# Mental Content and Content-Based Cognitive Ergonomics

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## Abstract

In interacting with technologies, people represent their action and technical artefacts in their minds. The information in their mental representations, i.e., mental contents, explains what people do and why they do it. Therefore, mental contents and its analysis provide a good tool for analyzing several different types of issues in ergonomic. As argumentation is such ergonomic research is grounded on the properties of mental contents one can call this perspective to ergonomics content based cognitive ergonomics.

**Keywords:** Cognitive ergonomics; Conceptual engineering; Foundational Analysis

**Abbreviations:** HTI: Human–Technology Interaction.

## Introduction

Conceptual engineering provides a new way of looking at the foundations of human–technology interaction (HTI) research and design thinking [1,2]. Conceptual engineering offers a way out of practices where concepts are taken as given, and the focus has been on empirical investigations and makes it possible to critically analyze foundations of scientific thinking and design [3].

Broadbent [4] and Miller [5] demonstrated that people have a limited capacity to process information. The idea of people as limited-capacity information processors inspired researchers, and one can also find this notion underlying research in considering programming as situation awareness [6,7]. Mental workload has been one of the most important explanatory concepts in different fields of HTI in analyzing human performance [8,9].

It is difficult to find a more successful approach that investigates how people interact with technologies than to study people as limited-capacity information processing systems. In the mid-20th century, Broadbent [4] and Miller [5] demonstrated that people have a limited capacity to process information. Ever since, the idea of people as limited-capacity information processors inspired researchers, and one can also find this notion underlying research in considering programming as situation awareness [6,7]. Mental workload has been one of the most important explanatory concepts in different fields of HTI in analyzing human performance [8,9].

Capacity does not open an effective perspective for investigating the contents of conveyed information. However, the pieces of information requiring the same capacity can have opposite contents [10,11]. Thus, it makes sense to add a new tool to cognitive ergonomics. This tool analyzes mental content. As the argumentation in working with mental content must be based on the properties of the content itself, the approach can be termed content-based thinking because the explanations are based on the properties of information in mind [10,12,13].

## Information Contents in Mind

Modern cognitive research is based on the idea that people mentally represent their actions and environments in their minds. The information in mental representations has its contents [14]. Intuitively, mental content refers to a thought, belief, desire, intention, proposition, or concept. These representational elements refer to some state of affairs in the mind or external world. The content can also be seen as a state in a mental representation [15]. The information content of mental representation defines how the world is represented. Mental content needs not be true and must not refer precisely to its references.

Pilots, for example, can mistakenly represent the altitude or orientation of their planes; thus, the contents of mistaken representation explain why pilots do what they do. In Three Mile Island, the nuclear power plant operators represented hours the state of the system in an incorrect manner [16]. A concrete example can be found in Saariluoma [17].

An important result was that many thought errors originated from risky thought models. They were often common ways of thinking and also surpassed domain limits. The function of thought models in the construction of erroneous representations was easiest to examine in the thought processes described in the interviews and documents.

The following example shows how the same patterns of thinking can emerge in different situations.
- Case I: I forgot to bind the second (security) belt and fell, thanks to this omission [17].
- Case II: In conducting the experiment, Chernobyl operators violated their own operating rules and allowed the reactor to go into an unstable state [18].
- Case III: In fatal accidents at work in the years 94–96, 62% had problems with their working methods. The methods were in common use but in reality risky [17].

This information has the same core in each case: The actors have violated pre-set precautions. For Chernobyl, it is quite clear that the instructions were known because precautions had to be actively turned off [18]. In this way, it is not a matter of forgetting but of a wrong way of thinking. However, Chernobyl's way of thinking is not uncommon. Variants of the same sloppy practices can be seen in the two other cases. People know safety practices but do not follow them because they do not take risks seriously.

Neglecting safety regulations is an erroneous and risky way of thinking. It makes sense to identify this error- prone thought model and see it as an important explanation for thought errors in work life. The thought model as a whole can be called Chernobyl, for example. The danger of this model is that the safety instructions are usually intended to reduce the risks; thus, failure to do so induces risks. Some other risky thought models were found in Saariluoma [17].

The main explanatory argument in working with filthy or risky thought models is to define what causes misrepresentations in them; for example, for the Chernobyl model, putting aside empirical experience supporting safety rules is required.

Thus, the contents of mental representation and their truth differ; information and knowledge, as justified true information, are good to keep apart. Importantly, the faulty representations provide one possible example: how cognitive ergonomists can use the analysis of mental content to improve ergonomics.

Mental content is a phenomenon that should be studied in terms of information content.

## The Idea of Content-Based Cognitive Ergonomics

Cognitive theories of mind are applied to solve questions of ergonomics inside cognitive ergonomics [19]. In cognitive ergonomics, the core of content-based thinking is in explaining human action on the grounds of related mental contents and their properties. If people can carry out some actions, it means that the representational content has been correct. If they fail to reach their goals, they have mistaken mental contents. In such research, it is sensible to define precisely which part of the mental content was mistaken. The properties of the mental contents behind any action form the ground on which people have had in their minds during the action Mental contents are not per se an unanalyzable basis for cognitive thinking. An important discourse for mental content was opened by Kant [20] and Hegel [21].

The central notion of this human research approach was "Geist" or spirit. The term could refer, for example, to perception, feeling, consciousness, experience, soul, intuition, thinking, culture, customs, laws, spirit of time, and absolute spirit [22]. Obviously, the concept of spirit comes close to the information thinking of modern cognitive concepts. Though the present-day concept of information in mind is not identical in content with "Geist," the two notions have numerous common ground points. Following the first-named thinkers, such eminent researchers as Dilthey [23], Freud [24], Husserl [25], Heidegger [26] and have considered the mind from content's viewpoint.

Modern cognitive researchers, especially Allport [14], Fodor [27], Kahnemann [28], Newell and Simon [15], and

Siegel [28], have paid attention to different aspects of mental content. However, mental content has remained a side stream of cognitive research, and much attention has not been given to human–machine interaction and ergonomics.

The main attention of researchers has not been focused on how to use the analysis and properties of representational content in explication. Instead, it has been common for content-specific notions such as productions [6], scripts [30], schemas [31], mental models [32], or semantic networks [6] to be used to tackle the problems of representational contents in cognitive research. In content-based thinking, contents are taken as contents, and the properties of the analyzed contents are used to explain human actions [10-12,33,34].

Content-based thinking has no intention to "refute" capacity-based thinking. It just opens a new way of looking at problems of the human mind in ergonomics. It will be possible to find important questions and empirical solutions. Understanding mental content enables researchers and designers to set new kinds of design goals. Instead of merely asking how to organize meters and controls in a cockpit, one can ask what kind of errors may be caused by inefficient design solutions. The human–machine communication system of "Herald of Free Enterprise," for example, could not warn cockpit personnel of the fact that keel was open when ship sailed to see and consequently the ship fell. The core of content-based thinking in ergonomics is investigating the information contents of mental contents and using the observed properties to explain relevant properties of actions.

Content-based thinking opens is complementary but not contradictory with capacity-based thinking. One can consider situation awareness as capacity based phenomenon and analyze as well as explain it of the ground of human limited capacity process information [7]. However, one can also consider the information contents of situation awareness in the mind of the operator. The content-based thinking opens a new perspective to phenomena. Especially, in cases in which mistaken information is as complex as correct one it is good to consider the contents of mental representations [10,11].

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