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Cognitive Readiness – Training for Non-Routine Control-Room Situations

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Ruhr-University Bochum, Germany

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Human Factors in Control

Human Factors in Operational Risk Management

Focus on Barrier Management

BUSINESS-PSYCHOLOGY

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About the coming 45 min…

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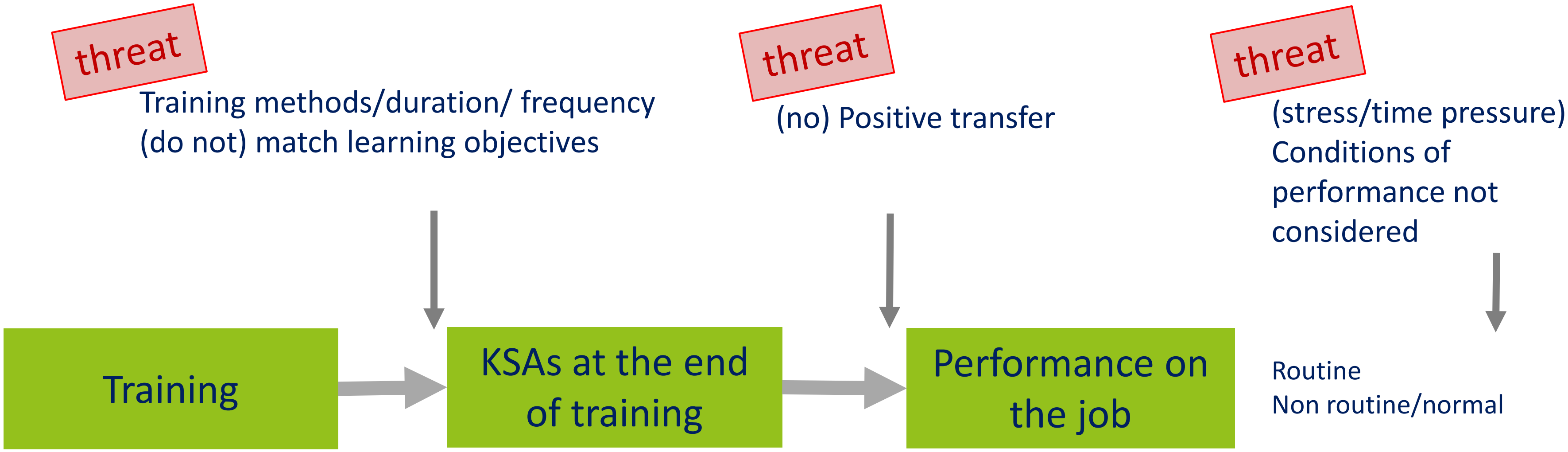
- Cognitive readiness: An introduction
- Training outcomes as safety barriers
- The challenging conditions for task work and team work skill execution
- Training science principles for task work & team work skill acquisition to become cognitive ready
- Training design für cognitive readiness: The „Staged Process Control Readiness Training“
- Maintaining cognitive readiness through refresher interventions
- Take home message

Cognitive readiness:
An introduction

„Inert knowledge is the opposite of cognitive readiness to perform under stressful conditions“

Cognitive readiness – training for non-routine control-room situations

General challenges in training



Cognitive readiness – training for non-routine control-room situations

- Training = „A planned and systematic effort to modify or develop knowledge/skill/attitude (KSAs) through learning experience, to achieve effective performance in an activity or range of activities
  - It's purpose in the work situation is to enable an individual to acquire abilities in oder to that he or she can perform adequately a given task or job" (Buckley & Caple, 2008, p. 5)
- **Positive** transfer of training: The extend to which the learning that results from training experience transfers **to the job** and leads to meaningful changes in work performance (Baldwin, Ford & Blume, 2009)

Buckley, R., & Caple, J. (2008). *The theory and practice of training*. London: Kogan Page.

Baldwin, T.T., Ford, K.J. & Blume, B. D. (2009). Transfer of Training 1988-2008: An updated Review and Agenda for future research. International Review of Industrial and Organizational Psychology, 24, 41-70.

Cognitive readiness – training for non-routine control-room situations

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The challenge for training design **in HROs**

threat
Training methods/duration/ frequency (do not) match learning objectives

threat
(no) Positive transfer

threat
(stress/time pressure) Conditions of performance not considered

Training → Cognitive readiness → Performance on the job

Routine
Non routine/normal
Non routine/abnormal

threat
Learning objectives do not consider performance conditions:

- Information overload and intransparency
- Task overload
- Peer/ Supervisor pressure
- Coping with physiological reaction

threat
Skill decay due to long periods of non-use

threat
(stress/time pressure) Conditions of performance not considered

→HF/Human Error

Cognitive readiness

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Cognitive readiness (CR) is possessing the

→ **Action-oriented competencies** (experienced knowledge, skills and attitudes, KSAs) that individuals and team members need to establish and sustain competent professional performance **in the dynamic, complex, and unpredictable environments** (...) (Kluge & Burkolter, 2013; Bolstad, Cuevas, Costello, & Babbitt, 2008, p. 970; adapted from Morrison & Fletcher, 2002)

Cognitive readiness = Optimization and enhancement of human cognitive performance (→ action) which is critical for effective performance, especially

- for performing multiple functions and
- for adaptation to **dynamic threats** (Fatkin & Patton, 2008)
- and non-routine situations

Kluge, A. & Burkolter, D. (2013). Training for Cognitive Readiness: Research Issues and Experimental Designs. *Journal of Cognitive Engineering and Decision Making* ,7, 96 -118.

Cognitive readiness for process control means…

Couplings and interconnections *require the operator to simultaneously process the interplay of cross-coupled variables in order to either assess a process state or predict the dynamic evolution of the plant*

Dynamic effects *require the operator to mentally process and envisage the change rates of cross-coupled variables and to develop sensitivity for the right timing of decisions in order to be successful*

Non-transparency *requires the operator to work with more or less abstract visual cues that need to be composed into a mental representation and need to be compared with the operator's mental model*

Kluge, A., Nazir, S. & Manca, D. (2014). Advanced Applications in Process Control and Training Needs of Field and Control Room Operators, IIE Transactions on Occupational Ergonomics and Human Factors, 2:3-4, 121-136, DOI: 10.1080/21577323.2014.920437

Cognitive readiness for process control means…

Multiple or conflicting goals *require the operators either to balance management intentions or to decide on priorities in case of goal conflicts in the decision making process,* e.g. *which course of actions to take*

Comprehension of MPC and RTO philosophies and making sure that *CROPs understand the advanced control and optimization philosophies that are at the basis of MPC and RTO, since they have to validate the proposed results before accepting/rejecting their implementation in the on-line control strategy*

model predictive control (MPC)/ real-time optimization (RTO)

Crew coordination complexity incorporates small crews, e.g., CROPs, FOPs and supervisors, who are responsible for overall system operations *and calls for the operators to concurrently interact with team members in order to orchestrate individual actions into a coordinated flow of actions to either assess the situation or choose a course of actions*

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Cognitive readiness training in process control

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- It is called “readiness training” because it **prepares** operators for the non-routine situations
- As a large proportion of the training objectives and performance are **not routinely called upon every day**, the training should foster the readiness for controlling complex systems and also prepare for non-routine situations
- *Readiness* is defined as possessing the **task work** and **team work knowledge** and skills an operator needs to establish and sustain competent performance in order to be in control in routine, non-routine/normal and non-routine/abnormal situations

Training is <u>not</u> the barrier – it‘s the training outcome!

Training is useless if it does not support the acquisition of skills that are needed and applied in harzardous situations!

Training outcomes as safety barriers

Training **outcomes** as safety barriers

„Safety Barriers are physical and/or non-physical means planned to prevent, control, or mitigate undesired events or accidents“ (Sklet, 2006)

<table>
<tr><td colspan="5">The accident sequence</td><td></td></tr>
<tr><td colspan="2">Normal condition</td><td>Initial phase</td><td>Concluding phase</td><td>Injury phase</td><td></td></tr>
<tr><td colspan="3">Lack of control</td><td>Loss of control</td><td>Energy exposure</td><td></td></tr>
<tr><td colspan="3">Prevent</td><td colspan="2">Protect</td><td>(Hollnagel, 2004)</td></tr>
<tr><td colspan="2">Prevent</td><td colspan="2">Control</td><td>Mitigate</td><td>(IEC 61508/11
ISO 13702</td></tr>
<tr><td>Avoid</td><td>Prevent</td><td colspan="2">Control</td><td>Protect</td><td>(Duijm et al., 2004)</td></tr>
</table>

Generic safety functions related to a process mode (Sklet, 2006, p. 498)

Sklet, S. (2006). Safety barriers: Definition, classification, and performance.*Journal of loss prevention in the process industries*, *19*(5), 494-506.

Training **outcomes** as safety barriers

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Cognitive Readiness (CR) is a training outcome:
The **action-oriented competencies** (experienced knowledge, skills and attitudes, KSAs) that individuals and team members need to establish and sustain competent professional performance **in the dynamic, complex, and unpredictable environments** (…)”

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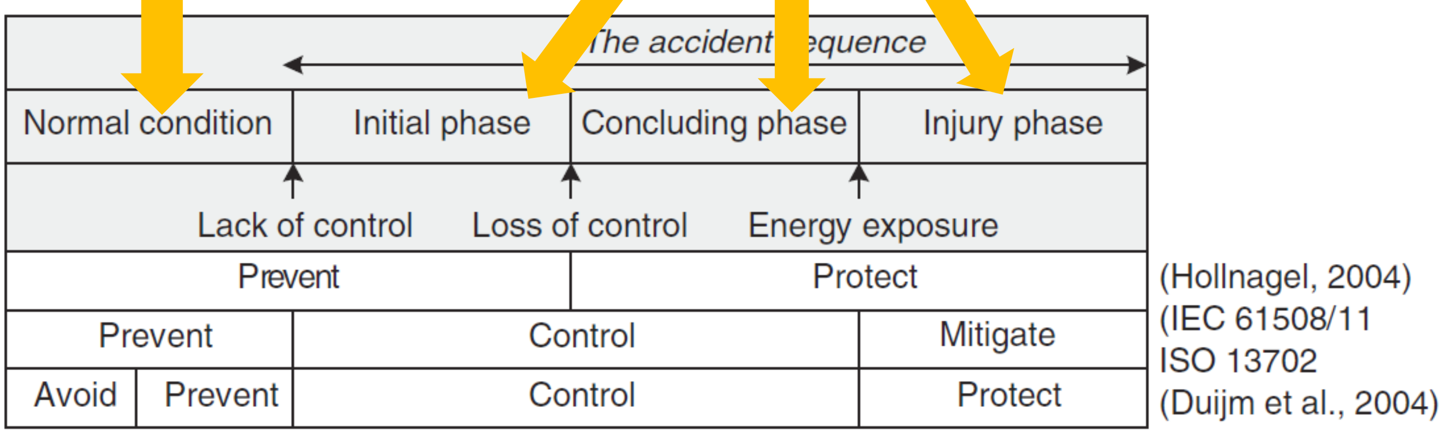
ev… ts“ (Sklet, 200…

Cognitive readiness to **establish** competent professional performance

Cognitive readiness to **sustain** competent professional performance



Generic safety functions related to a process mode (Sklet, 2006, p. 498)

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Training **outcomes** as safety barriers

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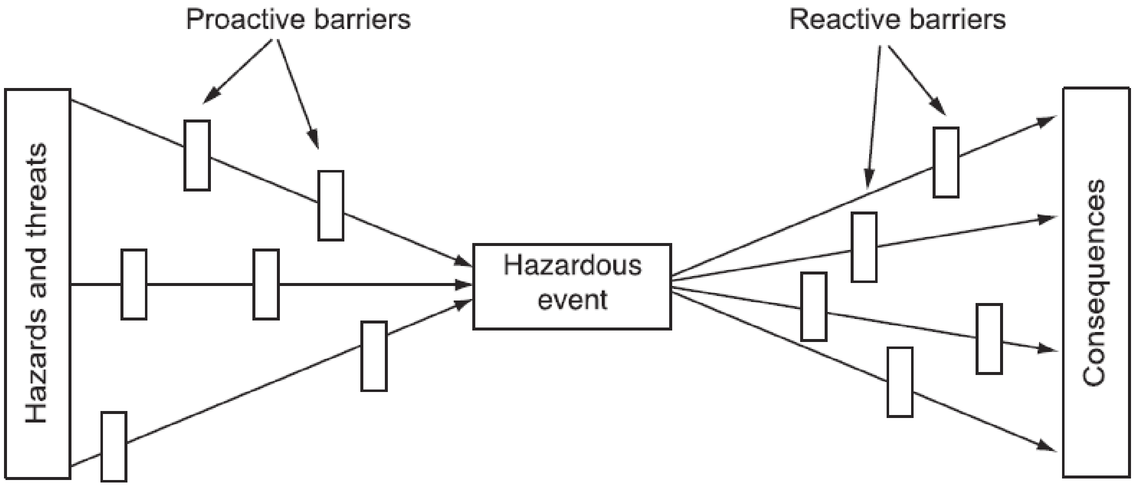
„(…)a hazardous event can be prevented by a set of proactive barrier functions and mitigated by a set of reactive barriers functions“ (Johansen & Rausand, 2015. p. 50)



Johansen, I. L., & Rausand, M. (2015). Barrier management in the offshore oil and gas industry. *Journal of Loss Prevention in the Process Industries*, *34*, 49-55.

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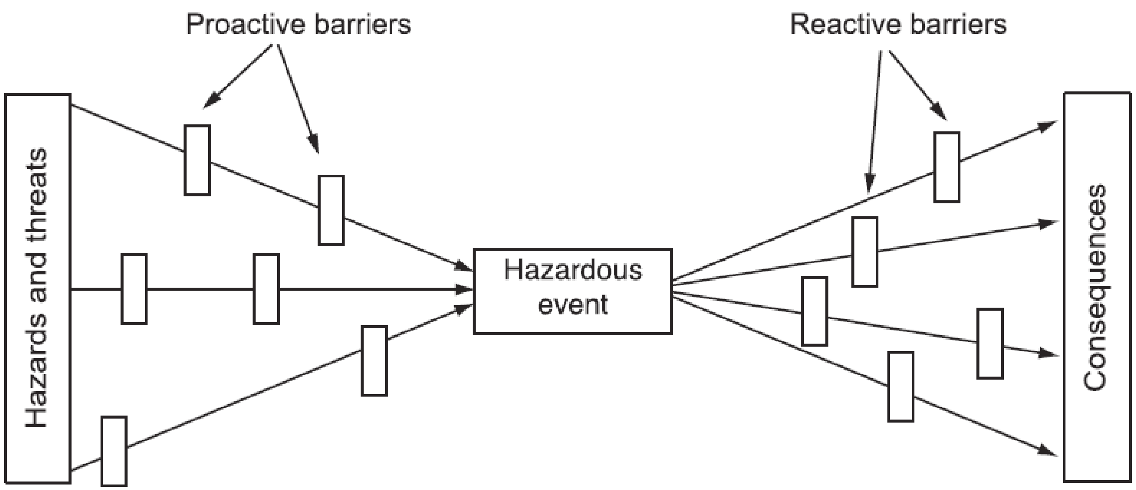

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Training **outcomes** as safety barriers

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„(…) distinction between hardware and behavioural barriers and their related management delivery systems is made (…)“ (Guldenmund et al., 2006)

Hardware related systems	Behavior Related Systems
- Risk identification, barrier selection, and specification - Monitoring, feedback, learning, and change management - Design specification, purcase, construction, installation, interface layout and spares - Inspection, testing, performance monitoring, maintenance & repair	- Procedures, plans, rules & goals - Availability, manpower-planning - Competence , suitability - Commitment, conflict resolution - Coordination, communication

Guldenmund, F., Hale, A., Goossens, L., Betten, J., & Duijm, N. J. (2006). The development of an audit technique to assess the quality of safety barrier management. *Journal of hazardous materials*, *130*(3), 234-241.

Training **outcomes** as safety barriers

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The challenging conditions for task work and team work skill execution

Cognitive readiness – training for non-routine control-room situations

The challenge for training design **in HROs**

Training → Cognitive readiness → Performance on the job

threat: Training methods/duration/ frequency (do not) match learning objectives

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Routine
Non routine/normal
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- Information overload and intransparency
- Task overload
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- Coping with physiological reaction

threat: Skill decay due to long periods of non-use

threat: (stress/time pressure) Conditions of performance not considered→ HF/Human Error

Cognitive readiness – training for non-routine control-room situations

Where is cognitive readiness needed?
When performance needs to be applied
… under time pressure
… in a personally threatening and
… in intransparent & dynamically changing situations

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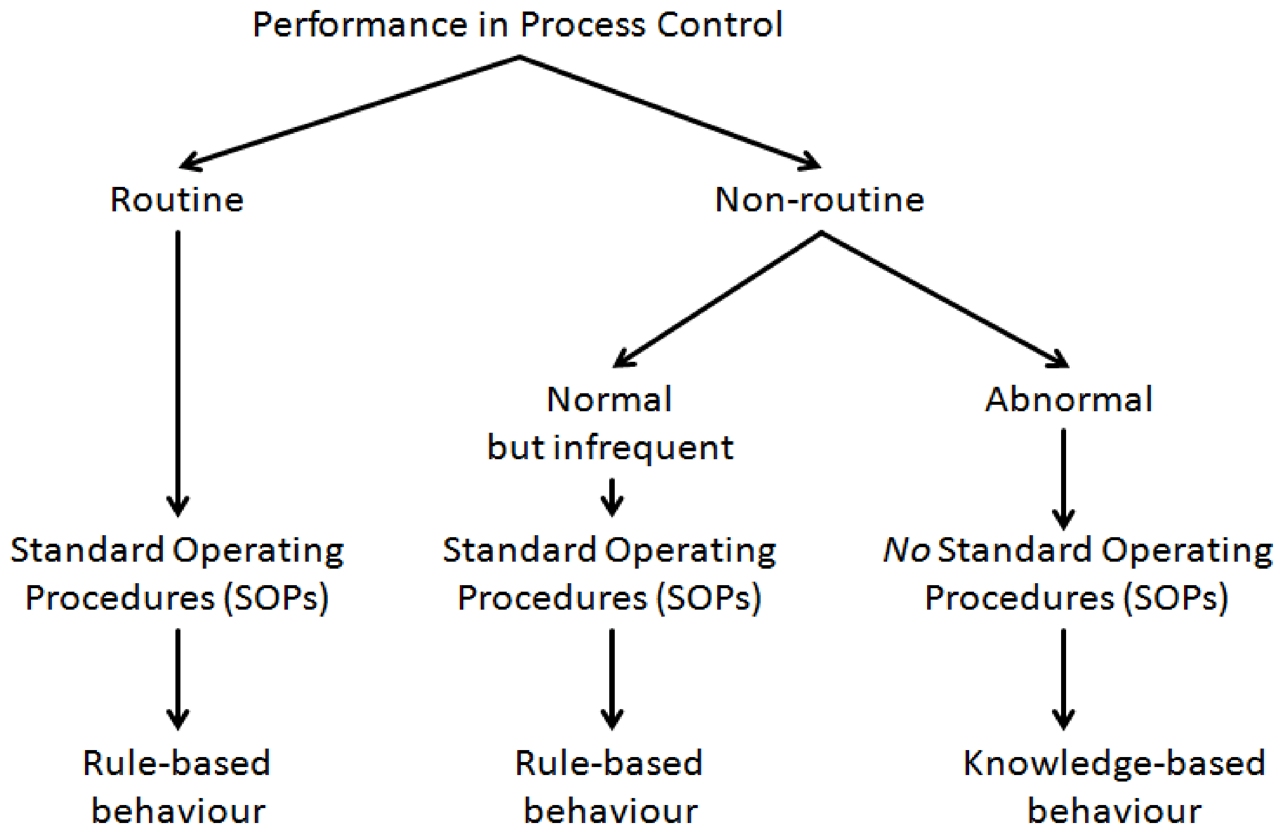

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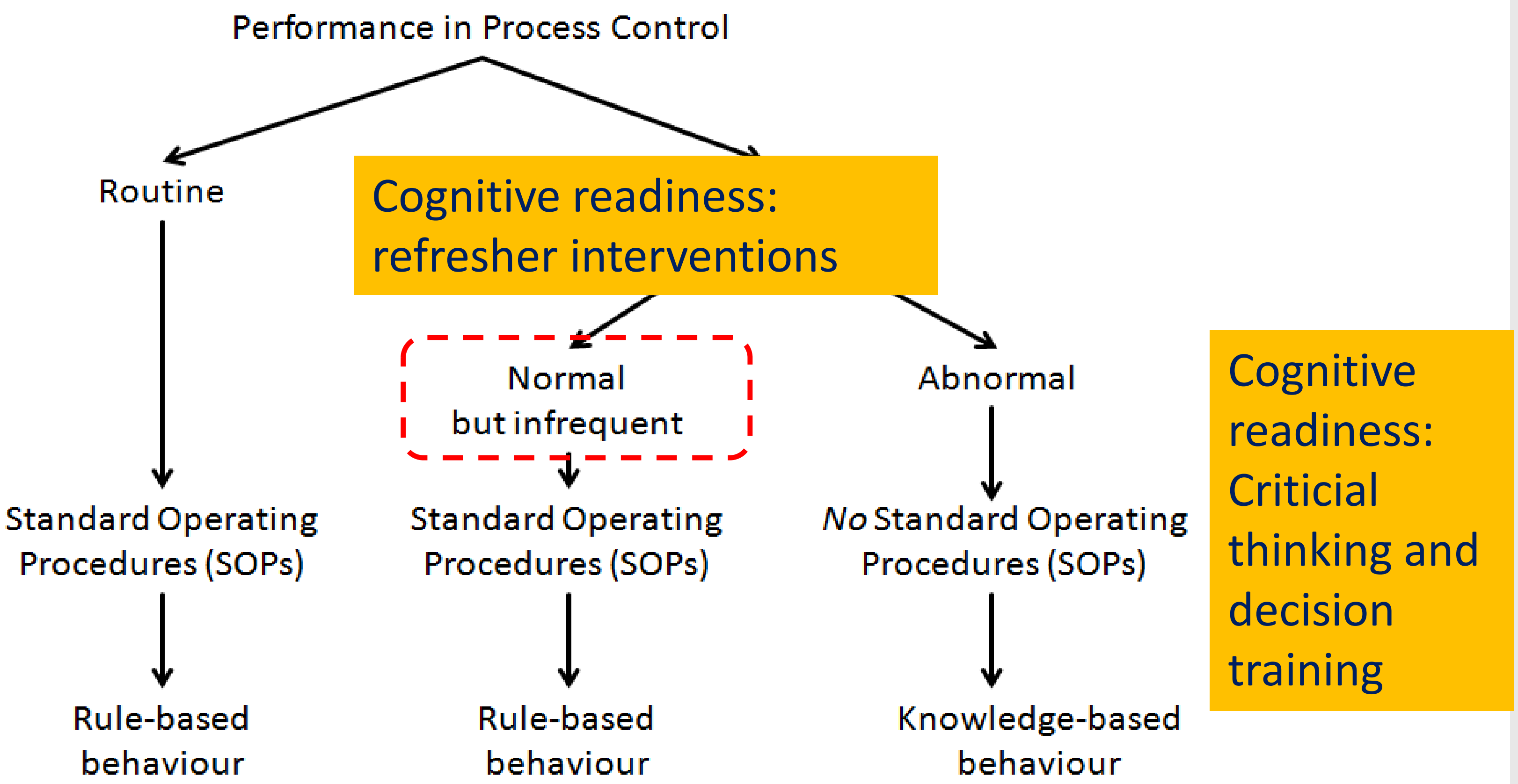

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Skill acquisition for cognitive readiness

Skill acquisition includes:

– Learning AND Performance of these skills
– Skill Execution under challenging conditions

Challenging conditions are situations which….

Conditions for transfer	Description
Routine situations	– Require routine control and regulation of the process – Based on rule-based behaviour – The situation is well handled by Standard Operating Procedures (SOPs) – E.g. “daily business”, plant monitoring and control
Non-routine/normal situations	– Require drawing on skills which have not been used for a longer period of time – Rule-based behaviour – The situation is well handled by Standard Operating Procedures (SOPs) – E.g. “exceptional business”, fault repair or start-up of plant, but is still rule-based behaviour
Non-routine/abnormal situations	– Require problem-solving skills and knowledge-based behaviour – Situation is a) ambiguous and includes b) unanticipated major c) threats to system survival coupled with d) limited time to respond – E.g. low-probability, high-impact situation, an explosion in a subunit of the plant caused by a safety-related rule violation or natural disasters such as earthquakes, tsunami

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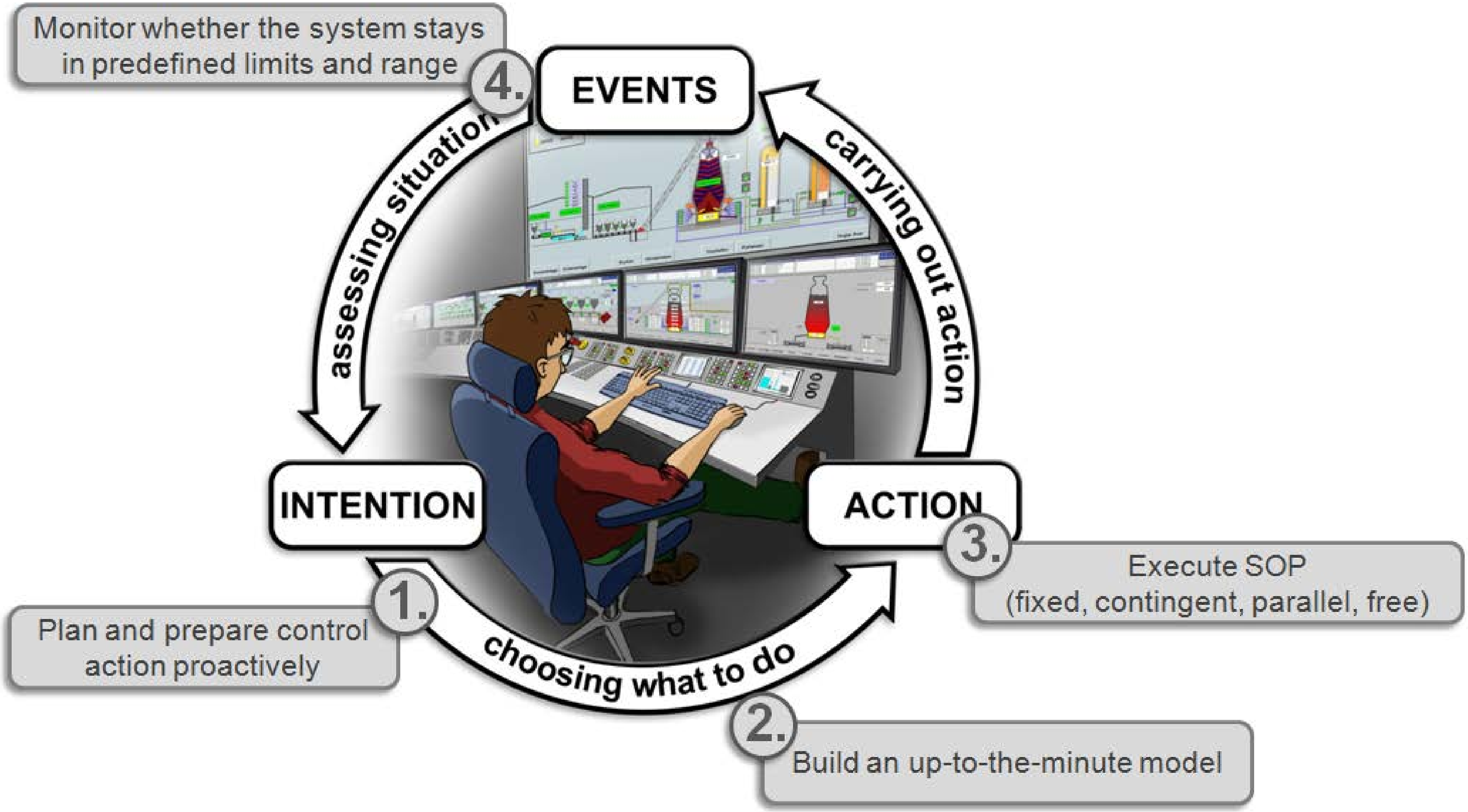
Cognitive readiness for non-routine/normal situations

Non routine/normal situations



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Skill acquisition for cognitive readiness

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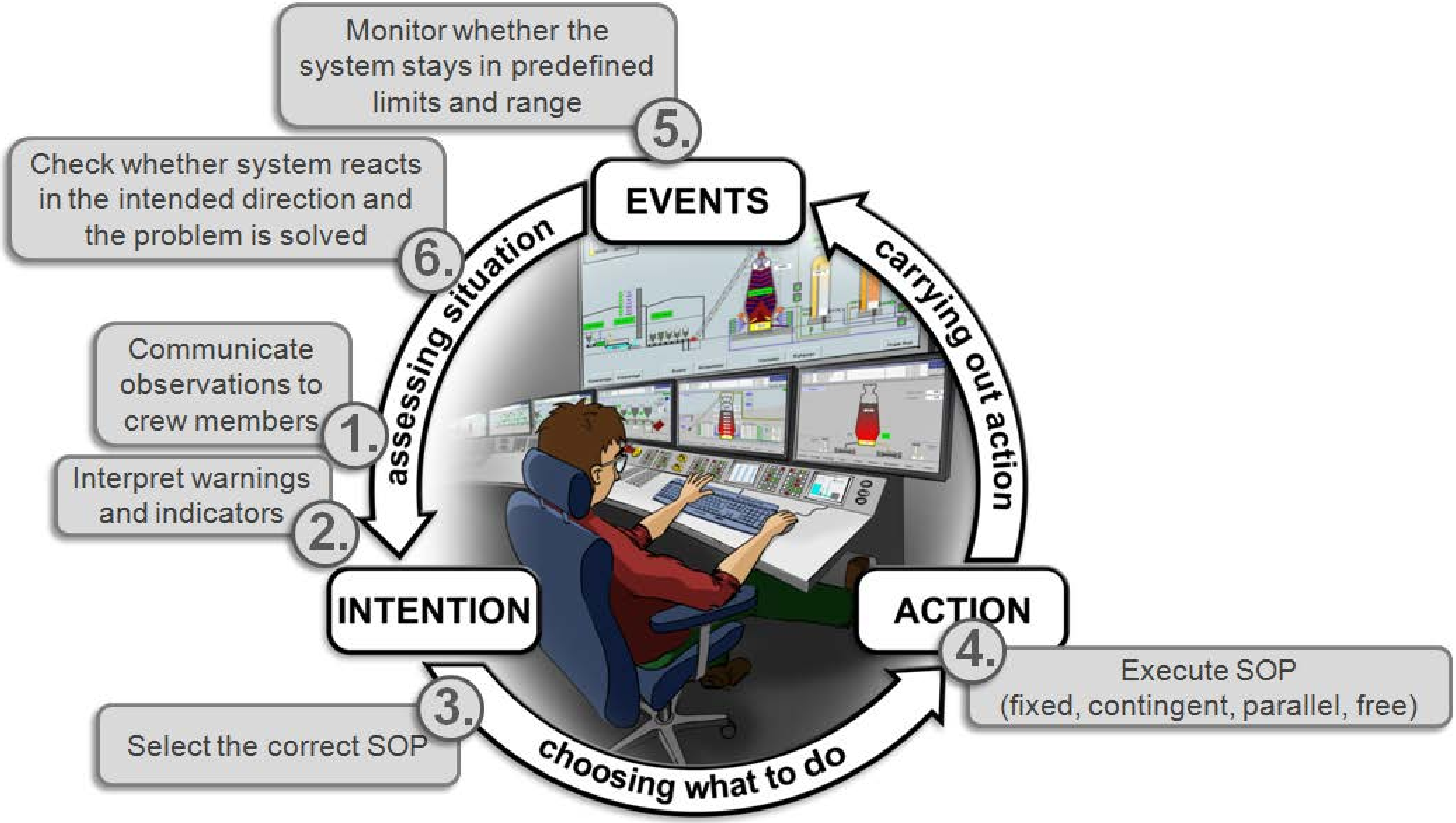
Task work requirements for non routine/abnormal situations



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Skill acquisition for cognitive readiness

Team work requirements for non routine/abnormal situations

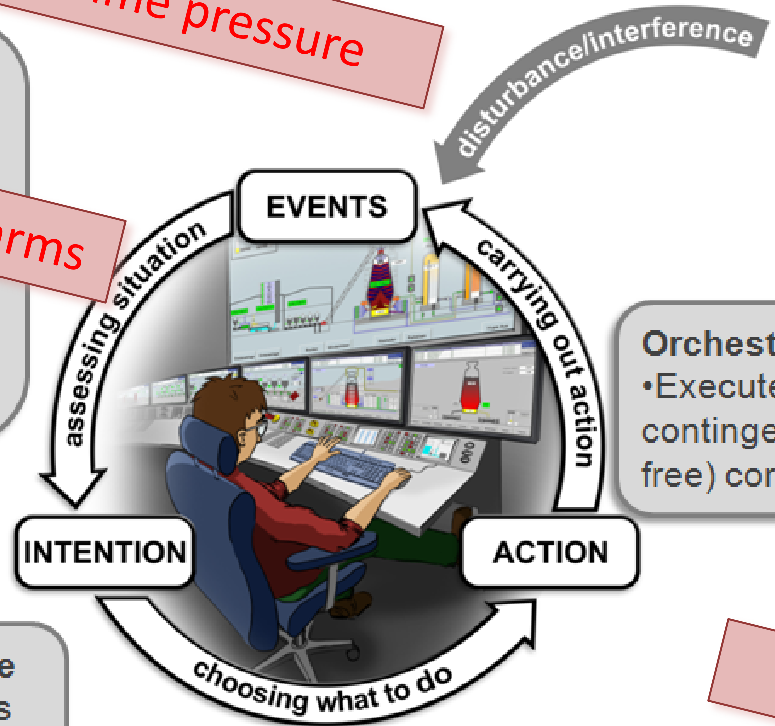
Monitor goal achievement

Alarms

Time pressure

Perceiving the difference between normal and abnormal
- Collecting and restructuring of data
- Combine, sort & filter cues
- Searching for patterns
- Detecting patterns of cues
- Sharing mental models
- Exchanging hypotheses about causes of problems

Alarms



Orchestrate actions
•Execute SOP (fixed, contingent, parallel & free) correctly

Alarms

Developing of joint problem space
- Resolving opposing interpretations
- Negotiate strategic team consensus
- Critical thinking

Alarms

Alarms

Selecting course of action

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Training science principles for **task work & team work** skill acqisition to become cognitive ready

Skill acquisition for cognitive readiness

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Main question: **How do we transform a novice into an expert who is able to execute skill under high workload?**

	Definition
Novice	Someone who is new and has had some minimal exposure to the domain
Expert	Someone whose judgments are uncommonly accurate and reliable, whose performance shows consummate skill and economy of effort, and who can manage effectively with rare and difficult cases and has special skills or knowledge derived from extensive work experience also with sub-domains

- The overall learning requirements include the development from a novice to an expert.
- The learning process implies the <u>**accumulation of instances**</u> through work experience and practice.
- Instances are stored in the <u>**episodic memory**</u>

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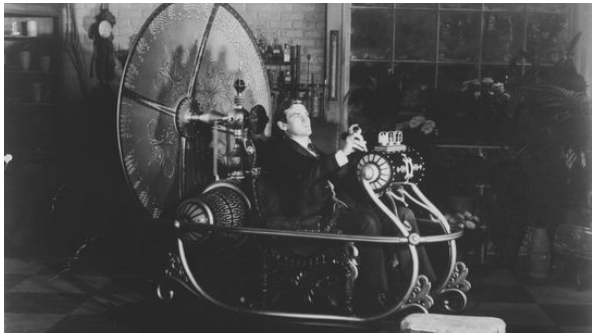
Skill acquisition for cognitive readiness

Episodic memory? What is that for?



- Involves **re-experiencing a past event** that is specific in time and place
- Represents "short time slices of experience“
- Is close to experience, predominantly represented in the form of images, has an observer’s perspective and contains sensory-perceptual-conceptual-affective summary features of that experience
- Is essential for learning, in particular for the abstraction and schematisation of knowledge
- Two or more contiguous episodic memory entries provide the structure and process to abstract knowledge from instances for that abstraction
- Is also necessary for **"mental simulation"** of future events
- Mentally reconstructing past episodes and mentally constructing future episodes are two sides of a coin of **mental time travel**
- Generalised episodes serve as an organising point for storing similar episodes

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Skill acquisition for cognitive readiness

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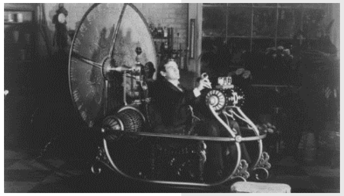
Skill acquisition means to fill the episodic memory with instances!

- Work experience and practice for becoming an expert means the acquisition of instances
- Instances are saved in episodic memory.
- Learning occurs through the accumulation of instances over repeated task exposure and execution
- The **instances enable a situation to be assessed** in a recognition-primed manner
- The **instances additionally enable mental time travel into the future** in order to estimate the effects of decision
- The assessment and prediction of precision are improved through the acquisition of further episodes



classroom training????

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Training design für cognitive readiness
„Staged Process Control Readiness Training“

Stage 1: Task work

Stage 2: Team work & deliberate practice

„Staged Process Control Readiness Training“

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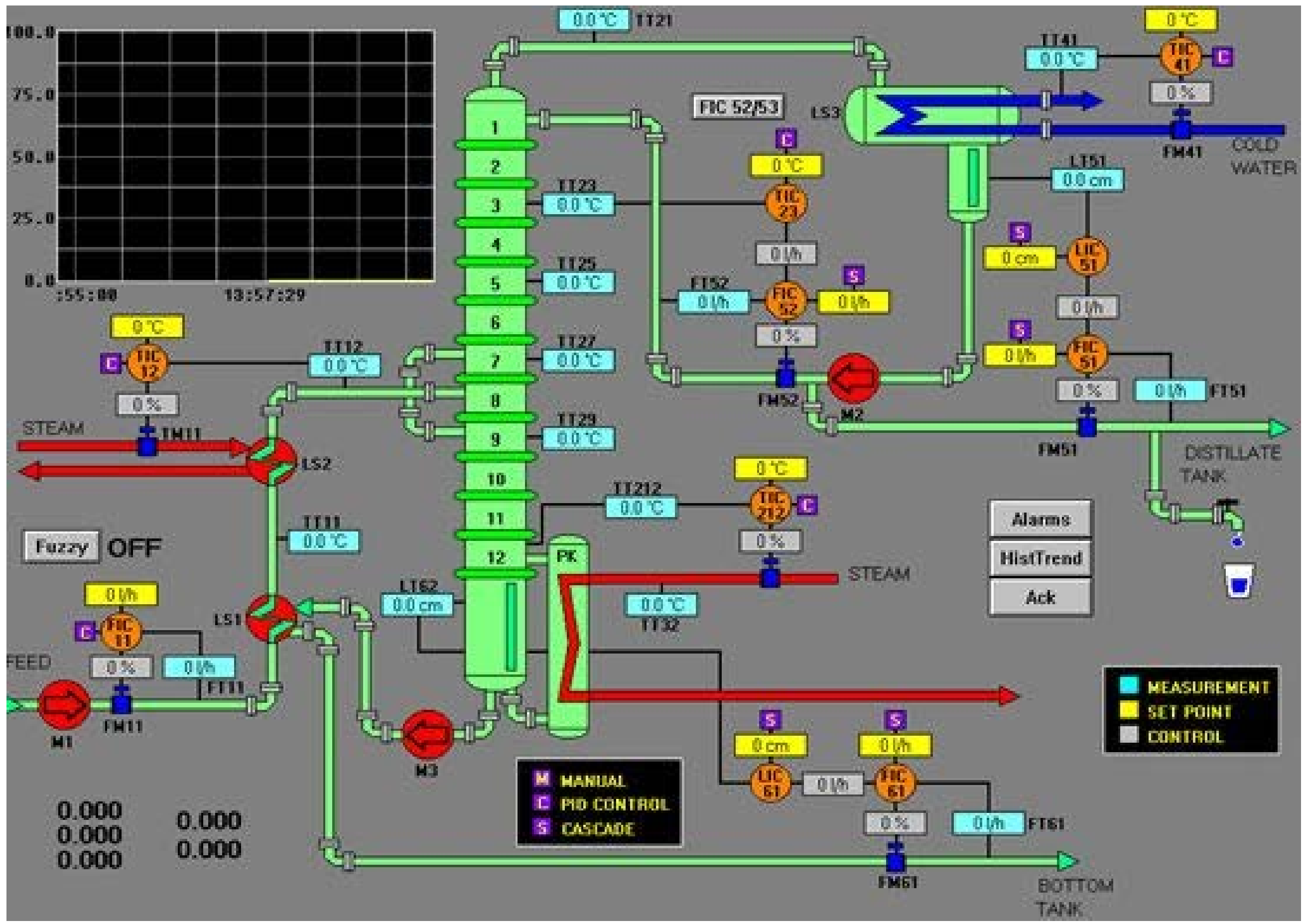
Training components

- A full scope simulator
- (The sequencing of) Instances
- Experiential learning
- Component practice
- Briefing
- Debriefing

„Although simulations are used for training, they seemed to be used without much consideration of what has been learned about cognition, training design and effectiveness“ (Salas et al., 2006)

Learning & training with 2-D simulators for cognitive readiness

Control room operator



Conventional DCS synoptic of a distillation column

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Learning & training with 3-D simulators for cognitive readiness

Field operator

3D representation of a distillation column (vertical cylinder on the right), and of auxiliary process units such as reboiler, condenser, and reflux drum (i.e. the three horizontal cylinders from left-bottom corner to the center of the figure)

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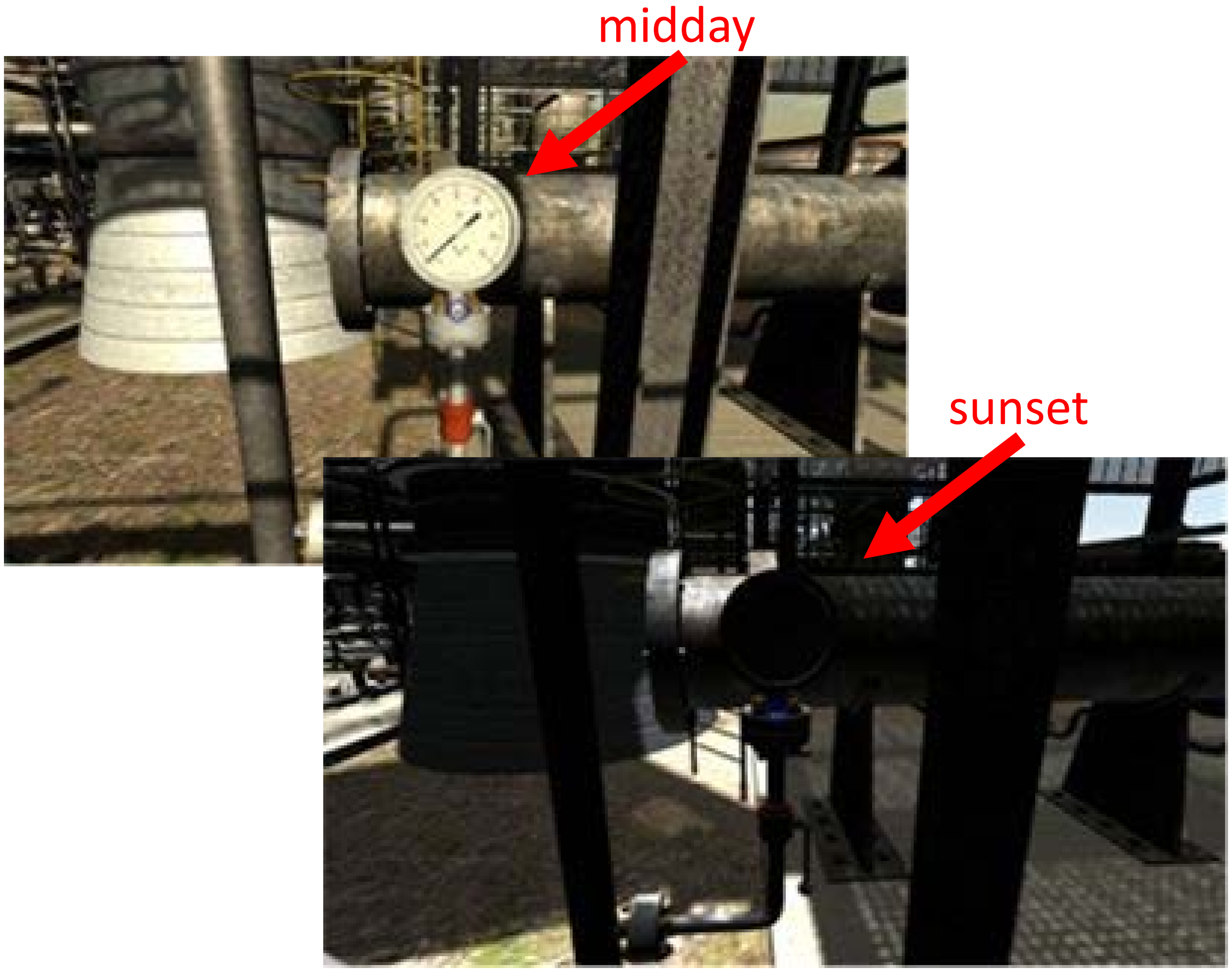
Learning & training with 3-D simulators for cognitive readiness

Field operator



The pressure gauge in a crude oil refinery apears different at midday (a) and at sunset (b).

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But isn‘t it too demanding for novices? Training techniques for beginners

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The Gradual Increase in Difficulty

What?	**Start with a simple version** of the task and gradually increase its difficulty as learning progresses
Why?	In parallel to the increasing task difficulty, skill develops over time, leading to resource demands (intrinsic load) that remain relatively stable over time, leaving enough resources for germane load
Challenge	Find out which aspects of a task increase difficulty

Error Prevention: Training Wheels

What?	Approach **locks out certain actions** that can have serious unintended consequences
Why?	Lower the resource demands of performing, preventing thrashing, and guide resources toward the mastery of mental models or skills to be acquired
Challenge	Designing a schedule for release

Part-task training: Fractionating

What?	Parts of a task are **performed concurrently** as time-shared tasks, between which attention must be divided
Why?	The development of time-sharing skills is an emergent property of the tasks
Challenge	Making available more part-task practice time for the part-tasks. For this, automaticity should be developed, due to its consistent mappings, and less time should be given to those parts with little consistency

Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

„Staged Process Control Readiness Training“

Training components

- A full scope simulator
- (The sequencing of) Instances
- Experiential learning
- Component practice
- Briefing
- Debriefing

- Increasing difficulty for novices
- Instances for experts
- Instances for skill retention

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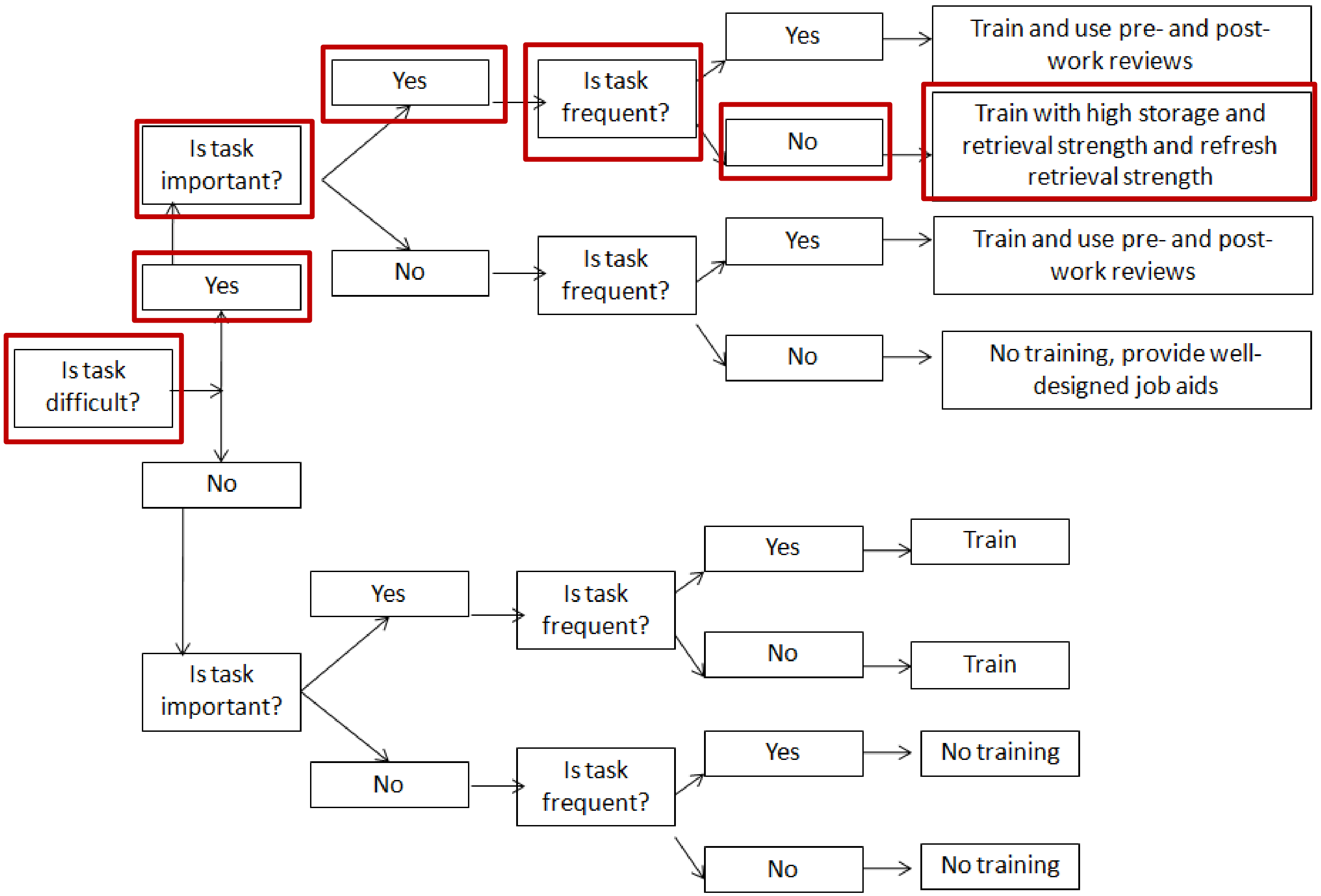
Selecting the relevant episodes/instance

E.g. The DIF-Analysis – Difficulty, Importance & Frequency Analysis



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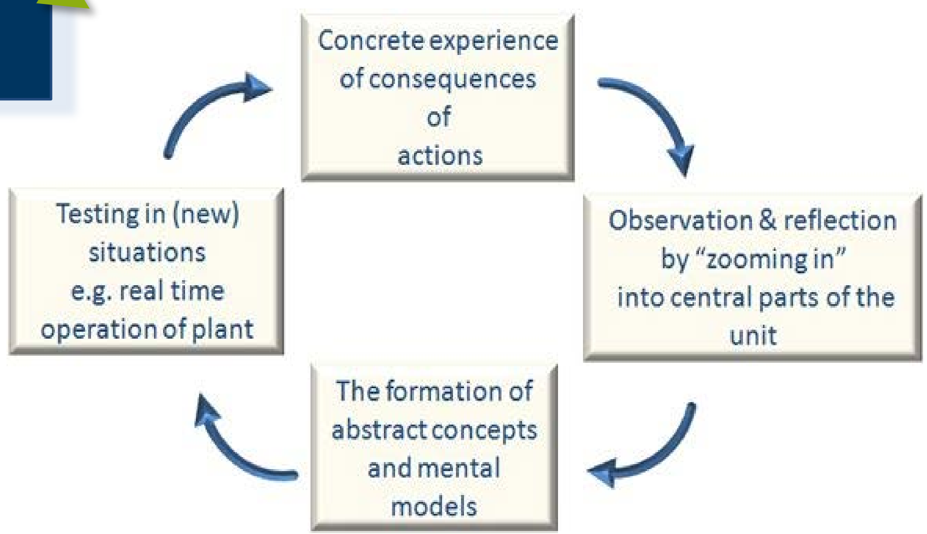

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„Staged Process Control Readiness Training“

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- Debriefing

“component practice” of task components that require time-sharing and attention allocation skills

Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

Kluge, A., Nazir, S. & Manca, D. (2014). Advanced Applications in Process Control and Training Needs of Field and Control Room Operators, IIE Transactions on Occupational Ergonomics and Human Factors, 2:3-4, 121-136, DOI: 10.1080/21577323.2014.920437

„Staged Process Control Readiness Training“

RUB

Training components

- A full scope simulator
- (The sequencing of) Instances
- Experiential learning
- Component practice
- Briefing
- Debriefing

Briefing: verbal introduction to the instance-based learning episode that “sets the scene”.

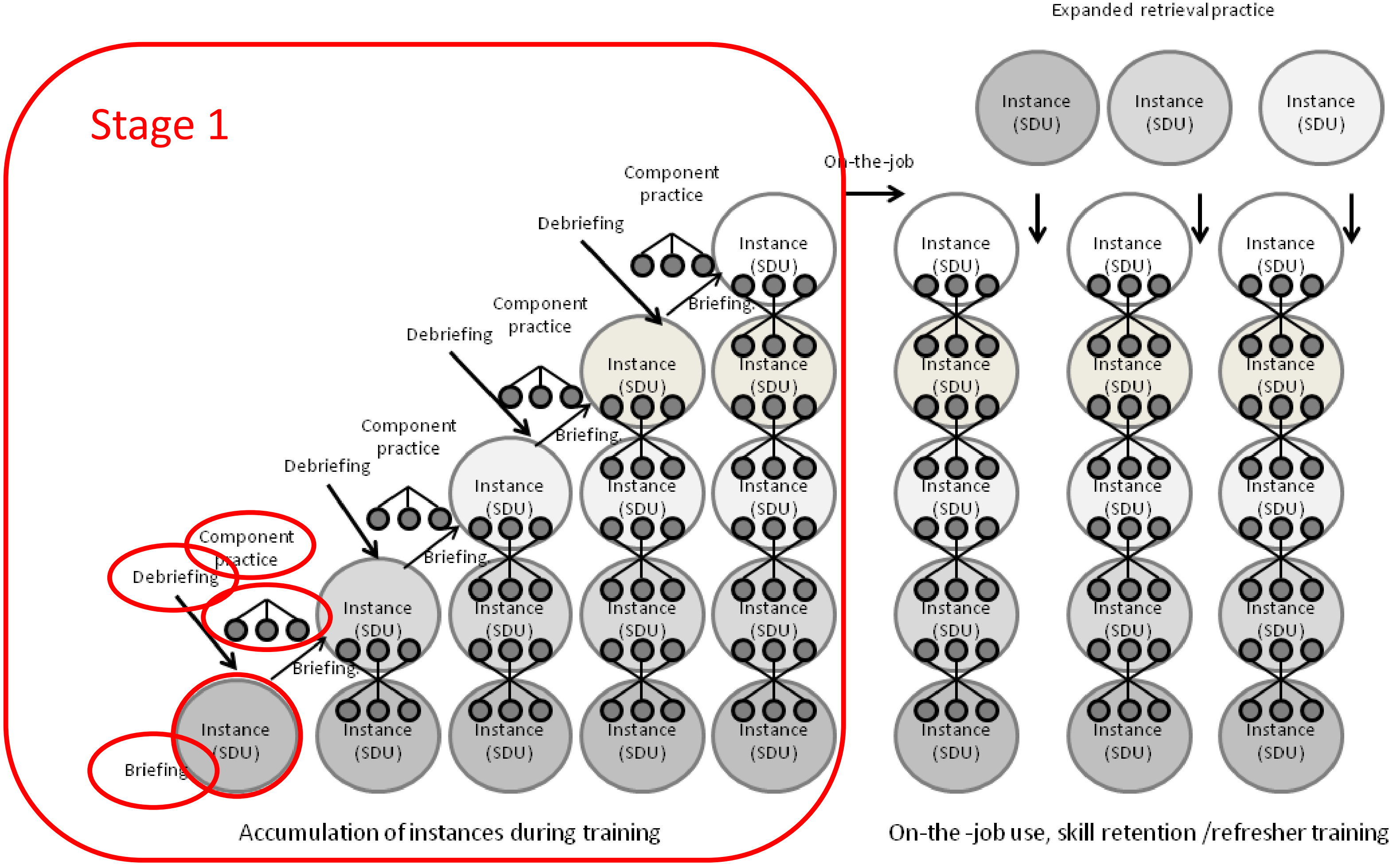
Debriefing: verbally guided analysis by the trainer of operator experience to extract rules and explicit knowledge, build up or correct mental models.

Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

Kluge, A., Nazir, S. & Manca, D. (2014). Advanced Applications in Process Control and Training Needs of Field and Control Room Operators, IIE Transactions on Occupational Ergonomics and Human Factors, 2:3-4, 121-136, DOI: 10.1080/21577323.2014.920437

„Staged Process Control Readiness Training“

Training components **Stage 1**: Task Work Skills



„Staged Process Control Readiness Training“

RUB

Training components **Stage 1**:

Task Work Skills

- Select instances, e.g. based on an event-based analysis
- Convert instances into training scenarios with a high physical and psychological fidelity,
- Sequence instances with increased difficulty, e.g. routine situation, non-routine/normal (planned & unexpected), non-routine/abnormal
- Brief to set the scene, e.g. in the form of a shift handover.
- Debrief with respect to results concerning quality and quantity of goal achievement, disclosure of complex technical processes, summarise cues, actions to be taken and similarities between instances
- Provide component practice for tasks that need to be automatized after introducing the whole task
- Use expanded retrieval practice with retention intervals between instance accumulations

Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

Task work simulator training with high psychological & cognitive fidelity

RUB

Fidelty	Description
Physical fidelity	Degree to which the equipment, interface, porcedures replicate the control room (Elliot et al., 2004)
Psychological fidelity	Extent to which the training environment prompts the essential underlying psychological processes relevant to key performance characteristics in the real world setting (Kozlowski & DeShon, 2004)
Cognitive fidelity	Degree to which scenario content is similar in cognitive demands for underlying cognition and information processing (Elliot et al., 2004)
Acton fidelity	Degree of correspondence between the behavior in a learning setting and the target setting (Stoffregen, Bardy, Smart & Pagulayan, 2003)

Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

„Staged Process Control Readiness Training“

RUB

Training components **Stage 2**:

Team Work Skills

- A full scope simulator
- (The sequencing of) Instances
- Experiential learning
- Component practice
- Briefing
- Debriefing

Deliberate practice by means of:

- Decision skill trainig
- Critical thinking training
- Stress exposure training
- Team training (Team guided self-correction, tram adaptation & coordination training)

Team work training for cognitive readiness

RUB

Team Work Skills

Communication

- Information exchange
- Phraseology
- Closed-loop communication

Coordination

- Knowledge requirements

Cooperation

- Mutual performance monitoring
- Back up behavior
- Adaptability
- Team orientation
- Collective efficacy
- Mutual Trust
- Team cohesion

Wilson, K.A., Salas, E. & Andrews, D.H. (2010). Preventing errors in the heat of the battle: formal and informal learning strategies to prevent teamwork breakdowns. In D.H. Andrews, R.P. Herz, & M.B. Wolf (Eds.), *Human factors issues in combat identification* (pp. 1-28). Aldershot, United Kingdom: Ashgate.

The logic of team work training

Training designed to develop **task-relevant skills** should be directed at individual team members
(Dyer, 1984)

Alternatively, **training teamwork skills**, or those focused on the behaviors and attitudes necessary for effective team functioning, are believed **to be best delivered to intact teams** rather than to individual members
(Cannon-Bowers, Tannenbaum, Salas & Volpe, 1995; Moreland,Argote, & Krishman, 1998)

The logic underlying this position is **that training intact teams provides opportunities for members to integrate their teamwork skills and to jointly practice complex coordinated** actions
(Kozlowski, 1998; Kozlowski, Brown, Weisbein, Cannon-Bowers, & Salas, 2000)

Mathieu, J., Maynard, M.T. Rapp, T. & Gilson, L. (2008). Team Effectiveness 1997-2007: A Review of Recent Advancements and a Glimpse Into the Future. Journal of Management, Vol. 34 No. 3, June 2008 410-476. DOI: 10.1177/0149206308316061

The challenge

RUB

Team work skills for non routine/abnormal situations

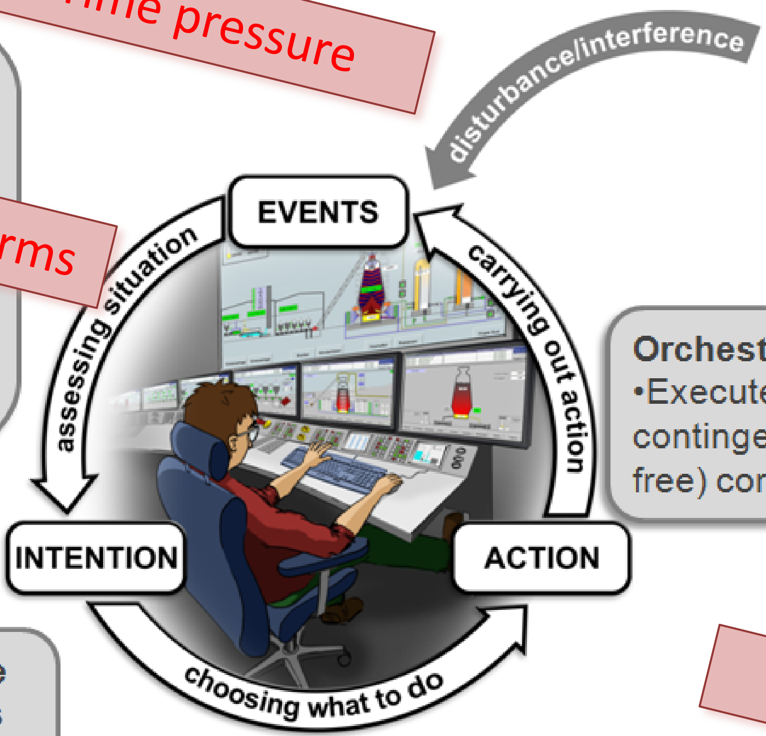
Monitor goal achievement

Alarms

Time pressure

Perceiving the difference between normal and abnormal
- Collecting and restructuring of data
- Combine, sort & filter cues
- Searching for patterns
- Detecting patterns of cues
- Sharing mental models
- Exchanging hypotheses about causes of problems

Alarms



Orchestrate actions
•Execute SOP (fixed, contingent, parallel & free) correctly

Alarms

Developing of joint problem space
- Resolving opposing interpretations
- Negotiate strategic team consensus
- Critical thinking

Alarms

Selecting course of action

Alarms

Team work simulator training with high **action fidelity**

RUB

Fidelty	Description
Physical fidelity	Degree to which the equipment, interface, porcedures replicate the control room (Elliot et al., 2004)
Psychological fidelity	Extent to which the training environment prompts the essential underlying psychological processes relevant to key performance characteristics in the real world setting (Kozlowski & DeShon, 2004)
Cognitive fidelity	Degree to which scenario content is similar in cognitive demands for underlying cognition and information processing (Elliot et al., 2004)
Acton fidelity	Degree of correspondence between the behavior in a learning setting and the target setting (Stoffregen, Bardy, Smart & Pagulayan, 2003)

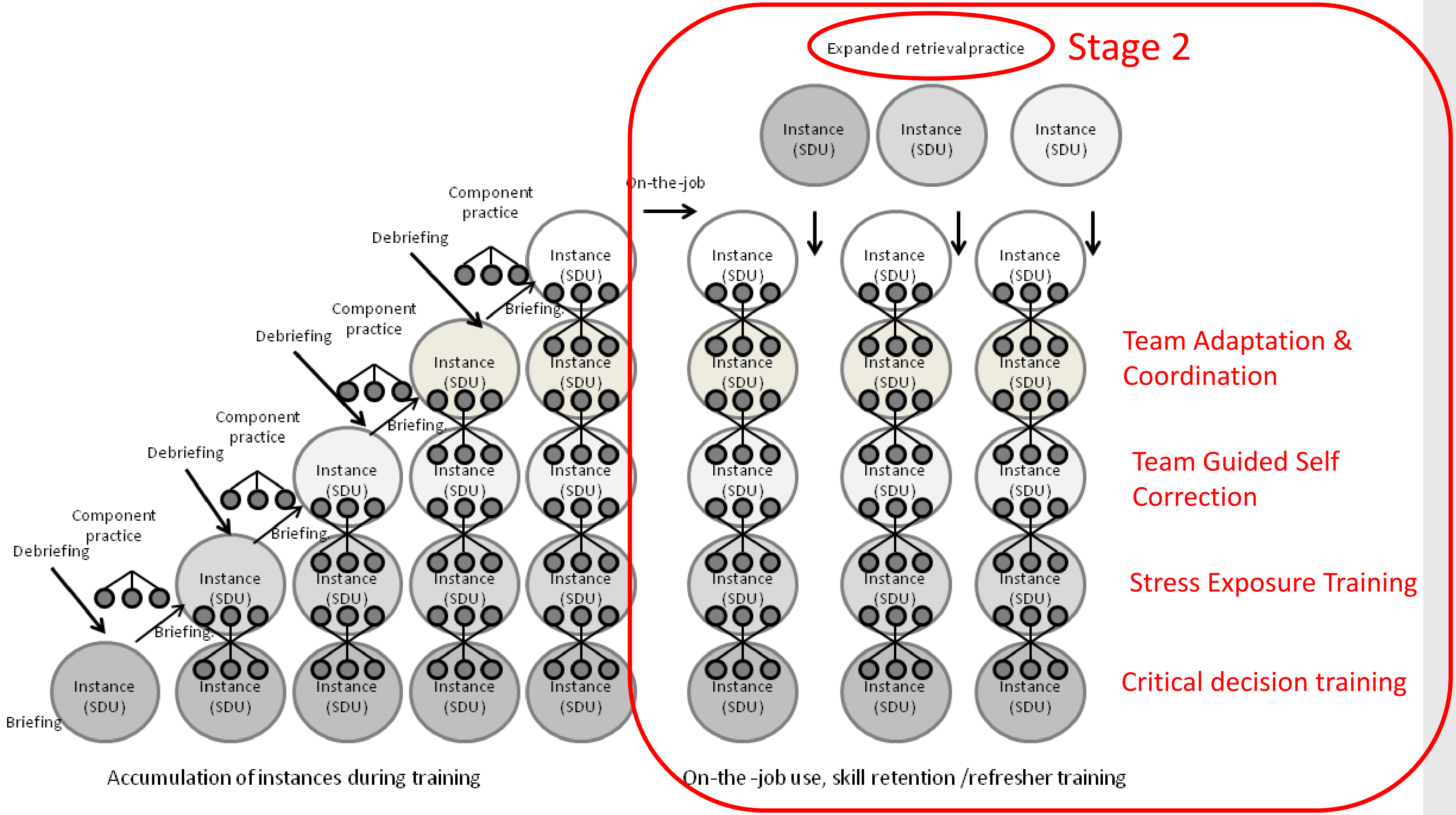
Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

„Staged Process Control Readiness Training"

RUB

Training components **Stage 2**:

Team Work Skills



Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

„Staged Process Control Readiness Training“

RUB

Training components **Stage 2**:

Deliberate practice and team work training

- Select instances which require collaborative problem-solving that stretch the shooting range of the mind
- Provide decision skill training in order to allow decision strategies of experts to be experienced rather than teaching these skills
- Provide Critical Thinking Training to train constructive controversy within collaborative problem-solving
- Provide Stress Exposure Training to enable operators to cope and maintain performance under stress
- Provide guided team self-correction to support teams in reflecting on their teamwork skills
- Provide team adaptation and coordination training to train the control room team in recognising and changing situational stress levels, in adapting coordination strategies, and the most appropriate conditions under which to use these strategies

Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

Maintaining cognitive readiness through **refresher interventions**

Cognitive readiness – training for non-routine control-room situations

RUB

threat
Training methods/duration/ frequency (do not) match learning objectives

threat
(no) Positive transfer

threat
(stress/time pressure) Conditions of performance not considered

Training → Cognitive readiness → Performance on the job

Routine
Non routine/normal
Non routine/abnormal

threat
Learning objectives do not consider performance conditions:
- Information overload and intransparency
- Task overload
- Peer/ Supervisor pressure
- Coping with physiologiccal reaction

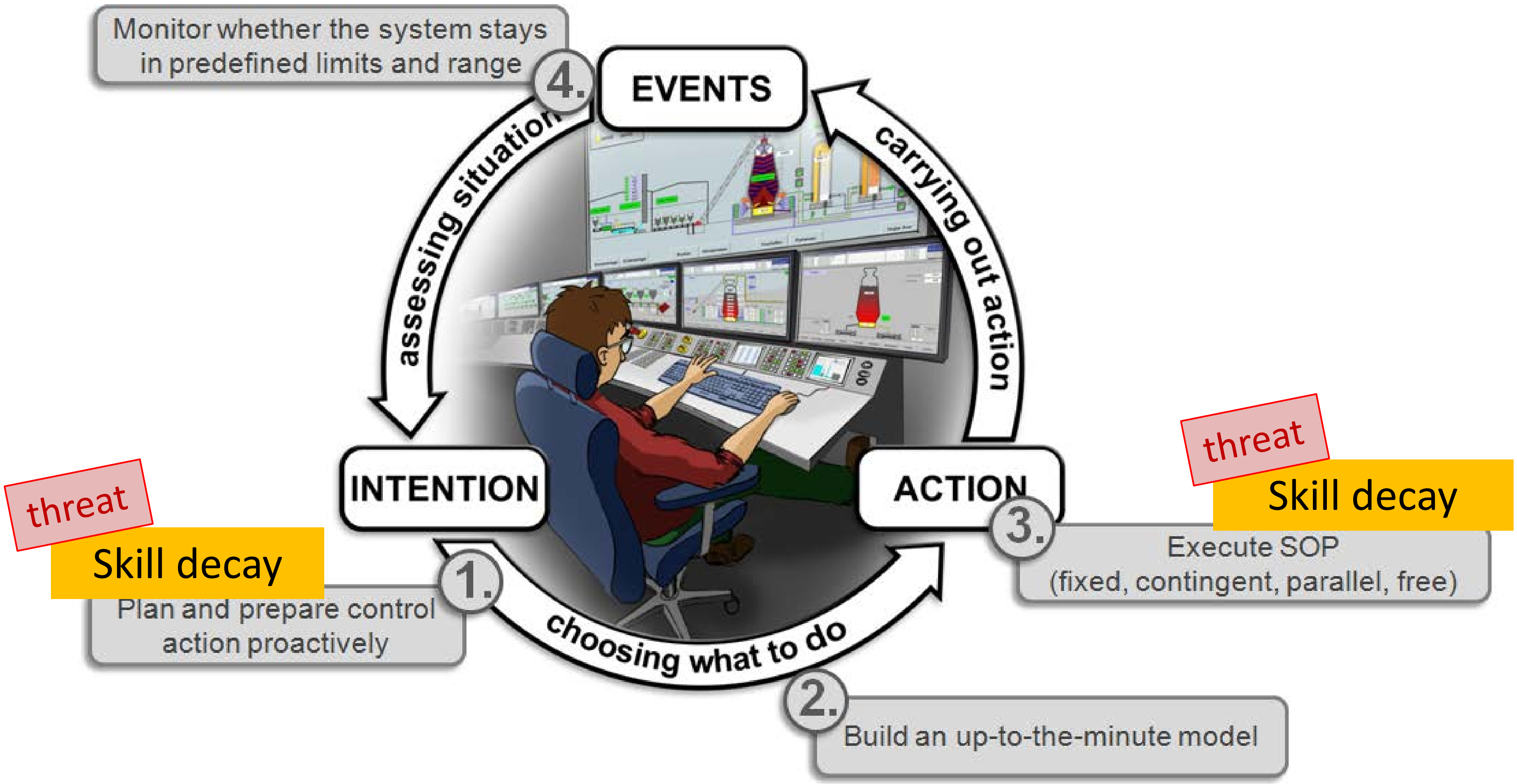
threat
Skill decay due to long periods of non-use

threat
(stress/time pressure) Conditions of performance not considered
→HF/Human Error

Cognitive readiness for non-routine situations

RUB

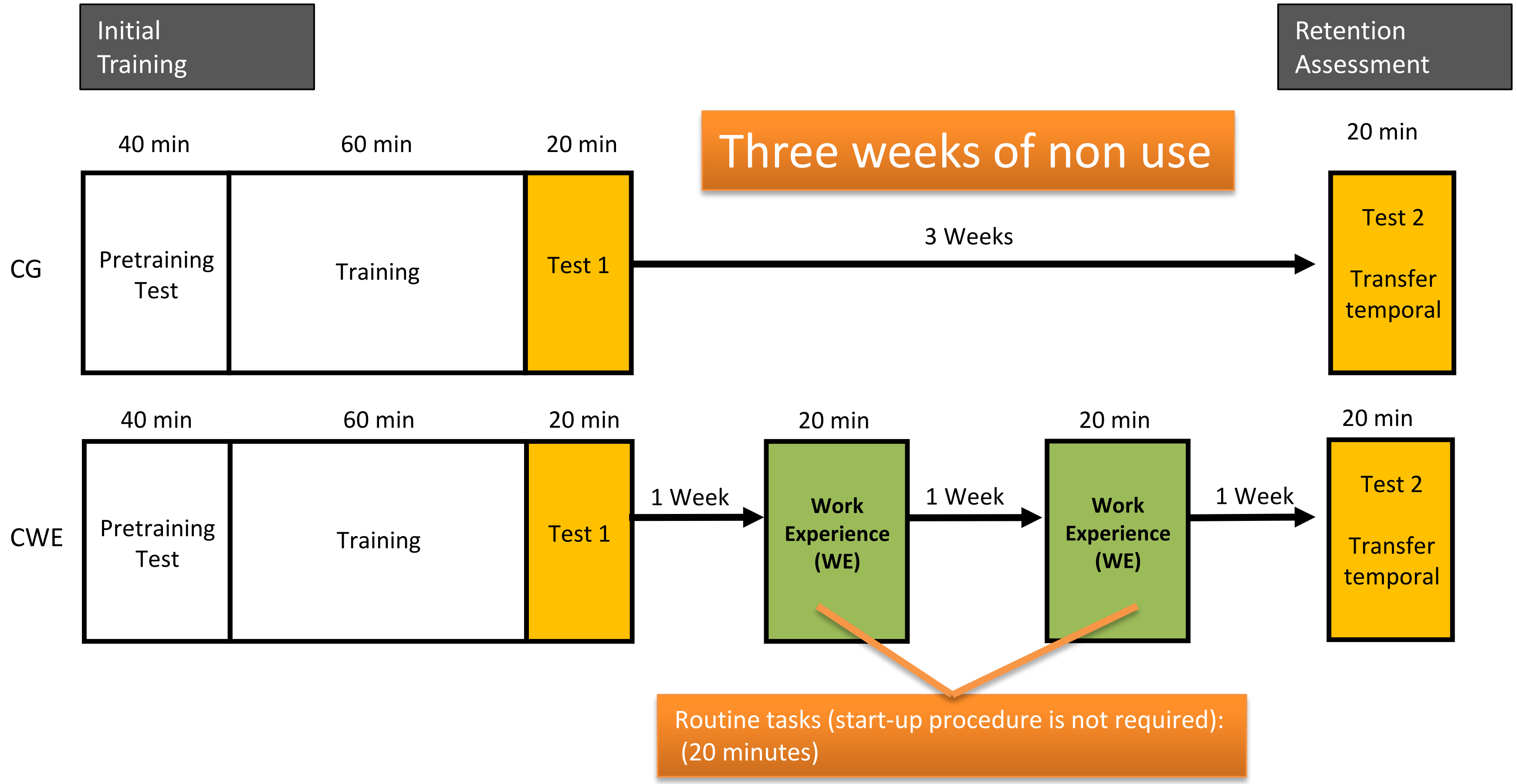
Non routine/normal situation: **"Start up procedure"**



Kluge, A. (2014) *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*. Springer: Dortrecht.

Does work experience in normal operations supports skill retention for non-routine situatons?

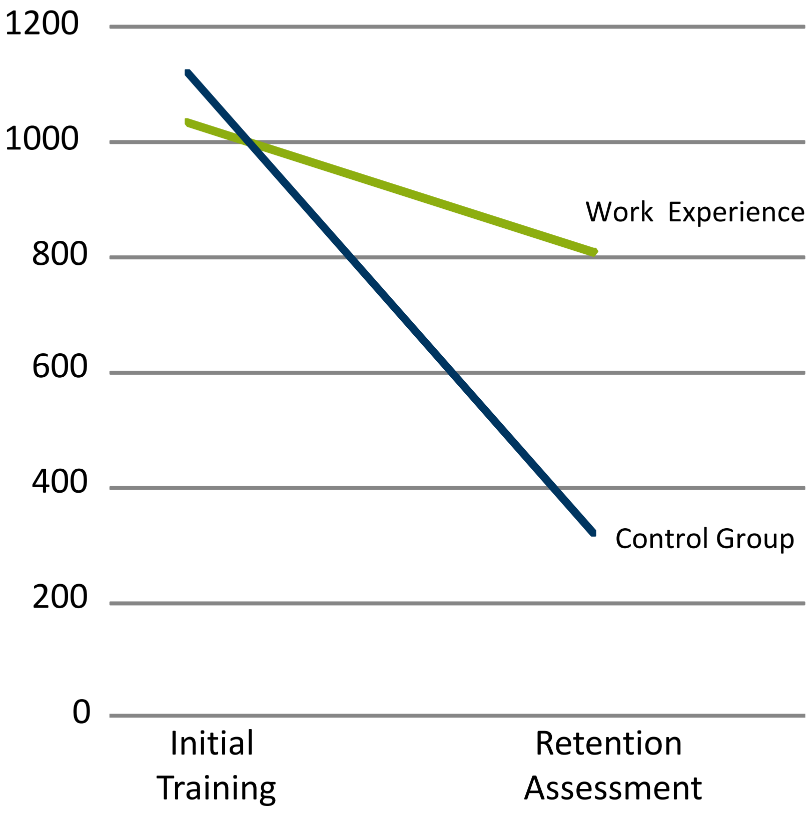
Results from one of our studies



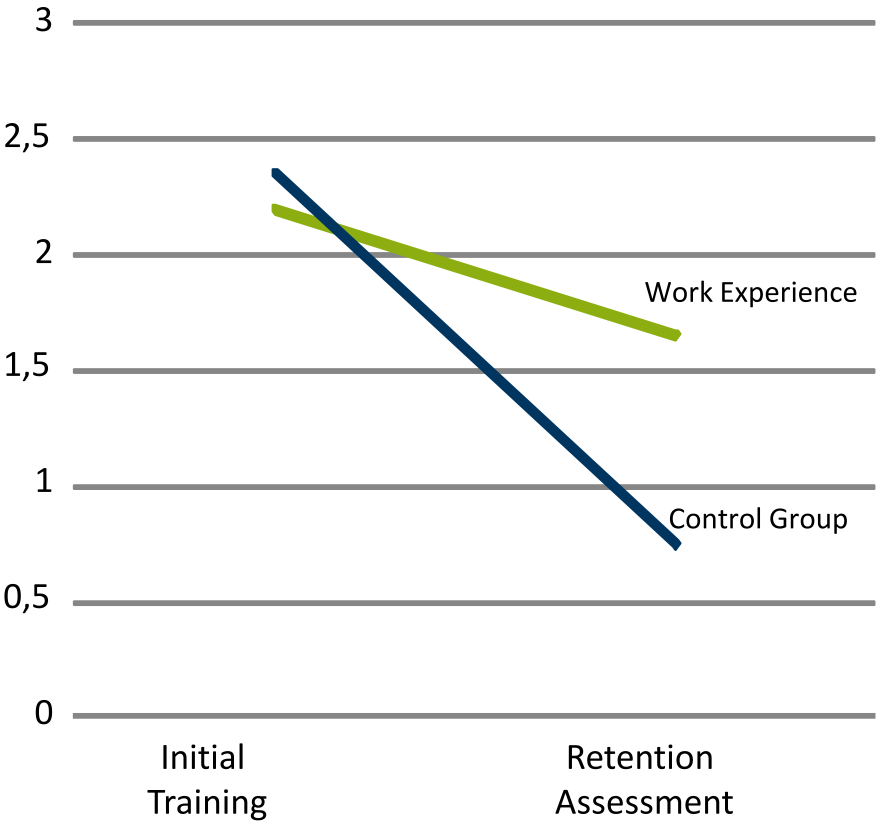
Kluge, A., Frank, B. & Miebach, J. (2013). Measuring skill decay in process control - results from four experiments with a simulated process control task. In De Waard, D., Brookhuis, K., Wiczorek, R., Di Nocera, F., Barham, P., Weikert, C., Kluge, A., Gerbino, W., and Toffetti, A., (Eds.) (2013), *Proceedings of the Human Factors and Ergonomics Society Europe Chapter 2013 Annual Conference*. Available as open source download from http://conference.hfes-europe.org/

Results
„Work experience/ normal operations“

Production

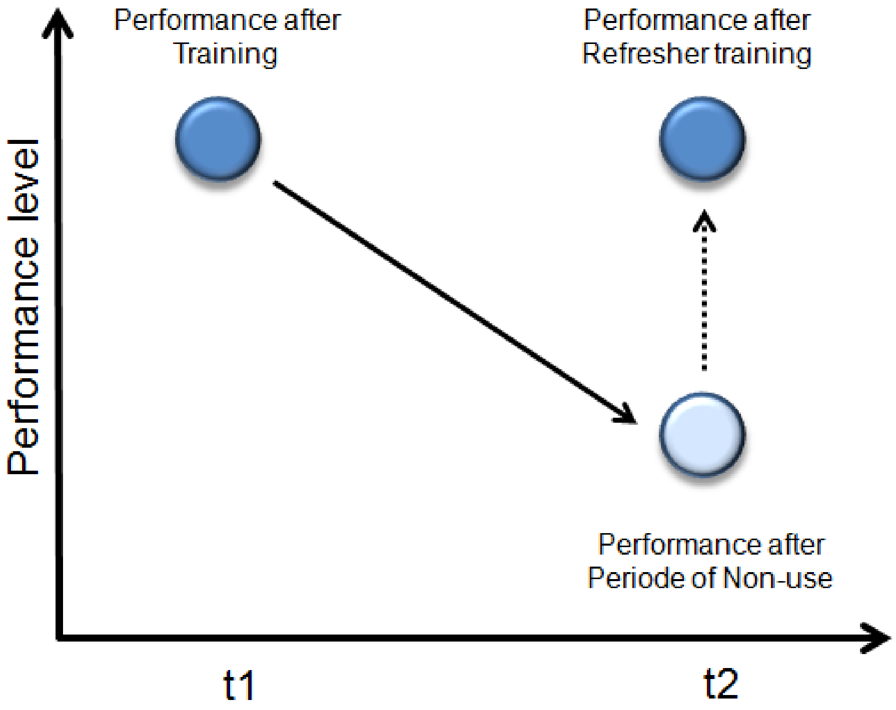


Secondary Task (mental workload)



That is the reason for Refresher Training

RUB



- Skill retention – research has tradition in military contexts (e.g. Arthur et al, 2010, Bodilly et al., 1986; Farr, 1986, Naylor & Briggs, 1961)
- Highly automated process industries also face the challenge of skill retention & decay (Bainbridge, 1983; Parasuraman et al. 2000)

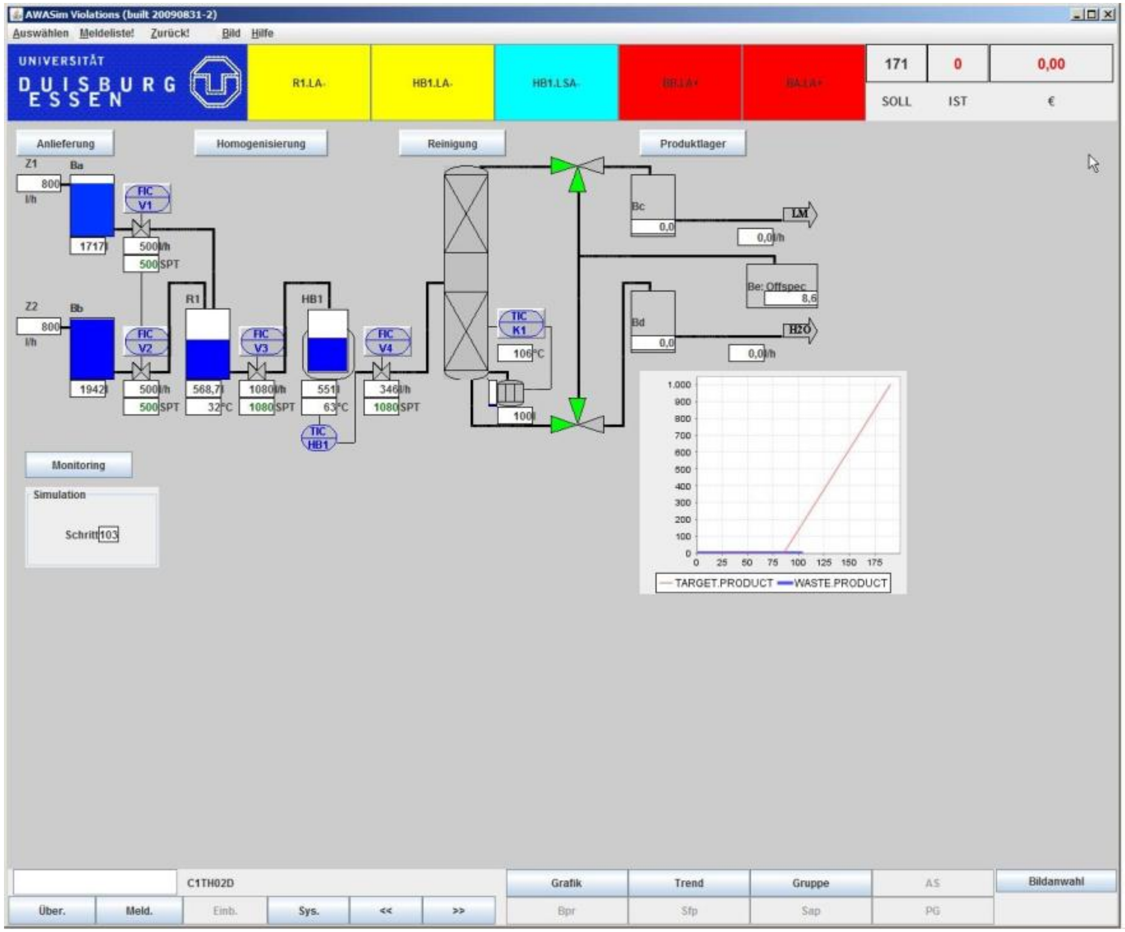
> *"Refresher training aims to re-establish a specific skill level that was acquired at the end of an initial training, which should be re-established after a certain time interval during which the skill was not required to be recalled"* (Kluge, Burkolter & Frank, 2012)

Kluge, A., Burkolter, D. & Frank, B. (2012). "Being prepared for the infrequent": A comparative study of two refresher training approaches and their effects on temporal and adaptive transfer in a process control task. *Proceedings of the Human Factors and Ergonomics Society 56th Annual Conference, Boston 2012,* pp. 2437-2441.
Kluge, A. Frank. B., Maafi, S. & Kuzmanovska, A. (2015). Does skill retention benefit from retentivity and symbolic rehearsal? Two studies with a simulated process control task. *Ergonomics.* DOI: 10.1080/00140139.2015.1101167
Kluge, A. & Frank, B. (2014). Counteracting skill decay: Four refresher interventions and their effect on skill retention in a simulated process control task. *Ergonomics.* 57(2), 175-190.

The Process Control Task WaTrSim

RUB

11 step start-up fixed sequence

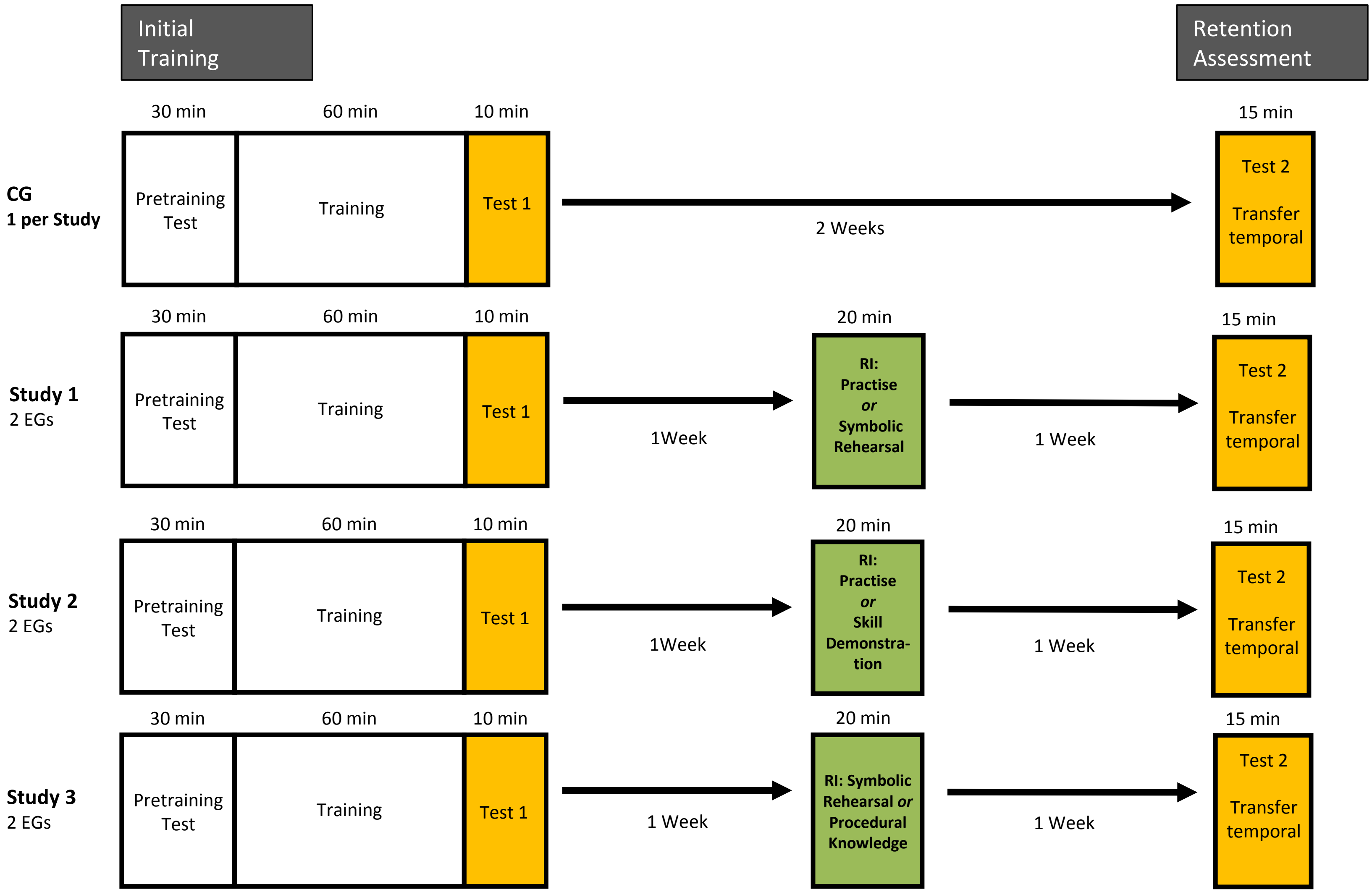


1. **Folgeregelung deaktivieren**
   - Regler V2 bedienen
   - Sollwertvorgabe von extern auf intern stellen
   - 2x Bestätigen mit „Ok"
   - Dialog schließen
2. **Ventil V1: Durchfluss 500 l/h**
   - Regler V1 bedienen
   - Sollwert 500l/h einstellen
   - 2x Bestätigung mit „Ok"
   - Dialog schließen
3. **Warten bis Inhalt von R1 > 200 l**
4. **Ventil V2: Durchfluss 500 l/h**
   - Regler V2 bedienen
   - Sollwert 500l/h einstellen
   - 2x Bestätigung mit „Ok"
   - Dialog schließen
5. **Warten bis Inhalt R1 > 400 l**
6. **Ventil V3: Durchfluss 1000 l/h**
   - Regler V3 bedienen
   - Sollwert 1000l/h einstellen
   - 2x Bestätigung mit „Ok"
   - Dialog schließen
7. **Warten bis Inhalt von HB1 > 100 l**
8. **Heizung H1 einschalten**
   - Regler HB1 bedienen
   - von Hand- auf Automatikbetrieb stellen
   - 2x Bestätigung mit „Ok"
   - Dialog schließen
9. **Warten bis HB1 > 60 C**
10. **Kolonne K1 in Betrieb nehmen**
    - Regler K1 bedienen
    - von Hand- auf Automatikbetrieb stellen
    - 2x Bestätigung mit „Ok"
    - Dialog schließen
11. **Ventil V4: Durchfluss 1000 l/h**
    - Regler V4 bedienen
    - Sollwert 1000l/h einstellen
    - 2x Bestätigung mit „Ok"
    - Dialog schließen

Kluge, A. & Frank, B. (2014). Counteracting skill decay: Four refresher interventions and their effect on skill retention in a simulated process control task. *Ergonomics.* 57(2), 175-190.

Comparing our studies

Refresher interventions
(*n* = 22 per group)

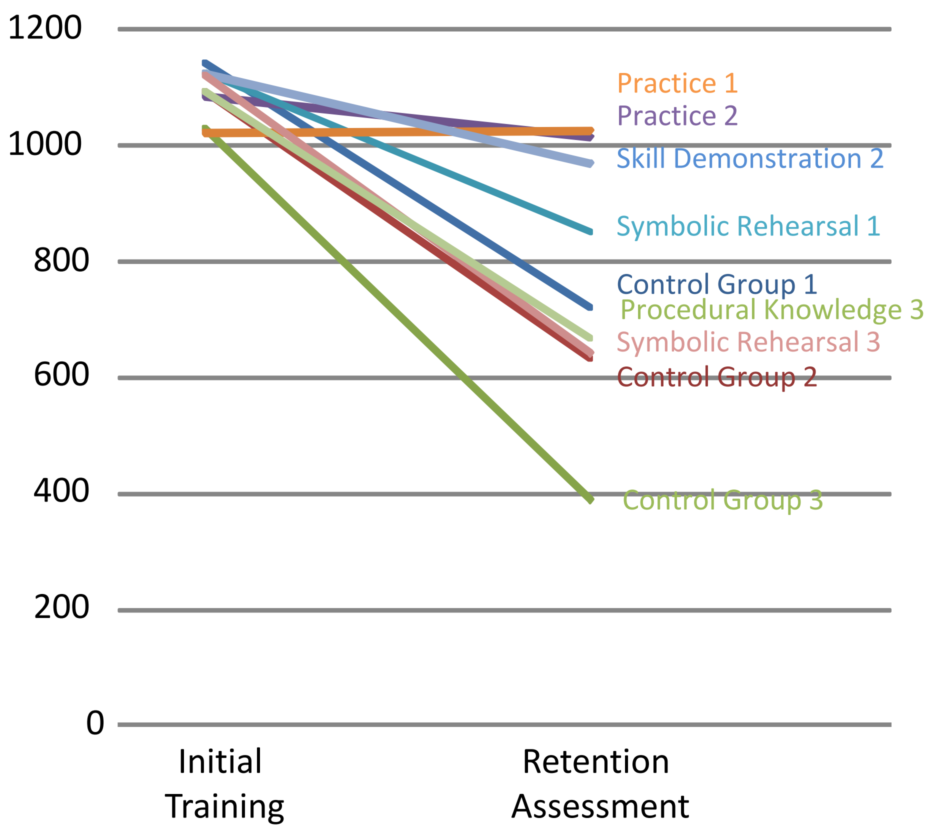


Kluge, A. & Frank, B. (2014). Counteracting skill decay: Four refresher interventions and their effect on skill retention in a simulated process control task. *Ergonomics.* 57(2), 175-190.

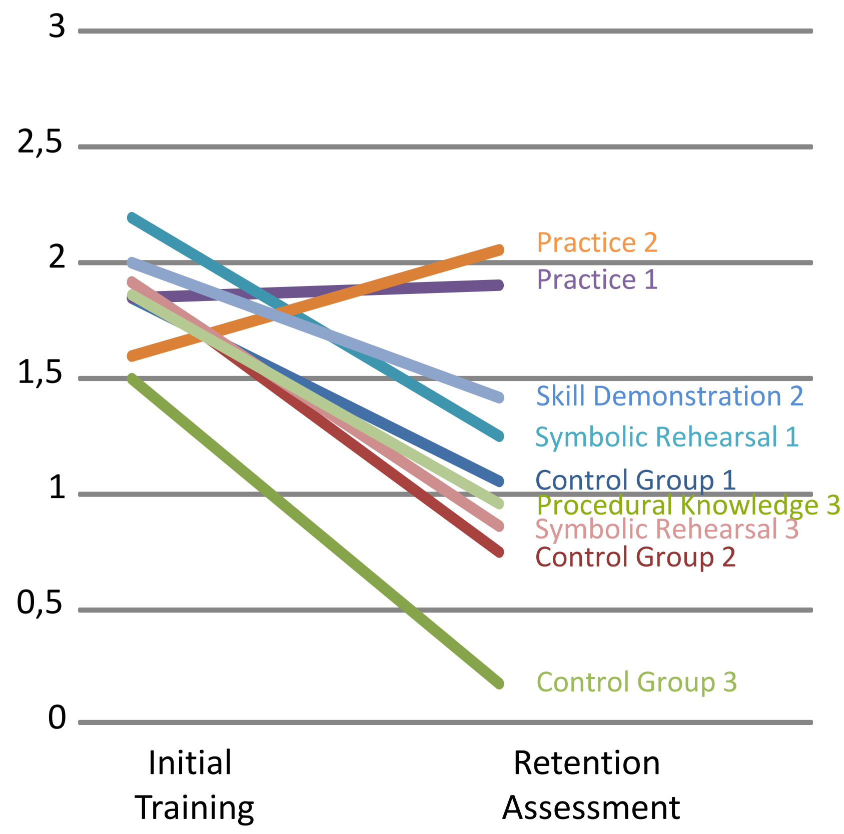
Results

RUB

Production Task



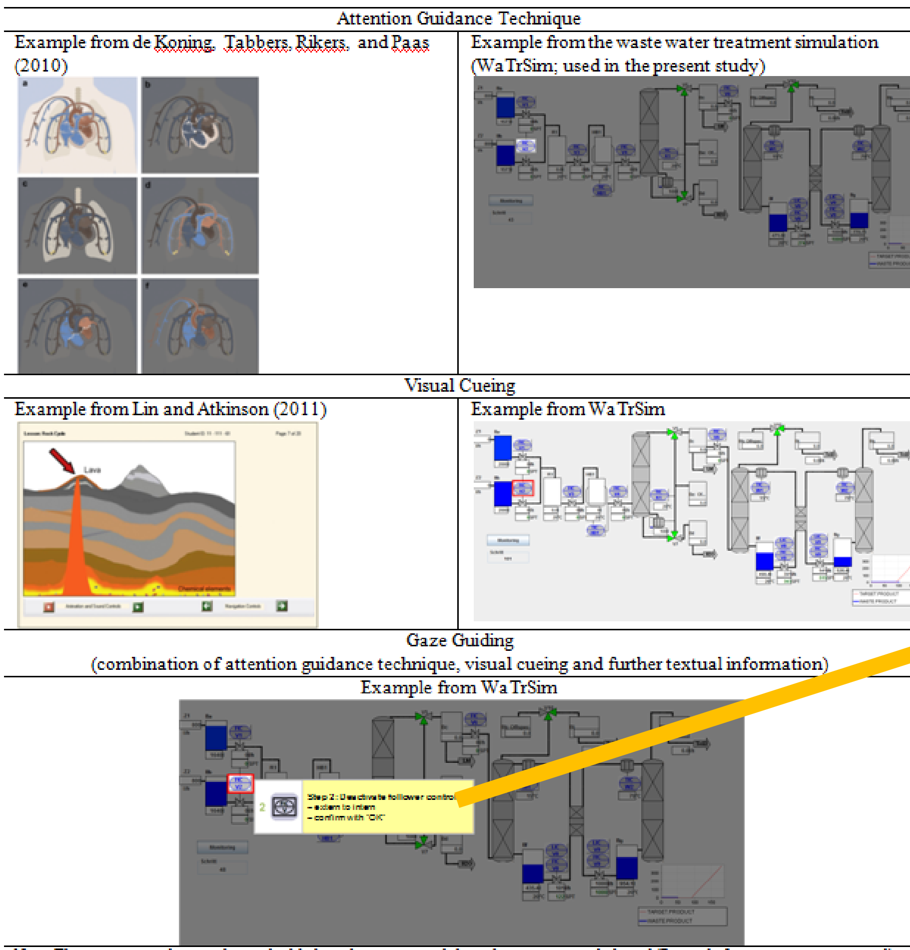
Secondary Task (mental workload, 0-3)

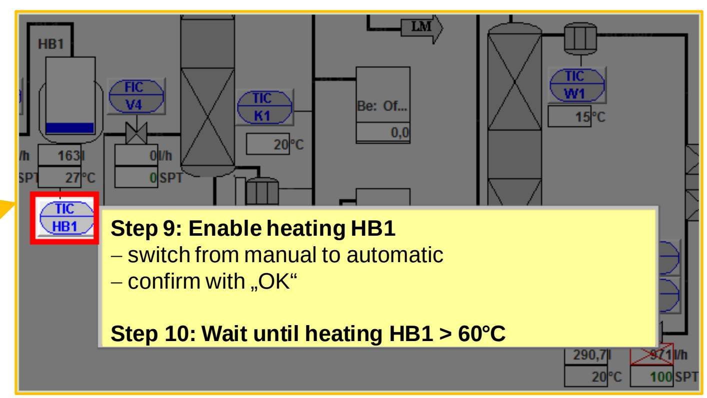


(Explanation: Practice 1 = Practice Study 1)

A different approach to skill retention- supported by gaze guiding (B. Frank & A.Kluge)

Cued recall with gaze guiding – reduction of human errors with a gaze-guiding tool





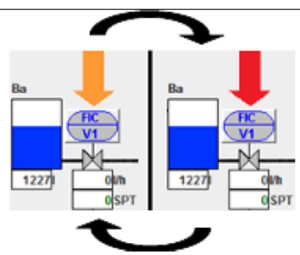
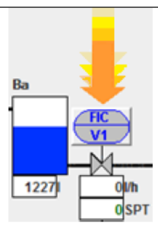
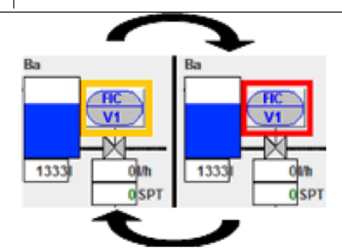
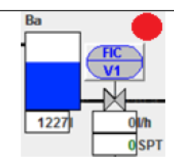
Frank, B. & Kluge, A. (2016). Cued recall with gaze guiding – reduction of human errors with a gaze guiding tool, AHFE Konferenz, 27.-31. Juli, Orlando.

Frank, B. & Kluge, A. (under review) Cued skill recall: The effect of gaze guiding to support of complex cognitive skill recall to reduce errors and retain performance.

Weyers, B., Frank, B., Frank, Bischof, K. & Kluge, A (2015). Gaze guiding as Support for the Control of Technical Systems. *International Journal of Information Systems for Crisis Response and Management, Special Issue on Human Computer Interaction in Critical Systems,* 7(2), 59-80.

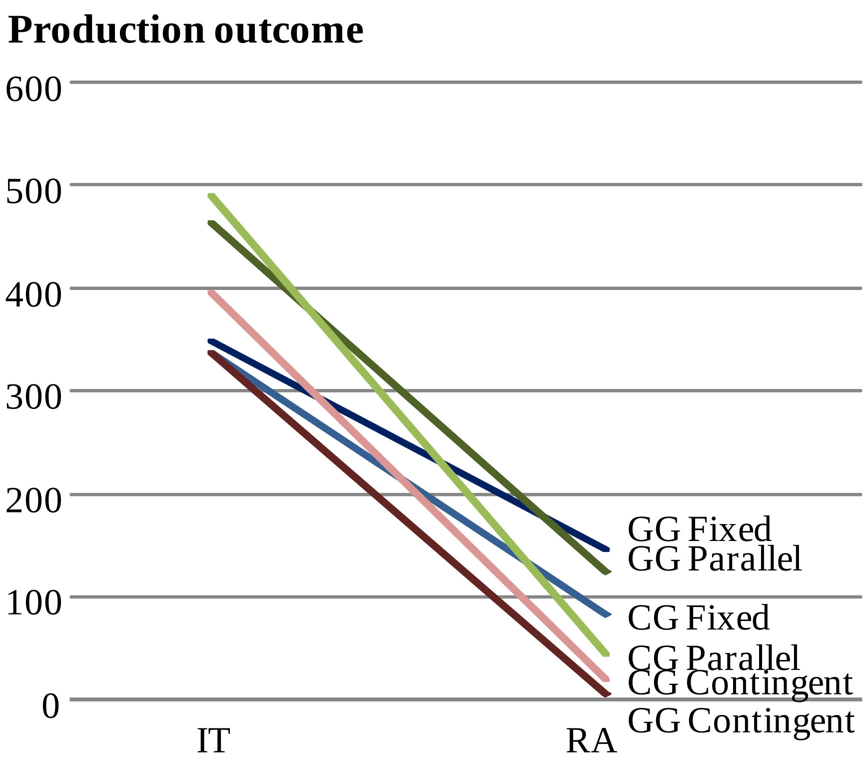
Kluge, A., Greve, J. Borisov, N. & Weyers, B. (2014). Exploring the usefulness of two variants of gaze-guiding-based dynamic job aids for performing a fixed-sequence start-up procedure after longer periods of non-use. *International Journal of Human Factors and Ergonomics, 3(2),* 148-169

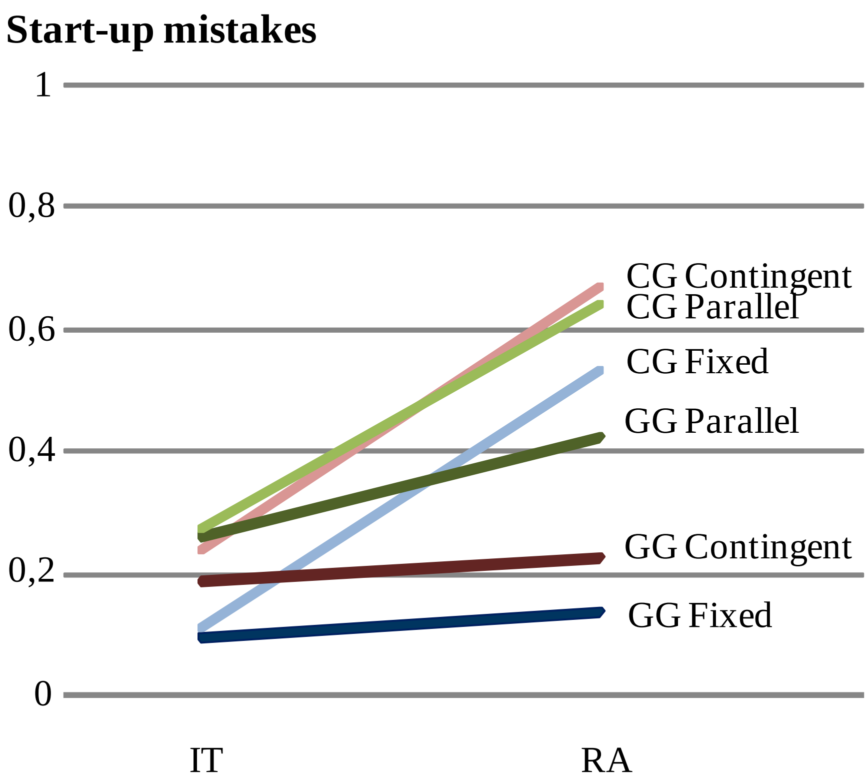
Design consideration for the gaze guiding tool

Name	Example Picture	Parameters
(1) Transparent Overlay	see Figure 4	1) size and position 2) alpha value for transparency 3) color 4) optionally with help text 5) position of cutout(s)
(2) Fixed Arrow		1) position of arrowhead 2) arrow direction 3) color 4) auxiliary variables for shape of arrow, 5) optional blink interval, initial state and second color
(3) Animated Arrow		1) position of arrowhead 2) arrow direction 3) color 4) auxiliary variab… 5) number of step… 6) step size
(4) Frame		1) size and position 2) shape 3) color 4) border thickness 5) optional blink interval, initial state and second color
(5) Attention Marker		1) size and position 2) shape 3) color 4) optional blink interval, initial state and second color
(6) Help Text		1) size (or adapted to text length) and position 2) background color of text box and/or of pictogram box 3) color of the frames 4) font, font color, font size, font style, 5) line spacing 6) optionally with one or more pictograms

Weyers, B., Frank, B., Frank, Bischof, K. & Kluge, A (2015). Gaze guiding as Support for the Control of Technical Systems. *International Journal of Information Systems for Crisis Response and Management, Special Issue on Human Computer Interaction in Critical Systems,* 7(2), 59-80.

Results: Cued recall with gaze guiding – reduction of human errors with a gaze-guiding tool





Frank, B. & Kluge, A. (2016). Cued recall with gaze guiding – reduction of human errors with a gaze guiding tool, AHFE Konferenz, 27.-31. Juli, Orlando.

Take home message

- Inert knowledge is the opposite of cognitive readiness (CR)
- CR= possessing the **task work** and **teamwork knowledge** and skills an operator needs to establish and sustain competent performance in order to be in control in routine, non-routine/normal and non-routine/abnormal situations
- Training is not the barrier- it‘s the training outcome!
- CR serves as a active and a passive barrier
- CR is relevant for skills which have not been used for a longer period of time
- CR is relevant for situations which are a) ambiguous and includes b) unanticipated major c) threats to system survival coupled with d) limited time to respond
- Training for CR requires the accumulation of instances by simulator training with high cognitive fidelity
- Team work skills require the practice of team coordination in intact teams with high cognitive and action fidelity
- Normal operations only do not support CR
- Refresher interventions support the retention of cognitive readiness
- Gaze guiding might compensate for CR to some extent (after periods of non-use)

The end

Thanks to my marvelous team
for their research effort
and for your attention!

Dr. Vera Hagemann → Cognitive foundations of team work

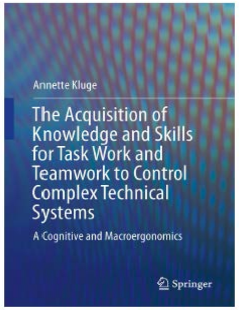
Barbara Frank, M.Sc. → Refresher interventions

Sebastian Brandhorst , M.Sc. → Safety related rule violations

Nikolaj Borisov , Dipl. Inf. → Human Machine Interface of the future

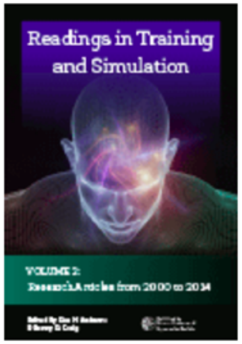
…und Merle Lau, Mike Silbert, Felix Miessen, Alina Tausch, Florian Engel, Julia Sagner, Rebecca Lürmann, Florian Engel (2) as student workers

More to read…



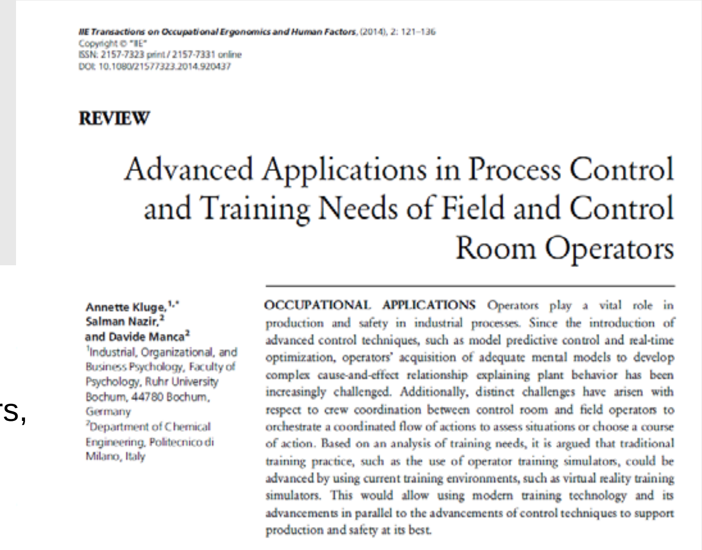
Kluge, A. (2014). *The acquisition of knowledge and skills for taskwork and teamwork to control complex technical systems. A cognitive and macroergonomics Perspective*.

Springer: Dortrecht. 193 pages



Readings in Training and Simulation, Volume 2: Research Articles from 2000 to 2014
Edited by Dee H. Andrews & Scotty D. Craig
Published by the Human Factors and Ergonomics Society
ISBN 978-0-945289-46-3, e-book, 865 pp.

Kluge, A. & Burkolter, D. (2013). Training for Cognitive Readiness: Research Issues and Experimental Designs. *Journal of Cognitive Engineering and Decision Making, 7*, 96 -118.



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DOI: 10.1080/21577323.2014.920437

REVIEW

Advanced Applications in Process Control and Training Needs of Field and Control Room Operators

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Salman Nazir,[2]
and Davide Manca[2]
[1]Industrial, Organizational, and Business Psychology, Faculty of Psychology, Ruhr University Bochum, 44780 Bochum, Germany
[2]Department of Chemical Engineering, Politecnico di Milano, Italy

OCCUPATIONAL APPLICATIONS Operators play a vital role in production and safety in industrial processes. Since the introduction of advanced control techniques, such as model predictive control and real-time optimization, operators' acquisition of adequate mental models to develop complex cause-and-effect relationship explaining plant behavior has been increasingly challenged. Additionally, distinct challenges have arisen with respect to crew coordination between control room and field operators to orchestrate a coordinated flow of actions to assess situations or choose a course of action. Based on an analysis of training needs, it is argued that traditional training practice, such as the use of operator training simulators, could be advanced by using current training environments, such as virtual reality training simulators. This would allow using modern training technology and its advancements in parallel to the advancements of control techniques to support production and safety at its best.

Kluge, A., Nazir, S. & Manca, D. (2014). Advanced Applications in Process Control and Training Needs of Field and Control Room Operators, *IIE Transactions on Occupational Ergonomics and Human Factors, 2(3-4*), 121-136