Boston, MA: Springer US.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77–101.

Dekker, S. (2003). Failure to adapt or adaptations that fail: contrasting models on procedures and safety. *Applied Ergonomics*, 34, 233–238.

DoE (2009a). *Human Performance Improvement Handbook Volume 1: Concepts and Principles*. DOE Standards. Washington, D.C.: U.S. Department of energy.

DoE (2009b). *Human Performance Improvement Handbook Volume 2, Human Performance Tools for Individuals, Work Teams, and Management*. Department of Energy Washington, DC: Government Printing Office.

Grote, G. (2006). Rules management as source for loose coupling in high-risk systems. In *Proc. of the Second Resilience Engineering Symposium* (pp. 116–124).

Grote, G., Weichbrodt, J. C., Günter, H., Zala-Mezö, E., & Künzle, B. (2009). Coordination in high-risk organizations: the need for flexible routines. *Cognition, Technology & Work*, 11, 17–27.

Hollnagel, E. (2013). A tale of two safeties. *Nuclear Safety and Simulation*, 4, 1–9.

Oedewald, P., Skjerve, A. B., Axelsson, C., Viitanen, K., & Bisio, R. (2015). Human performance tools in nuclear power plant maintenance activities - Final report of HUMAX project (No. NKS-328). NKS.

Oedewald, P., Skjerve, A. B., Axelsson, C., Viitanen, K., Pietikäinen, E., & Reiman, T. (2014). The expected and experienced benefits of Human performance tools in nuclear power plant maintenance activities - Intermediate report of HUMAX project (No. NKS-300). NKS.

Pariès, M. J., Hollnagel, E., Wreathall, M. J., & Woods, D. D. (2012). *Resilience Engineering in Practice: A Guidebook*. Ashgate Publishing, Ltd.

Skjerve, A. B., & Axelsson, C. (2014). Human-Performance Tools in Maintenance Work - A Case Study in a Nordic Nuclear Power Plant (No. NKS-321). NKS.