Cognitive Work Analysis (CWA)

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HP Activity Categories:
Task allocation between the human and machine [1]

Resource Type:
Technique

Abstract:

Cognitive Work Analysis was developed in the 1970s at the Risø National Laboratory in Denmark, to facilitate human-centred design. Cognitive work analysis focuses on identifying the constraints that shape behaviour rather than trying to predict behaviour itself. CWA systematically bridges the gap between the demands imposed by the work environment and human capabilities and limitations. CWA is a formative approach; this allows users of systems developed using CWA to adapt to new and unfamiliar situations and seeks to identify how work could be done if the appropriate tools were made available. CWA aids in distinguishing between workers' essential goal-directed actions and 'workaround' activities required to cope with existing work support systems.

References

Developer and source:


Year of development / publication, updates etc:
2006

**General Description**

**Purpose:**

The purpose of Cognitive Work Analysis (CWA) is to guide the design of technology for use in the work place. When applied to information behaviour, the approach guides the analysis of human-information interaction in order to inform the design of information systems. Based on temporal goals and work demands, CWA is principally concerned with designing systems for adaptation. This is achieved by focusing on the overall purpose of the system under examination, and by realising the constraints forced upon that system, both physical and social. To systematically explore work possibilities, CWA focuses on identifying the constraints that shape workers? purposeful goal-directed behaviour rather than cataloguing specific worker tasks and procedures. This approach is inspired by ecological psychology?s tenet that complex human behaviour in operational settings can be usefully explained by analyzing the complexity of their surroundings. These characteristics make CWA useful for complex socio-technical systems where traditional task-based analyses produce voluminous and un-interpretable data, or do not systematically address risks posted by unanticipated events.

**Type (e.g. observation, questionnaire, interview, checklist, measurement instrument, etc.):**

Questionnaire, observation, framework

**Technical description of method or tool etc**

Description of the content/study:

Cognitive Work Analysis can be parsed into six stages (see also figure below):

- the capabilities and constraints associated with the work domain,
- the capabilities and constraints associated with work organization,
- the cognitive states associated with cognitive work tasks (states such as being aware that something is present, understanding what it means, or knowing what to do about it) and the cognitive processes used to transition between cognitive states (for example, the process used to transition from being aware that something is present to understanding what it means),
- the cognitive strategies that may be used to execute cognitive processes,
- the cognitive competencies (skills rules and knowledge) used in execution ofcognitive processes or strategies, and
- the capabilities and constraints associated with social organization, especially those associated with management and distribution of work and with communication and coordination.
Work domain analysis

A work domain is an intentional-functional-physical space in which work can be accomplished. The term intention refers to purpose and the term function refers to an activity-independent capability (potential) to accomplish something specific. Work domain analysis identifies the activity-independent properties that support and shape work. It does so at different levels of functional abstraction and to different degrees of decomposition.

The product of this stage of analysis is an abstraction-decomposition space, which is an activity-independent representation of both the intentional and the physical capabilities and constraints embedded in the work domain. An abstraction-decomposition space is a two-dimensional matrix. The vertical dimension is an abstraction hierarchy extending over the five levels of domain purpose, domain values and priorities, work functions, technical functions, and physical objects.

The horizontal dimension is a decomposition hierarchy extending over the number of levels identified during analysis as relevant to an understanding of the functional structure of the work.

Work organization analysis

As noted above, work domain analysis identifies the activity-independent properties that support and shape work. However, the execution of work involves activity and the remaining stages of cognitive work analysis focus on various dimensions of that activity. Work can be described in terms of work situations (the situational contexts for work), work functions (device-independent functional descriptions of properties essential to satisfying the domain purpose) and work tasks (what is to be accomplished by goal directed activity within the work domain). Work organization analysis identifies the work tasks that rely on the work functions identified in work domain analysis and identifies the work situations in which those work tasks are typically activated.

Work situations are different modes of work or different situational contexts that influence the pattern of work. For example, Naikar, Moylan and Pearce (2006) have identified a sequence of work situations for an airborne surveillance team as on ground not in aircraft (pre-mission), on ground in aircraft, en route to station, on station, en route to base, on ground in aircraft, and on ground not in aircraft (post-mission). Similarly, work situations for a process control plant may be described in terms of startup, routine operations, shutdown, maintenance operations and emergency operations. Notice that the first example is of a series of work situations that unfold sequentially. The work situations of the second example do not unfold sequentially.

More generally, work situations may be classified in terms of temporal sequence or location or both. It can be useful to start this analysis by entering the work tasks, inferred from the domain functions of the abstraction-decomposition space, into a scratch pad. A separate scratch pad can be used for each work situation. External entities that can impact the way work is done should also be noted even if they are not to be included in the design or redesign of the system. The final product of this stage of analysis is a matrix referred to as a work task docket (alternatively, a contextual activity matrix, Naikar el al, 2006). This docket identifies work tasks that will be required to satisfy the work functions identified in the abstraction-decomposition space and will show how those work tasks are distributed over work situations. Work organization analysis, at least as a stand-alone stage, is a relatively new feature of cognitive work analysis. However, because Cognitive Work Analysis is an extensive framework, Naikar, et al (2006) have promoted work organization analysis as an organizing structure between the analysis of the work domain and the analyses of cognitive activity and include it in an activity analysis stage that also includes work task analysis.
**Work Task Analysis**

A work task is something to be accomplished (e.g., resolution of a problem, development of a plan, a decision). A cognitive work task is executed by use of cognitive processes that transform cognitive states as the work task is executed. Work task analysis results in a description of work tasks in terms of transitions between cognitive states as generated by cognitive processes. The product of this stage of analysis is a work task trajectory mapped into a decision ladder template. A decision ladder template depicts all generic cognitive states and cognitive processes that could be involved in execution of a work task. A cognitive state is a condition of being (e.g., the state of being alert, the state of being aware of the situation, the state of being certain or uncertain, the state of knowing something) while a cognitive process is an activity (e.g., the process of seeking information, the process of formulating a plan). Vicente (1999) refers to this stage as control task analysis. To many, the term *control* will imply moment-to-moment adjustments in a closed-loop feedback activity such as maintaining an automobile in the center of a lane. As noted above, a work task is something to be accomplished. For example, the disarming of an explosive device is a work task. In identifying a work task in this way, the goal is implied and any further elaboration is redundant.

*A decision ladder template with cognitive states depicted as ovals and cognitive processes depicted as arrows*

**Cognitive Strategies Analysis**

A cognitive strategy is a generic pattern or, alternatively, a behavioural prototype for a work task or a component of a work task. It is a way of transforming one cognitive state into another and is therefore a class of cognitive process. In contrast to work task analysis, cognitive strategies analysis develops more detailed descriptions of the way in which one cognitive state can be transformed into another. If our knowledge elicitation effort reveals that a particular work task does employ this process, we may want to identify one or more strategies that might be used in execution of that process. Klein (1998) observes that experts will often use mental simulation. In contrast, a novice may ask a more experienced person or may follow guidelines. These alternatives constitute three different generic strategies that could be employed in execution of that same cognitive process.

A cognitive strategy may be a generic method of executing a single process or a generic method of executing multiple processes.

Cognitive strategies analysis identifies the actual and potential strategies that are or could be used in execution of a work task and also the reasons that a particular strategy might be selected in preference to other possible strategies. Particular strategies might be preferred because of task demands such as the amount of time, memory load, or level of knowledge. However, all work tasks must support realization of the values and priorities identified in work domain analysis. Strategies that result in violation of those values and priorities should be discouraged. Problematically, there may be a conflict between the preferences shaped by task demands and the constraints imposed by the values and priorities.

The analysis should identify the range of possible strategies rather than the strategies actually used. If workers avoid potentially valuable strategies because they impose unacceptable demands we might find that we can resolve that problem by designing effective support for such strategies. Cognitive strategies analysis results in a description of the cognitive strategies that might be used to execute cognitive processes identified in work task analysis. While it is possible map the alternate strategies onto a decision ladder, a two-column table offers a more convenient representational format. The first column identifies the potential strategies with sufficient detail to clarify how the strategy is executed. The second column specifies the circumstances
under which a particular strategy may be preferred. Cognitive strategies analysis can then be used to identify a range of generic methods for executing some of the cognitive processes.

**Cognitive Competencies Analysis**

A competency is a capability to perform a task to a certain level of effectiveness. Cognitive work analysis focuses on cognitive competencies of three types;

- a skill-based mode of cognition, which has no conscious processing between perception and action and results in highly automated and integrated patterns performed in real time and coupled directly to the environment in a continuous perception-action loop,

- a rule-based mode of cognition, guided by sets of procedural instructions or familiar perceptual properties that specify sequences of actions, and

- a knowledge-based mode of cognition, grounded in conscious and explicit reasoning based on a symbolic mental representation of relevant capabilities and constraints.

Cognitive competencies analysis identifies the competencies used with various cognitive processes or strategies in the execution of a work task. Cognitive processes and cognitive strategies do not typically involve only one level of cognitive competency but rather may rely on a combination of two competencies or on all three.

The product of this stage of analysis is a description of the activity elements associated with the different modes of cognitive processing. As in cognitive strategies analysis, it is possible to annotate a decision ladder with the appropriate information but an adaptation of the two-column table developed for cognitive strategies analysis offers a more convenient representational format. As before, the first column identifies the potential strategies (or, alternatively, other work task elements such as cognitive processes or clusters of cognitive processes). The second column specifies the cognitive competencies associated with particular strategies or work task elements.

Cognitive competencies analysis can be used to identify the competency levels at which each of the cognitive processes is executed.

**Social Organization Analysis**

Within a work environment, social organization refers to the way in which work is distributed, coordinated and managed. Social organization analysis identifies how work can be shared between workers, how it can be distributed temporally and spatially, and how it can be supported and guided through the hierarchical levels of an enterprise. Social organization analysis is concerned firstly with organizational structure and distribution of work. Organizational structures will necessarily be based on needs for authority, oversight, strategic guidance and reporting, and on the size of the organization.

For large enterprises, structures will need to be designed at several levels of scale, for example at the scale of the whole organization, at the scale of individual business units within the organization, and at the scale of work teams. It is unlikely that a particular organizational structure will work for all business units or all teams. Additionally, the work teams must be structured to accommodate the nature of the work. Skill levels and experience needed for work components, needs for assistance, and requirements for specialty expertise must all be considered. Once a structure is in place, work units are coordinated through collaboration between peers and collaboration between management and workers; the lateral connectivity that supports essential collaboration (and sometimes, competition) between peers and the vertical connectivity that supports essential manager-worker coordination. There will also be needs interaction, information access and product delivery across the boundary of the organization. The supporting coordination processes are primarily communication events of various types.
Social organization analysis identifies the generic properties of characteristic communication events that maintain social organization within a work domain. Social organization analysis results in a description of the organizational structures and of the coordinative work processes that support collaboration between peers within a team or work group at any of the hierarchical levels within an organization. It also develops a description of the overall organizational structure and of the coordinative work processes that support interactions between the hierarchical levels within an organization such as those between a team leader and team members or between management and workers. Processes that support organizational integration such as statements of intent by senior management, rules, processes and procedures that guide the organization, and worker support processes such as those that may be provided by human resource or administrative support departments constitute important elements of the vertical connectivity that supports organizational integration. Finally, social organization analysis takes account of interactions with entities external to the organization, interactions such as acquisition of information and promulgation of plans and reports.

As a result of the analyses that have been conducted since the work organization analysis, it should be possible to think about which work tasks can be undertaken with a particular skill set and level of expertise. A set of closely linked tasks that demand a common skill set and level of expertise can be viewed as a module of work. The prior analyses will also have generated ideas for technological support for these work tasks and so it may now be possible to propose staffing levels. Where the work demands within a module exceed what can be handled by one person, staffing numbers can be increased to the appropriate level. The nature of the work will suggest how the work might be distributed among workers and that will lead to development of an appropriate teaming structure.

For example, it may be preferable to give different workers responsibility for different components of a work module or it may be preferable to have the different workers take care of complete jobs within that work module. The nature of the work and the way in which it is distributed will have implications for communication demands within a work module. Additionally, it will be useful to assess the communication demands with external agencies and to that end, it will be necessary to articulate to at least some degree the functional structures of those entities and the sorts of roles they play in shaping the work within the organizational entity that is being analyzed.

A situation-specific scratch pad for analysis of the social organization of work

Technical requirements for using the method, tool, etc:

CWA incorporates a set of analytic tools for exploration of different types of work capabilities and constraints. At their simplest, the CWA phases can be applied using pen and paper only. However, typically interviews and observational study are required, and so audio and video recorded equipment may be needed. CWA outputs are also typically large and require software support in their construction.

Measure/Response Type:

n/a

Results obtained and interpretation:

n/a

Evaluation
Advantages:

CWA offers a mechanism to transfer results from an in-depth analysis of human-information-work interaction directly to design requirements.

CWA is based on sound underpinning theory.

The CWA is extremely flexible and can be applied for a number of different purposes.

The subjective measures questionnaires are quick to complete.

The diversity of the different methods within the framework ensures comprehensiveness.

Objective measures cannot consciously be influenced by individuals and they not only provide a measure of mental effort for a task as a whole, but also indicate how it varies throughout the task.

The methods within the framework are extremely useful. The abstraction decomposition space in particular can be used for a wide range of purposes.

CWA can be applied in a number of different domains.

Disadvantages:

CWA can elicit a large amount of data which correspondingly takes a long time to analyze and because of the amount of data generated, Cognitive Work Analysis researchers, who often work alone or in small research groups, do not use large sample sizes.

To apply additional theories, the researcher must become familiar with literatures outside of his or her field and be comfortable with multidisciplinary work. Knowledge of LIS or computer science theories alone are generally insufficient to explain all of the observations uncovered during the study.

In the ideal situation, after system design, researchers and designers would return to evaluate the system and make changes as necessary. Unfortunately, this is expensive and time consuming. It is easier for organizations to go with the initial design until problems erupt again.

The questionnaires do not reveal the exact nature of any interface problems which may exist.

Taking physiological measurements such as heart and respiration rate can itself appear intimidating.

Alternative Methods:

The CWA approach does not explicitly define the methods for each of the different CWA phases. Vicente (1999) describes the following approaches for the CWA framework: the abstract ion ? decomposition space (work domain analysis), decision ladders, (control task analysis), information flow maps (strategies analysis) and the SRK framework (workers competencies analysis).

Usability (ease of use, efficiency, effectiveness)

Ease of use:
high
Efficiency:
high
Effectiveness:
high
Constraints concerning conditions of use:
Cognitive work analysis will not always be appropriate for analysis of small, contained systems or for independent analyses of parts of systems but for analysis of large-scale socio-technical systems, it adds a unique capability to our human factors and cognitive systems engineering tool set.

Reliability:

The reliability and validity of the CWA framework is difficult to assess. The flexibility and diversity of the methods used ensure that reliability is impossible to address, although it is apparent that the reliability of the approaches used may be questionable.

Required effort (to conduct & to analyse):

n/a

**Level of HF expertise needed (required user qualification)**

High: high level of expertise required, only for experts, lots of training required

Other expertise needed (required user qualification):

Cognitive Work Analysis researchers.

**Cost Information**

Medium: (1000-5000 €) considerable cost to purchase or for licensing, or certain devices required

Experiences of use by SESAR partners (including references):

n/a

Reported and/or published experiences of use (including references):

The origins of CWA lie in research conducted from 1968 to the 1980s at the Risø National Laboratory in Denmark. Empirical studies and conceptual developments were documented in a series of internal publications analyzing mental strategies (Rasmussen and Jensen 1973), control tasks (Rasmussen 1974), work domains (Rasmussen 1979), and worker competencies (Rasmussen 1980). These concepts were further developed into a coherent, systematic framework (Rasmussen 1986; Rasmussen, Pejtersen et al. 1994; Vicente 1999).

Applicability to lifecycle phase (E-OCVM):

V1,V2,V3

Application Area:

CWA applications have taken place in a wide range of different domains, including Nuclear Power domain, Aviation, Transport, Military, Naval, Health care.

Applications of CWA are diverse. The Australian Department of Defense has applied CWA to a wide range of projects including specifying, designing and using training systems; evaluating alternative equipment design proposals; and developing team designs (Naikar 2006). CWA has been used extensively by CEL to design interfaces, experiments, and training, to analyze data, and to categorize performance measures and knowledge elicitation techniques (Vicente 1995). It has proven to be an invaluable research and design tool.

Keywords:
Cognitive Work Analysis

Short Description:

The purpose of CWA is to guide the design of technology for use in the workplace. It shall systematically bridge the gap between the demands imposed by the work environment and human capabilities and limitations. CWA is a formative approach and incorporates a set of analytic tools for exploration of different types of work capabilities and constraints.

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