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What contributes to the complexity of visuospatial displays?

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What we understand on the complexity of visuospatial displays (e.g., Brychtová, Çöltekin, & Paszto, 2016; Castner & Eastman, 1984, 1985; Çöltekin et al., 2016; Fairbairn, Andrienko, Andrienko, Buziek, & Dykes, 2001; Krejtz, Çöltekin, Duchowski, & Niedzielska, 2017; MacEachren, 1982; Schnur, Bektaş, & Çöltekin, 2018), as well as natural scenes (e.g., Oliva et al., 1994; Rosenholtz et al., 2007) so far tells us that there are many different factors to consider in the examination of display complexity from the perspectives of design, technology, human factors and the context in which a task is executed. In this short paper, a preliminary, yet overarching, conceptual framework on the complexity of visuospatial displays is proposed. The framework is organized over three dimensions: *Technology and design*; *Human factors / individual and group differences;* and *Contextual / task related factors* (Figure 1). I believe these three dimensions and associated factors unify what we demonstrably know about complexity of visuospatial displays.

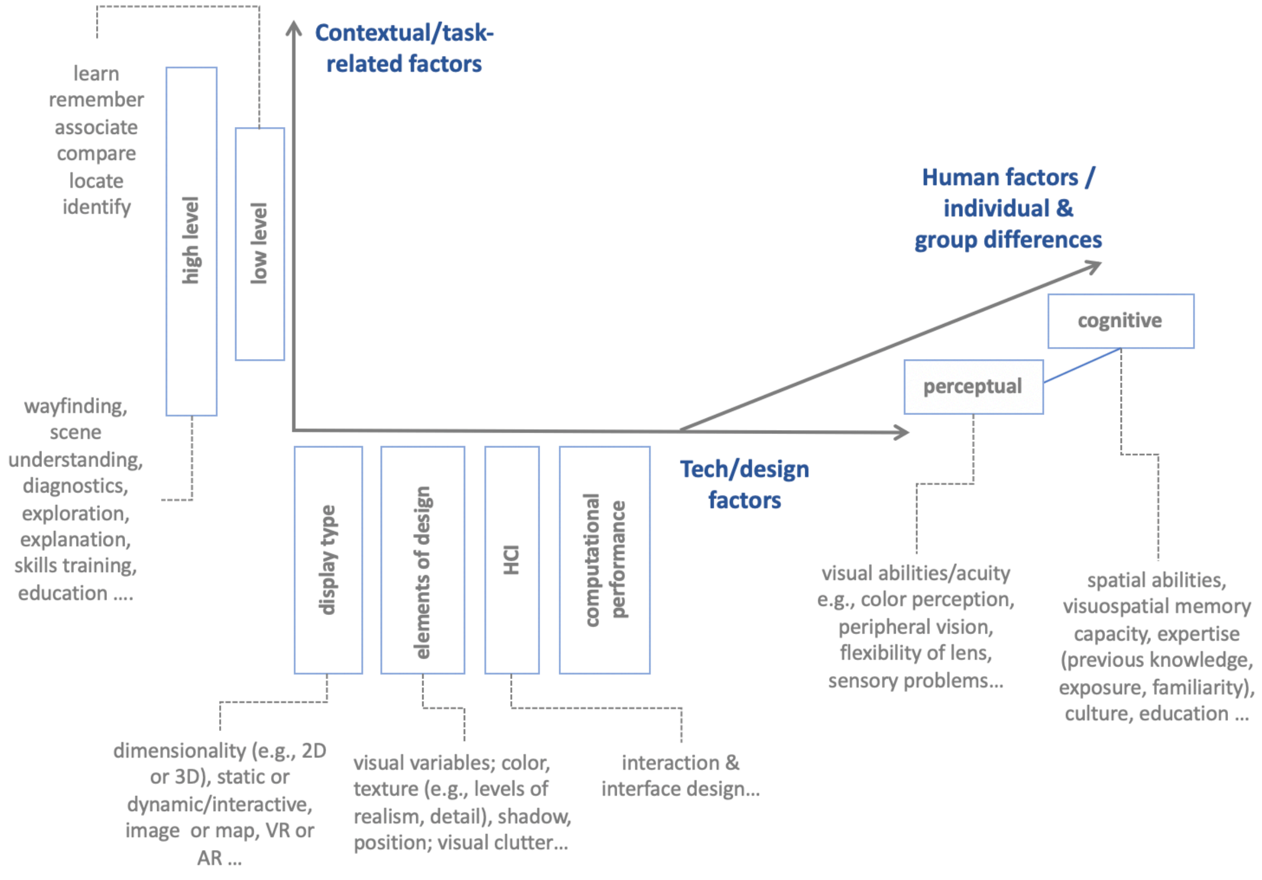

Figure 1. Many factors contribute to visual complexity. Taking a broad view in this framework, contributors to visual complexity are organized along three main dimensions: *Human factors*/individual & group differences, *Tech/design factors*, *Contextual/task-related factors*. Each dimension then is broken down to super-factors (items listed in boxes) and sub-factors (annotated examples), though eventually this approach can be extended towards a dendrogram-like taxonomy. In the current framework, perception and cognition are linked with a line because the two are a spectrum and not binary categories. Factors under the other dimensions also interact with each other, and also with factors in other dimensions, however they are easier to conceptualize on their own compared to the perception-cognition dimension. Every high-level task has low-level elements inspired from Knapp (1995), and every low-level task occurs at the service of a high-level task. Acronyms used in the figure: HCI: Human-computer interaction, 2/3D: Two/Three-dimensional, VR: Virtual reality, AR: Augmented Reality.

Figure 1 illustrates a unifying view in the sense that; 1) each **dimension** captures a broader contributor to visual complexity of displays, and then, 2) For each dimension, selected important super-**factors** and sub-**factors** are listed as more specific contributors of complexity. Each contributing factor is a source of complexity, but at the same time can be viewed as a key approach towards a solution as it breaks the larger problem down into smaller pieces and treats the issues as a portion of the whole. Once defined, understood, and assessed; issues related to each factor can be addressed through technology and design solutions; and in the case it is rooted in humans through exploring how to improve their skills, e.g., training interventions, education, and exposure. As a result, one might be able to customize, and even better, personalize the information display for the given audience and task/context. This can be done by simplifying the display and creating sensible combinations of displays with different levels of realism and abstraction, perhaps 'redefining' the tasks to manage their complexity (e.g., through interaction design), or by providing the guidance, assistance and/or training to specific users or user groups.

As demonstrated in Figure 1, each proposed dimension contains a multitude of super-factors and sub-factors under them. In the scope of this short paper, it is not possible to elaborate on all of them or go deeper in even more specific micro-factors. However, each dimension's extent can be better understood based on a set of example questions that we might be able to study in relation to them:

> **Tech/design:** What is possible within the limits of technology; e.g., at what speed and accuracy we can obtain information-rich displays; how can hardware/software achieve best rendering speed; how should we deal with 'data deluge'? How should one design visuospatial displays; e.g., what elements of the display should be simplified, what must be shown when; what level of realism facilitates the best decisions for the intended use and user, which colors should be used and why, should the information be shown in 2D or 3D, what display type and design do users prefer/like? …
>
> **Human factors:** Can users successfully work with the visuospatial information; e.g., what do people notice or fail to notice on a display, and why; or what to people remember or fail to remember on a display, and why? Do experts have different behavioral patterns and needs than non-experts? Does a one-time user behave differently than a returning user, or a long-term user? What are the visual and spatial abilities of the users, do these affect the successful use of visuospatial displays? ….
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> **Tasks/context:** What is the goal of the user (e.g., sophisticated spatial analyses vs. quick information lookup; try to memorize/learn something vs. making an inference for the next step; important social/environmental decision making vs. hedonistic planning etc.), what are the low-level cognitive processes involved in each, and in which context are these tasks executed (under pressure vs. relaxed, short-term vs. long-term, with major uncertainty or not, group decision or solo decision, etc.) …

By conceptualizing complexity of a visuospatial information display under this framework, we obtain an overview of the contributing factors, and thus can consolidate findings form individual studies that often examine the effects of a single variable or few variables at a time.

References

Brychtová, A., Çöltekin, A., & Paszto, V. (2016). Do the visual complexity algorithms match the generalization process in geographical displays? In *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Prague.

Castner, H. W., & Eastman, J. R. (1984). Eye-Movement Parameters and Perceived Map Complexity-I. *October*, *11*(2), 107–117.

Castner, H. W., & Eastman, R. J. (1985). Eye-Movement Parameters and Perceived Map Complexity—II. *Cartography and Geographic Information Science*, *12*(1), 29–40.

Çöltekin, A., Brychtová, A., Griffin, A. L., Robinson, A. C., Imhof, M., & Pettit, C. (2016). Perceptual complexity of soil-landscape maps: a user evaluation of color organization in legend designs using eye tracking. *International Journal of Digital Earth*, 1–22.

Fairbairn, D., Andrienko, G., Andrienko, N., Buziek, G., & Dykes, J. (2001). Representation and its relationship with cartographic visualization: a research agenda. *Cartography and Geographic Information Science*, *28*(1).

Knapp, L. (1995). A Task Analysis Approach to the Visualization of Geographic Dara. In T. L. Nygeres, D. M. Mark, R. Laurini, & M. J. Egenhofer (Eds.), *Cognitive Aspects of Human Computer Interaction for Geographic Information Systems* (pp. 355–371). Springer.

Krejtz, K., Coltekin, A., Duchowski, A., & Niedzielska, A. (2017). Using coefficient K to distinguish ambient/focal visual attention during map viewing. *Journal of Eye Movement Research*, *10*(2), 1–13.

MacEachren, A. M. (1982). Map Complexity: Comparison and Measurement. *Cartography and Geographic Information Science*, *9*(1), 31–46.

Oliva, A., Mack, M. L., Shrestha, M., & Peeper, A. (1994). Identifying the Perceptual Dimensions of Visual Complexity of Scenes. In K. Forbus, D. Gentner, & T. Regier (Eds.), *Proceedings of the 26th Annual Cognitive Science Society* (pp. 1041–1046). Austin, TX: Cognitive Science Society.

Rosenholtz, R., Li, Y., & Nakano, L. (2007). Measuring Visual Clutter. *Journal of Vision*, *7*(2), 17.1-22.

Schnur, S., Bektaş, K., & Çöltekin, A. (2018). Measured and perceived visual complexity: a comparative study among three online map providers. *Cartography and Geographic Information Science*, *45*(3), 238–254.