Title
Direct Interaction Representation of Cockpit Information Displays: The Tradeoff between Internal and External Representations

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 19(0)

Authors
Zhang, Jiajie
Johnson, Todd R.
Chuah, Johnny
et al.

Publication Date
1997

Peer reviewed

Direct Interaction Representation of Cockpit Information Displays: The Tradeoff between Internal and External Representations

Jiajie Zhang[1], Todd R. Johnson[2], Johnny Chuah[1], & Kevin McGrory[3]
Department of Psychology[1]
Division of Informatics[2]
Department of Computer & Information Science[3]
The Ohio State University
Columbus, OH 43210
{zhang.52,johnson.25, chuah.5, mcgrory.1}@osu.edu

A large number of cockpit instruments, such as altimeters and navigation displays, are information displays that serve representational functions. It is commonly known that among a certain set of alternative displays that represent the same information, some can be better than others. For example, some types of altimeters (e.g., tape altimeter) are more efficient than others (e.g., analog altimeter) for certain tasks even if they all represent the same information—altitude. This *representational effect*, that different representations of a common abstract structure can have different representational efficiencies and produce different behavioral outcomes, is the central issue in the design of efficient cockpit information displays.

This study examines the representational effect in cockpit information displays from the perspective of *distributed representations* (Zhang & Norman 1994; Zhang, in press). The basic idea is that the information needed for many tasks in a cockpit is distributed across the external information displays of the cockpit and the internal minds of the pilots. Without the interactive processing of internal and external information, many cockpit tasks cannot be accomplished (e.g., Hutchins, 1995; Norman, 1991, 1993).

The major factor of a display's representational efficiency is the relative amount of information in external representations versus that in internal representations. The more information is represented externally, the more efficient is the display. This is because external information is processed by more efficient perceptual mechanisms, which require little or no resources of working memory because they are usually direct, automatic, unconscious, and parallel. In contrast, internal information is processed by less efficient cognitive mechanisms, which require more working memory resources because they are usually indirect, controlled, conscious, and sequential.

Five functionally equivalent but representationally different navigation systems are analyzed in terms of the distribution of information needed to perform the *position fixing task* across internal and external representations. The position fixing task is to identify the aircraft's present position with respect to the earth's surface by a latitude and longitude or by some bearings and/or ranges from one or more known, fixed points on the ground. From this analysis, an order of representational efficiency was obtained for the five systems: the most efficient representation is the one that has most information represented in external representations. The most efficient representation affords direction interaction in the sense that people are able to spend their full cognitive resources on the task, not the interface. In other words, the representation is invisible but the task is transparent to task performers.

We are currently conducting experiments to examine people's behaviors in the position fixing task with different navigation systems. We are also building an Act-R (Anderson, 1993) based computational model for these navigation tasks. Our ultimate goal for this project is to develop a cognitive theory and a computational model of direct interaction.

Acknowledgements

This research was supported by Grants N00014-95-1-0241 and N00014-96-1-0472 from the Office of Naval Research, Cognitive and Neural Sciences Technology Division, and by a summer fellowship from the Center for Cognitive Science at The Ohio State University.

References

Anderson, J. R. (1993). *Rules of the mind*. Hillsdale, NJ: Erlbaum.

Hutchins, E. (1995). How a cockpit remembers its speed. *Cognitive Science, 19*, 265-288.

Norman, D. A. (1991). Cognitive science in the cockpit. *CSERIAC Gateway, 11* (2), 1-6.

Norman, D. A. (1993). *Things that make us smart*. Reading, MA: Addison-Wesley.

Zhang, J. (1997, in press). The nature of external representations in problem solving. *Cognitive Science, 00*, 000-000.

Zhang, J. & Norman, D. A. (1994). Representations in distributed cognitive tasks. *Cognitive Science, 18*, 87-122.