

Ecological analysis of practice for developing resilient systems in safety critical domains

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Content of the presentation

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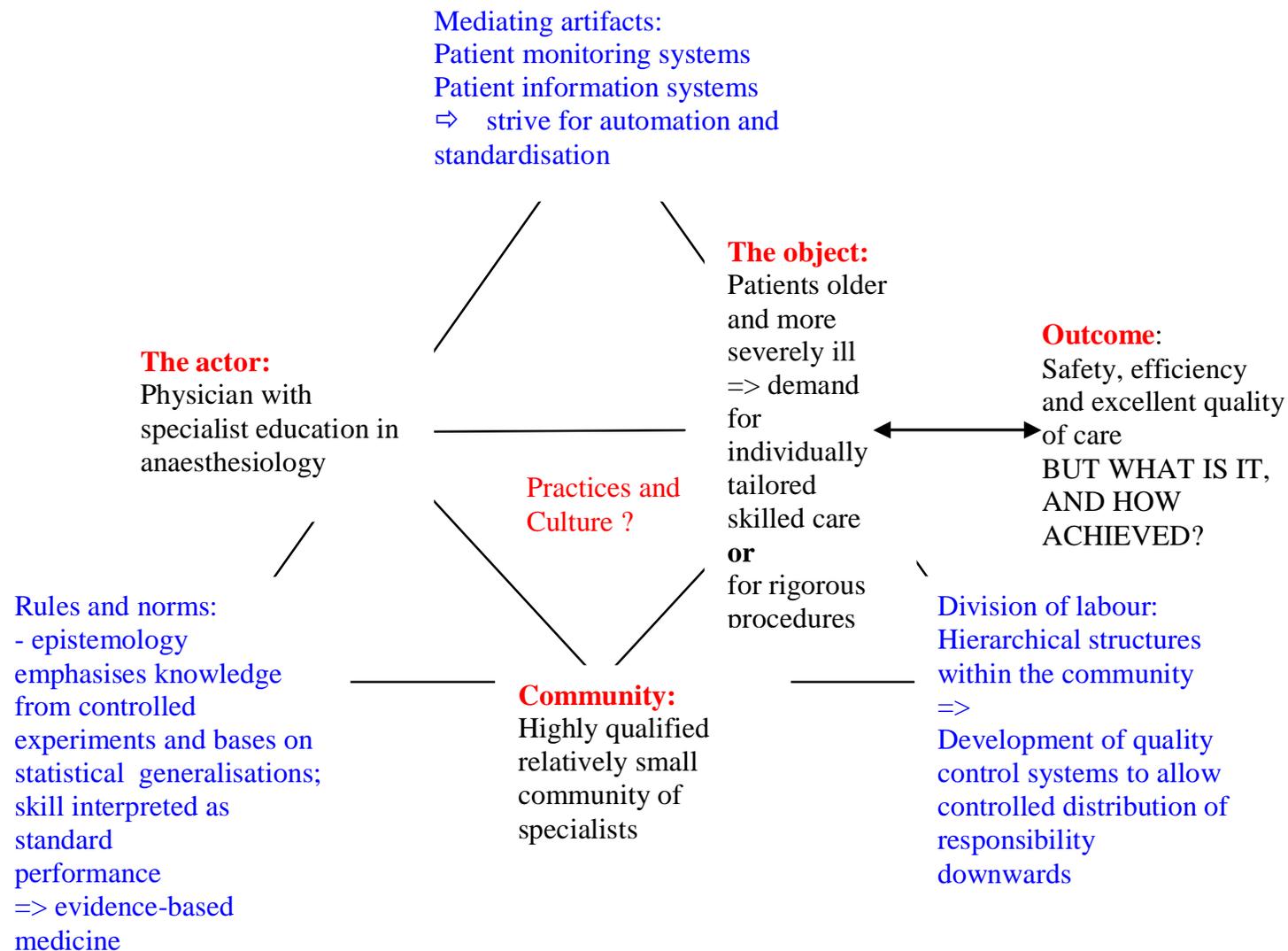
INTRODUCTION: ANESTHESIA ACTIVITY FROM A SYSTEMS POINT OF VIEW

Motivating the case study on anaesthesia

- The aim of the study - understanding of anaesthetists' clinical work as a basis for development of professional practice
 - Accomplished during 1995-2002 by U.-M.Klemola, expert anaesthetist, and L.Norros, human factors expert
- Reasons for choosing this case for demonstration of the approach:
 - One of the key projects in which the “ecological analysis of activity” approach was developed
- Reasons for post hoc connecting of the study to “resilience engineering” (RE) discourse:
 - practical aims correspond to those of RE
 - analysis of practices within RE is almost missing

The objective of anaesthesia activity

- Objective of the anaesthesia activity is to enable operative treatment of patients by ensuring a safe and sufficiently deep sleep during all phases of surgery



A systemic model of anaesthesia activity

Approaches to safety management in safety-critical domains

- Starting around 1980 safety-oriented research focused on analysis how accidents had happened. Human errors and performance shaping factors
- By 1990 focus had shifted towards how safety could be supported or even designed. Safety culture
- By 2000 claims for system-oriented safety management have increased as existing methods were identified deficient (focus on failure, particular event, fixes create new problems, circular explanations, deficient learning). New concepts needed?

Resilience engineering is a system-oriented approach to safety

Resilience is the intrinsic ability of a system to adjust its functioning, prior to or following changes and disturbances, so that it can sustain operations even after a major mishap or in the presence of continuous stress. (Hollnagel et al. 2012)

- Focus is shifted away from things that go wrong to those that go right - interest is in understanding the normal functioning of the organization
- Attention has so far been on organisational structures and management
- Our aim is to study resilience in actual individual and team performance

Attributes of resilience

- Resilience in the system emerges as a result of a joint effort of human actors and technology

- This joint effort should demonstrate:
 - Ability to address the actual situation
 - Ability to address (and identify) the critical factors for safety
 - Ability to (anticipate and) address the potential for safety
 - Ability to address the factual experience and learn from it

Hollnagel et al. 2011

How to identify whether behaviour has capability to support resilience of the system?

- Drawing on the pragmatist approach to human conduct (Ch.S. Peirce, J. Dewey) and Cultural historical theory of activity (A.N.Leont'ev)
 - we consider that behaviour that supports system resilience should demonstrate a particular relationship of the actor to the changing environment that is defined interpretative
 - individual/team behaviour supports resilience when it is oriented appropriately with regard to overall system objectives in any situation, i.e., actors make the connection between situational goals and general objectives of the system

ECOLOGICAL ANALYSIS OF PRACTICES

Ecological approach: Key concepts

- In an ecological approach to activity the unit of analysis is the *human-environment joint functioning*
 - The focus is not on internal processes of the human, or technology and the environment, but instead how these elements are organised to maintain the viability of the system
 - The environment is experienced as possibilities to act (affordance)
- *Practice* is the key concept that expresses the patterns of joint functioning
 - These patterns are *generic ways of acting* that can be inferred on the basis of situation specific *actions*
 - *Technologies and tools* are inherent in practice and their role needs to be elaborated in analyses
- Concepts of *activity and habit* are needed in defining practices

Analysis of behaviour is accomplished on two levels

Realized sequence of actions



Potential for action, i.e., practice



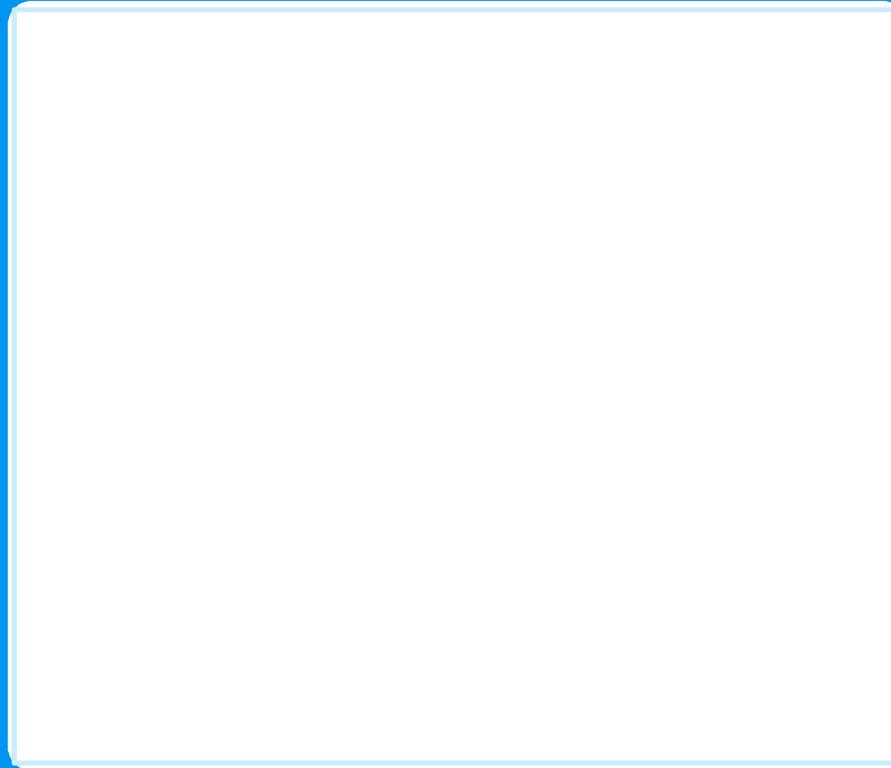
Activity for understanding
the context and meaning
of behaviour



Habit to identify the
connection between human
and the elements of the
environment

Step 1 in analysis of practices

MODELLING OF DOMAIN AND
CONTROL DEMANDS

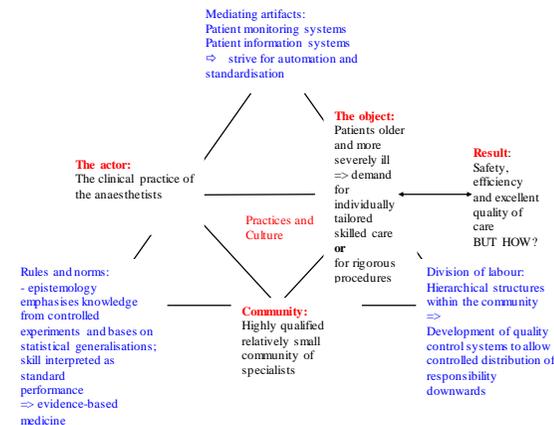


Activity

- The concept of activity is drawn from the cultural historical activity theory (CHAT)
- Activity defines the context or circumstance of acting
- Activity needs to be analysed and modelled because it is not necessarily immediately visible or evident
- Activity deals with the objectives, constraints, regularities and contradictions that people may take into account in their daily acting according different logics

The anaesthesia activity

- **Objective** of anaesthesia activity is to enable operative treatment by ensuring a safe and sufficiently deep sleep during all phases of surgery
- **Activity system** and the internal tensions of anaesthesia activity (Engeström 1987)



A systemic model of anaesthesia activity

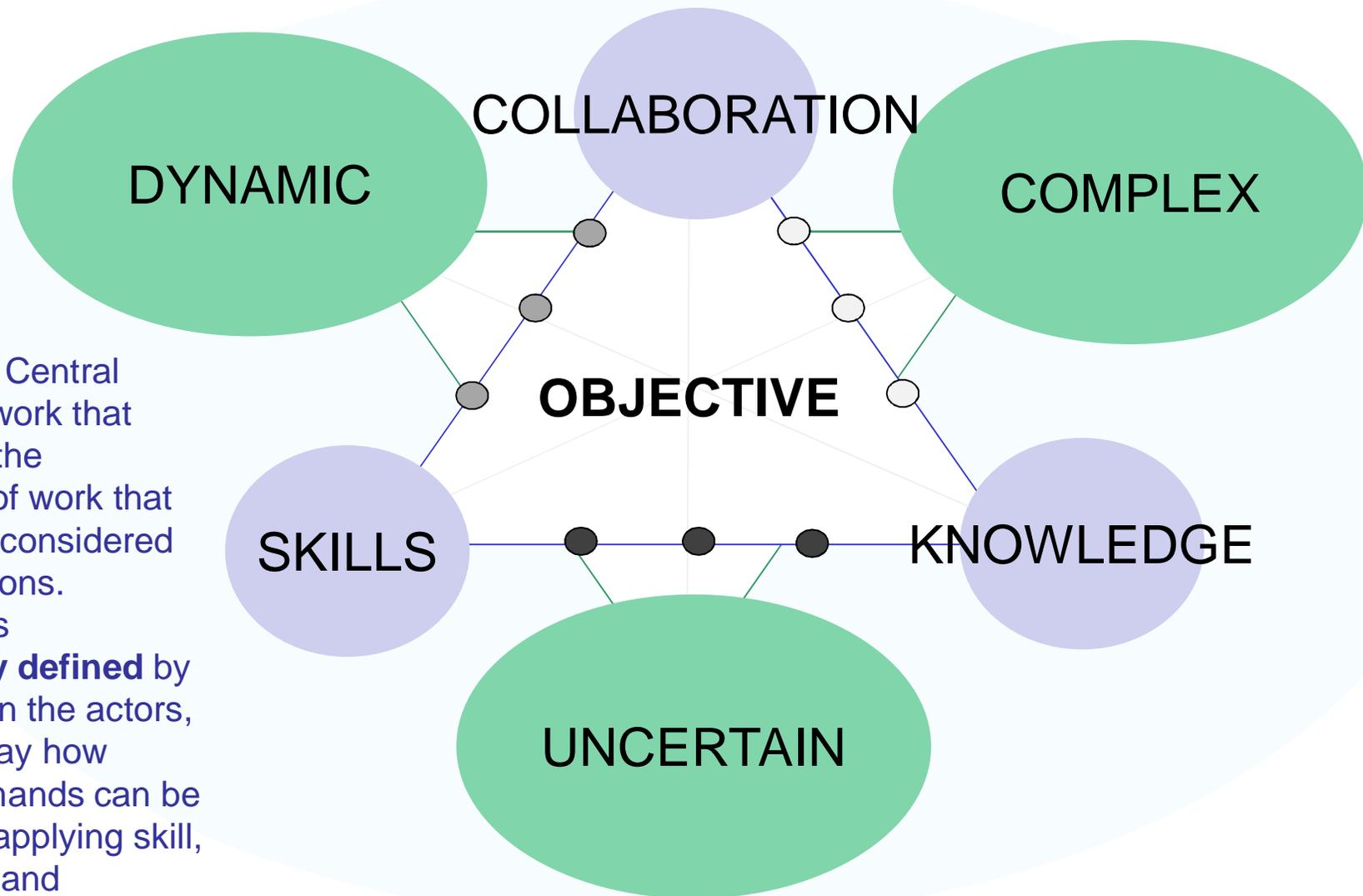
Intrinsic control demands of anaesthesia

- Striking balance between the complex physiological effects of the anaesthetic drug
 - cardiovascular repression due to anaesthetics during induction
 - acquisition of a dynamic balance between depth of anaesthesia and surgical stimulation
 - balancing between different anaesthesia drugs
- Coping with uncertainty due to the particularity of the patient
- Coping with the dynamics of the anaesthesia process, especially coping with the duration and delayed effects

The core-task demands of anaesthesia

- Core-task demands in anaesthesia:
 - Rich use of situational information
 - Forming a cumulative interpretation of the physiology of the patient
 - Anticipation in controlling the anaesthesia process
 - Preparedness and cross-checking in the use of instruments and drugs

Core-task modelling in DCU environments



Core-task: Central content of work that expresses the objectives of work that need to be considered in all situations. Core task is **empirically defined** by demands on the actors, which portray how control demands can be tackled by applying skill, knowledge and collaborative resources.

Anaesthetists conception of the their work: Orientation

- Orientation is the stance (epistemic attitude) to the object of activity in situations that require action (Galperin 1979)
- Operationalised in the case as conception of the nature of
 - the patient
 - the anaesthesia process
 - monitor information
- Assessed on the basis of interview data with the help following qualifiers:
 - **Realistic orientation:** particularity of the patient, uncertainty of the process and mediatedness of information recognised
 - **Objectivistic:** patient as an “average man”, uncertainty not recognised, mediatedness of information not recognised

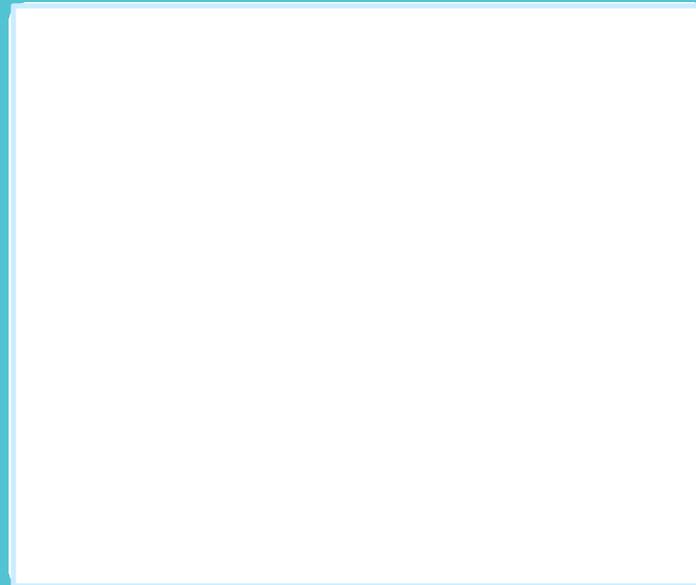
Results: Anaesthetists' basic orientation to work

- 16 expert anaesthetists (almost all specialists with over 10 years of experience in South Finland 1995-98) were interviewed
 - *Realistic orientation* i.e. acknowledgement of the uncertainty of the anaesthesia process and the uniqueness of the patient (33%)
 - *Objectivistic orientation* i.e. uncertainties in the process and the uniqueness of the patient not recognised (66%)

Steps 2 in analysis of practices

MODELLING OF DOMAIN AND
CONTROL DEMANDS

MODELLING OF SITUATIONAL
TASK DEMANDS



Tasks and tools of anaesthesia – data collection indicated

- Phases of anaesthesia :

- preparatory phase
- induction
- stable stage
- awakening

> short interview

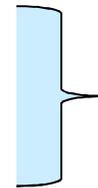


observation, video

> debriefing interview

- Main tools:

- drugs
- patient information
- professional concepts

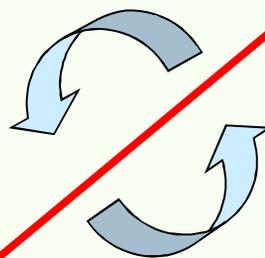


observation, comments

- Clinical cases were selected by the anaesthetists – normal cases with dynamic challenges; no pre-modelling of situations

Hypothesis regarding the mastery of core-task demands

Normal homeostatic state of the patient to be identified



Inducing anaesthesia and experimenting for learning the unique dynamics

=> Cumulative interpretation

New homeostatic state regulated by aid of the cumulative conception

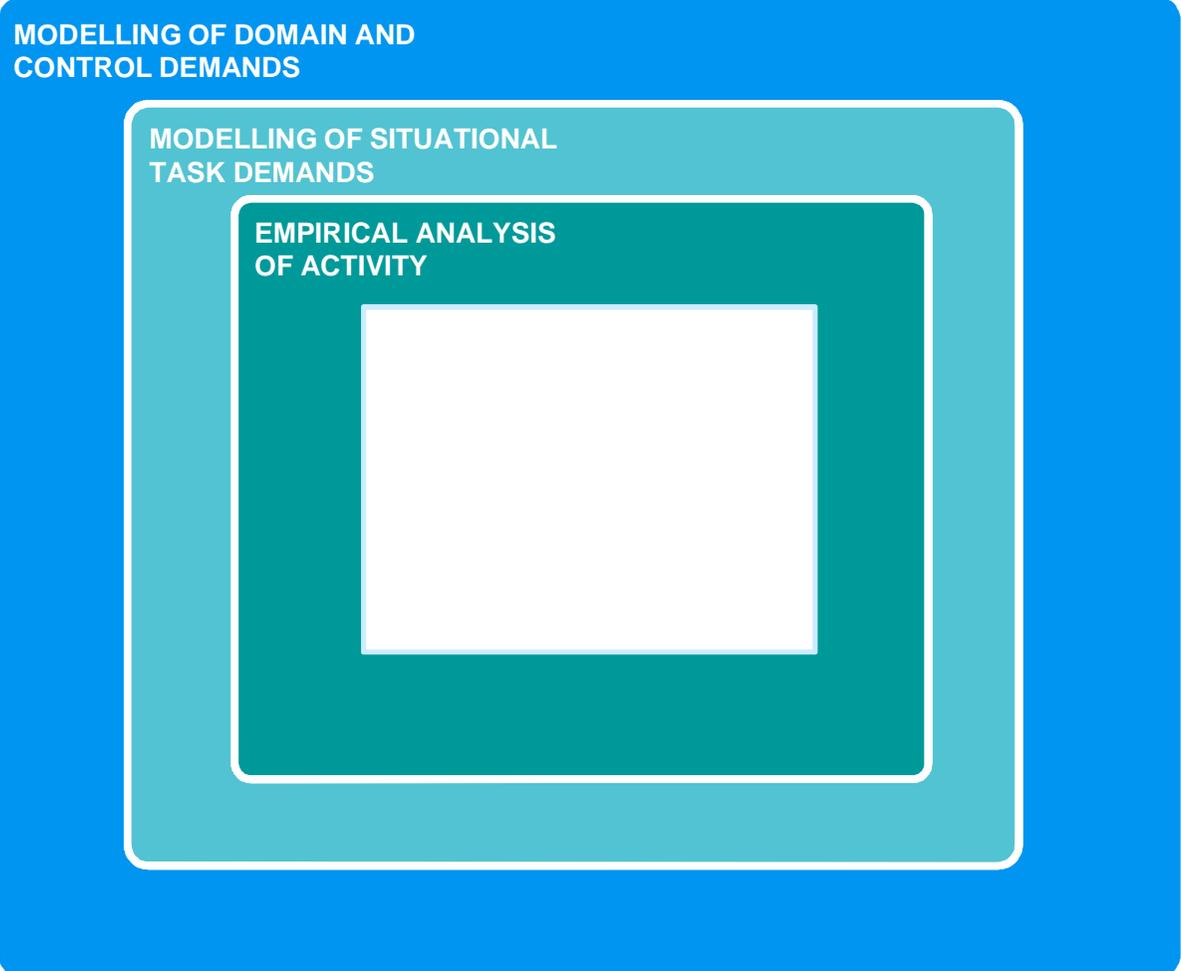
Waking up 

Steps 3 in analysis of practices

MODELLING OF DOMAIN AND
CONTROL DEMANDS

MODELLING OF SITUATIONAL
TASK DEMANDS

EMPIRICAL ANALYSIS
OF ACTIVITY



VIDEO

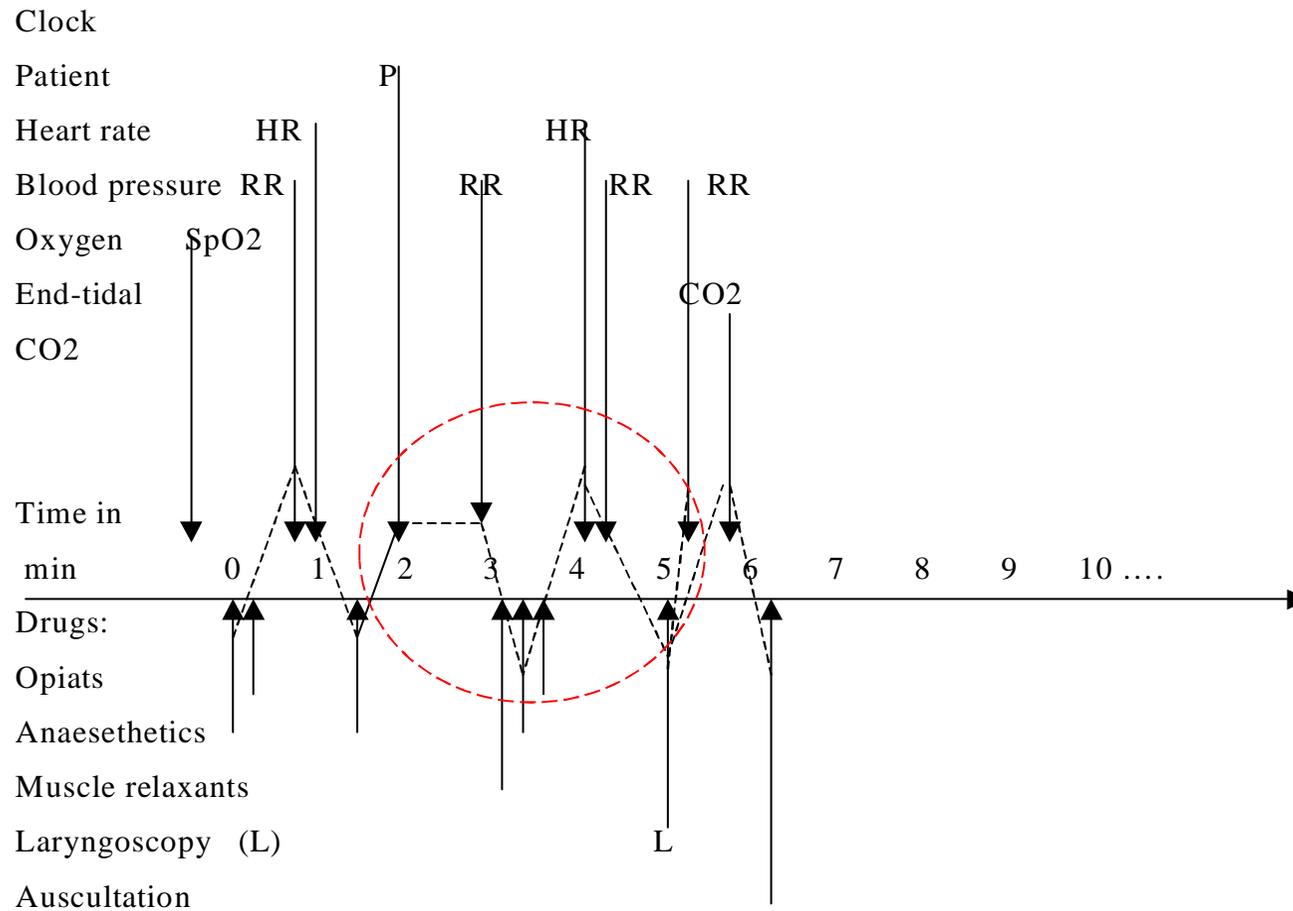


Figure XX. An example of a timeline from anaesthesia induction

Analysis of habits

From video recordings (16 clinical situations), commented in process tracing interviews:

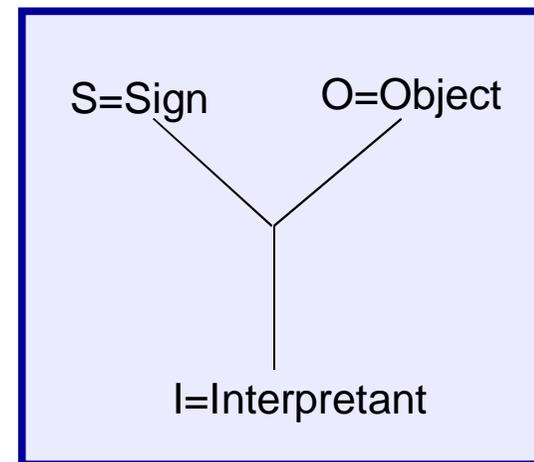
A) Relevant episodes in the course of action are selected (portray domain objectives in different phases of anaesthesia)

B) Habits are identified using the triadic semiotic model:

- Events are identified that draw the actor's attention [S]
- Operations and communications that events launch are determined [I]
- To understand the objectives in the situation [O]

C) Conclusions are drawn on

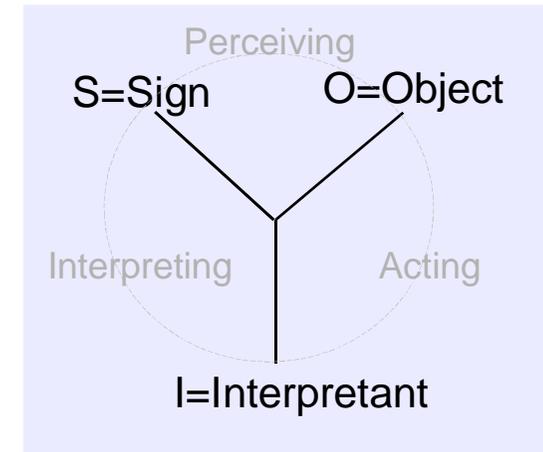
- ➔ Individual comprehensions of the situation
- ➔ Communication of the comprehension within the team (not included in the anaesthesia study)



Habit

Habit

- Habit is a pattern in action
 - Actor is connected with the environment via continuous perception-action cycle
 - As a result beliefs about the environment emerge that are corporeal meanings connected to certain objects
- As habit incorporates past experience
 - it enables anticipation of the results of own activity, i.e. it is a mechanism of anticipation
 - it also enables communication and control of others' actions
- Habit is a reflective routine because it assumes continuous accommodation to the environmental constraints



(After Ch. S. Peirce, Norros 2004, Määttänen 2009)

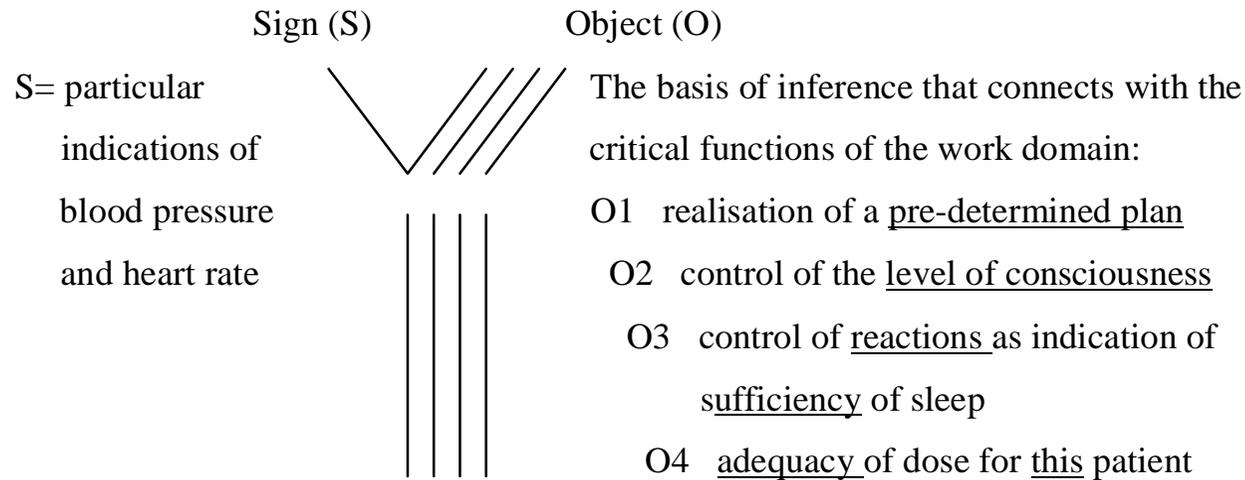
Quality of habits

- The underlying measure for appropriate acting in the environment is the capability for interpretation (i.e. generalisation in action), making sense or tuning to the situation, resonating with the environment (reflective or embodied)

- The scale that portrays grades of this capability:
 - **Interpretativeness** = acknowledging situational particularities and orienting actions with regard to them, connecting to objectives of the whole, anticipating and checking effect of action, effect is informative
 - **Confirmativeness** = taking situation as expected, matching with given possibilities to act, effects known, no information
 - **Reactiveness** = being lead by the situation, effect appears or is stated post-hoc

Example of different habits during anaesthetic induction episode

v



Interpretant (I)

The observable operation:

I1 induction of standard mean doses on a weight basis

I2 induction of a sleeping dose

I3 induction after controlling reaction to laryngoscopy

I4 induction after experimenting

Interpretants I1, I2, I3, I4) and their reasons (Objects O1, O2, O3 and O4) as reactions to the signs of blood pressure and heart rate (S).

Behavioural markers

- In 3 episodes 8 behavioural markers were identified
- 23 habits emerged with regard to each behavioural marker
- Habits were qualified according to the interpretative-reactive dimension

Evaluation of physiological condition regarding anaesthesia

- * Mere enumeration of concurrent diseases
- * Attempts to evaluate the severity of concurrent diseases
- * Interpretation of the patient's physiological potential regarding anaesthesia

Patients physiological condition as a constraint on the anaesthetist's activity

- * No constraints
- * Constraints according to common, classifications and general rules
- * Emphasis on situational information as grounds for guiding administration of anaesthetics

Transformation of the patient's homeostatic state by inducing anaesthesia

Interplay between administration of anaesthetic drugs and available information

- * Anaesthetics were given on a weight basis, or according to a predetermined scheme
- * The patient's sleeping dose was determined only by following the level of consciousness
- * Besides consciousness, information from the patient's physiological responses was chosen as grounds for dosing drugs for anaesthesia

Use of information from cardiovascular intubation response

- * Information was not used
- * Deliberate search for information

Evaluation of the patient's physiological condition after the transformation phase

- * Pre-formed conception was confirmed
- * Cumulative interpretation of the patient's physiological potential was constructed on the basis of his responses during the transformation phase

Maintenance and regulation of the transformed homeostatic state

Maintenance of balance between adequate depth of anaesthesia and optimal physiological state

- * Cardiovascular depression was minimized at the cost of anaesthetic depth
- * Balance was maintained with appropriate means

Maintenance of balance between cardiovascular stability and surgical stimulation

- * Reactive approach to maintaining balance
- * Anticipatory approach to maintaining balance

Regulation of the transformed homeostatic state by using tools

A. Use of information

- * Controversial reactions to information
- * Regulation was based on information trends and/or on a predetermined scheme
- * Regulation was based on internal tempo of the process in accordance with previous patient responses, and situational demands

B. Adjustment of anaesthetic drugs

- * Contradiction between drugs given and theoretical knowledge referred to by the practitioner
- * Anaesthetic drugs were adjusted with a mean accuracy, or their advantages were not exploited
- * Anaesthetic drugs were adjusted in accordance with the history of the process, and through anticipation of future situational demands

Results: Anaesthetist practices

- Description of interpretative / reactive practice qualified by:
 - Action-perception-interpretation cycles with rich/scarce use of situated information (monitors, direct patient, time)
 - Constructing/not constructing a cumulative interpretation of the state of the patient's physiological functions
 - Connecting/not connecting changes in the patients' state with the actions and used methods
 - In reactive: Dosing of drugs in discrepancy with expressed knowledge of drugs
- Correlation with earlier measured orientation:
 - Interpretative habit correlates with realistic orientation
 - Reactive habit correlates with objectivistic orientation
- Prevalence of types of practice among expert anaesthetists (N=16)
 - Interpretative 33 % ; Reactive 66%

Step 4 in analysis of practices

MODELLING OF DOMAIN AND
CONTROL DEMANDS

MODELLING OF SITUATIONAL
TASK DEMANDS

EMPIRICAL ANALYSIS
OF ACTIVITY

DESIGN AND
EVALUATION
OF TOOL
CHARACTER-
ISTICS

Study focused on young anaesthetists in their expert training: The method

- The research material:
 - 9 young anaesthetists in the middle of their specialist training
 - follow-up 6-8 months: theme interviews, observations of clinical work in operating theatres with process tracing interviews (in the beginning and the end)
- Methods:
 - Assessment of orientation
 - Functional information model
 - Inquiry of the conceptual mastery of monitor information (60 questions)
 - Assessment of the use of information in practice

Functional information model

- Information on standard multi-parameter monitor: 120 items
- Classified according to
 - information content
 - relevance in action
 - constraints on information
- Rated according to significance (essential, important, less important)

Results: Conceptual mastery of monitor information

- **General level** of mastery was modest
- **Vital safety relevant information** was mastered better (70-55%) than other information (34-2%)

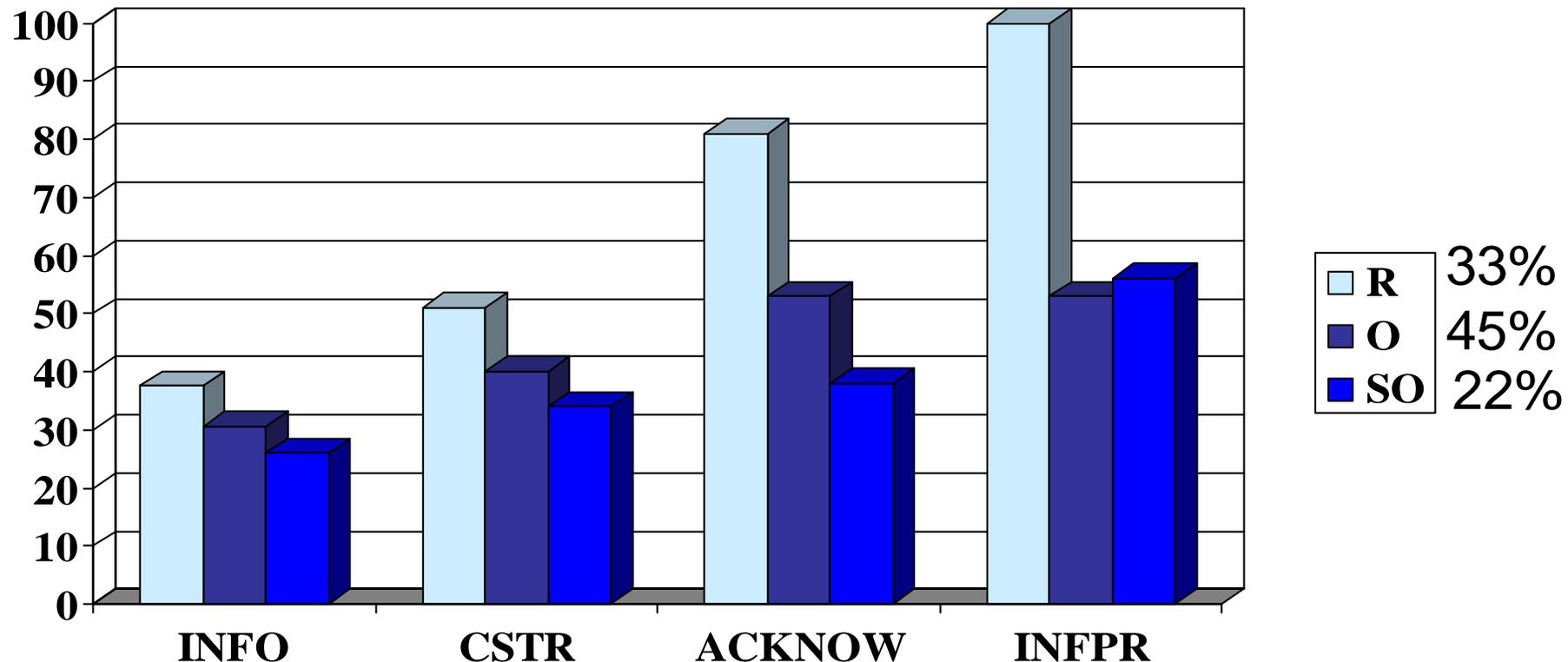
Results: Formation of actionable knowledge

- Actionable knowledge: Formal theoretical knowledge that is transformed into conceptual tools relevant for coping with problems commonly present in the practice
- Main themes:
 - Definition of anaesthesia and the depth of anaesthesia
 - Interaction between hypnotics and opioids
 - MAC-concept vs. monitor MAC-value
 - Principles of pharmacokinetic and -dynamic theory
 - Some basic physiological functions
- Assessment of the formation of actionable knowledge was based on clinical discussions

Results: Overview of the conceptual and practical mastery of information in different orientations

- Level of mastery of information **varies systematically** with regard to **orientation** (R higher, O average, SO lower)
- Differences of level of mastery between R, O, SO become larger the more practice-related the information is

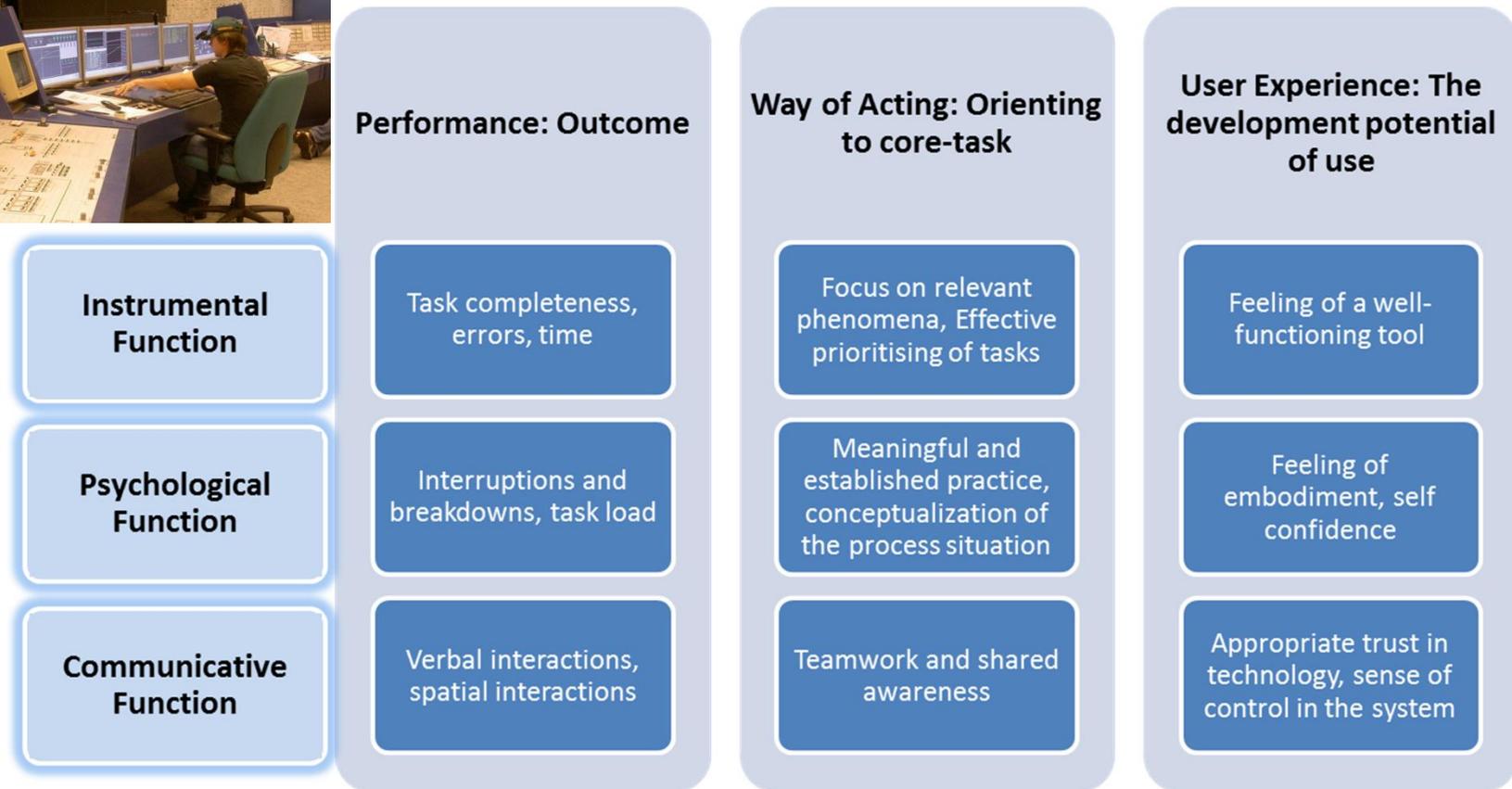
Level of mastery



Systems Usability of tools and technologies

- We assume that tools technologies used in work promote system resilience more or less effectively
- *Systems Usability* is the qualification we use to indicate the appropriateness of a technology for a particular work and its capability to support interpretative practices

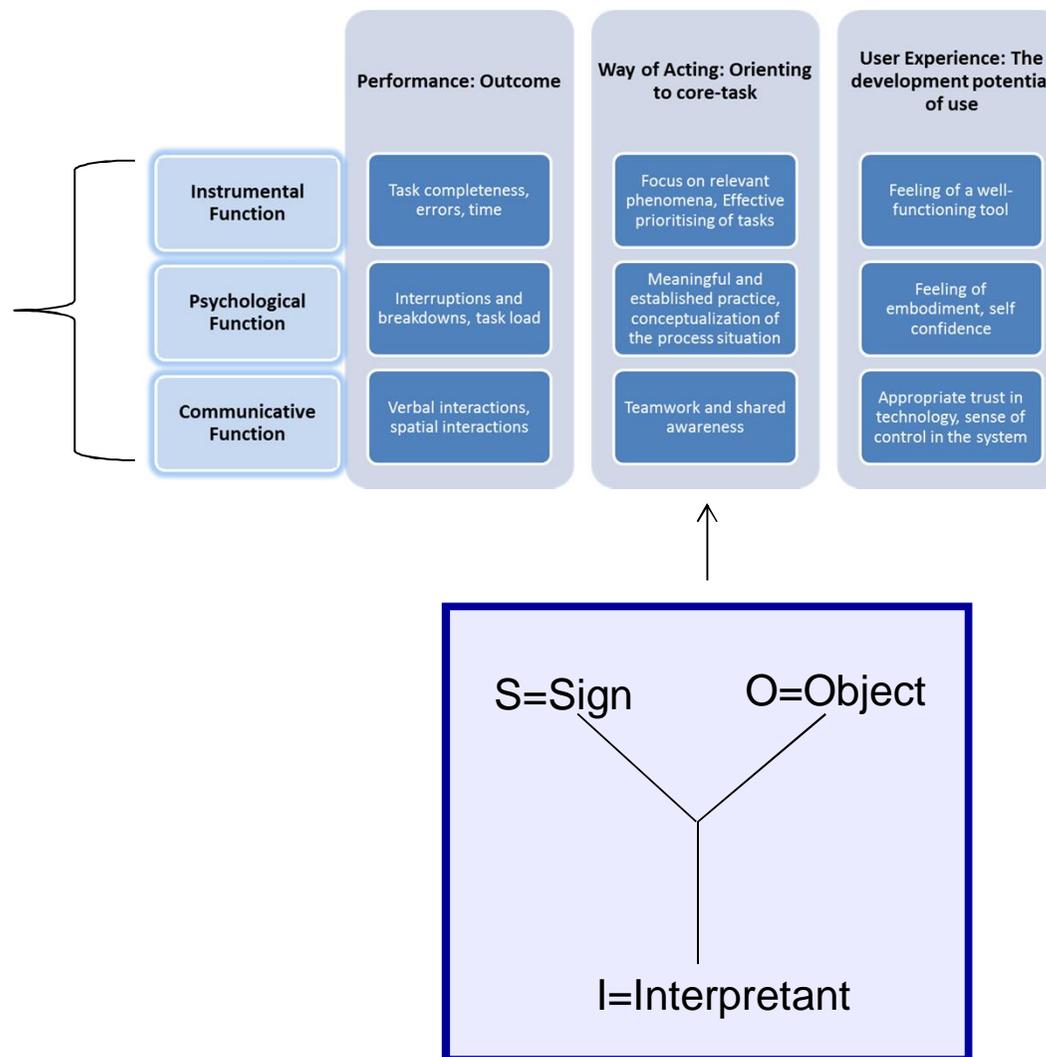
The systems usability metrics



CONCLUSIONS

Open issues: Medium features of instruments and forms of presentation of signs

Medium features;
Forms of presentation



Further open issues and possibilities

- Results from the anaesthesia study indicate that an interpretative practice enables better learning of professional practice – should be tested in systematic longitudinal study
- The triadic meaning structures. i.e. habits, are not cognitive (internal processes) but rather portray communication (external processes) between human and environment, including instruments
- The habit concept enables analysis of constructing and sharing meaning: should be tested further and used as an ecological alternative in analysis of situation awareness
- The approach could also be used in defining joint human-machine intelligence (Joint Cognitive Systems)

Practice level indicator for system resilience

- The method corresponds with expressed methodical requirements for behavioural markers for resilience (Furniss et al. 2011)
- The interpretative practice portrays features that fulfil critical attributes of resilience (Hollnagel 2011):
 - addressing the actual situation / orienting to the particular, presence
 - addressing the critical factors for safety / focusing and prioritising; connecting events to whole, understanding what events mean for the whole
 - addressing the potential for safety / dialogical communication is creative, new possibilities identified
 - address the factual experience and learn from it / connecting to outcomes, and learning from each case

Thank you!