Spatial Concepts in GIS and Design

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Armed with collected evidence through various systematic empirical evaluations I would like to argue for a theoretical and methodological design framework, grounded in cognitive theory and cartographic design principles, that support the construction of cognitively and perceptually inspired graphic displays for making more efficient and more effective spatial inferences with GISystems.

Geographical Information Systems (GIS) and highly interactive and dynamic visual analytics (VA) tools have become the tools of choice when dealing with complex spatio-temporal problems. Arguably, GIS and VA tools relying on a visuo-spatial paradigm, effectively support spatio-temporal analytical reasoning and decision-making. The popularity and use of such tools rests on the convincing assumption that humans are generally graphically enabled, and that they will better comprehend multidimensional dynamic spatial processes and phenomena that are congruently depicted with multivariate, interactive and dynamic displays. However, to this day, little is known about the effectiveness of interactive GIS displays for exploratory spatial data analysis, spatial problem solving, knowledge exploration and learning (Shah and Miyake, 2005).

Research in cognitive science has shown that *static* graphics can facilitate comprehension, learning, memorization, problem solving and communication, including inference of dynamic (spatial) processes (Hegarty, 1992; Hegarty and Sims, 1994). Previous cognitive visualization research has focused mainly on identifying how humans make inferences from graphics, but has not necessarily looked at the possible interplay of human's visual inference making capacities (e.g., visual learning and reasoning) with external, visual displays (Scaife and Rogers, 1996; Zhang and Norman, 1994). This is particularly true for maps or dynamic and interactive GIS displays. On the surface, one might generally argue that based on an already established 5000 year old success story of map existence and map use, humans have been quite successful at making inferences from and with maps.

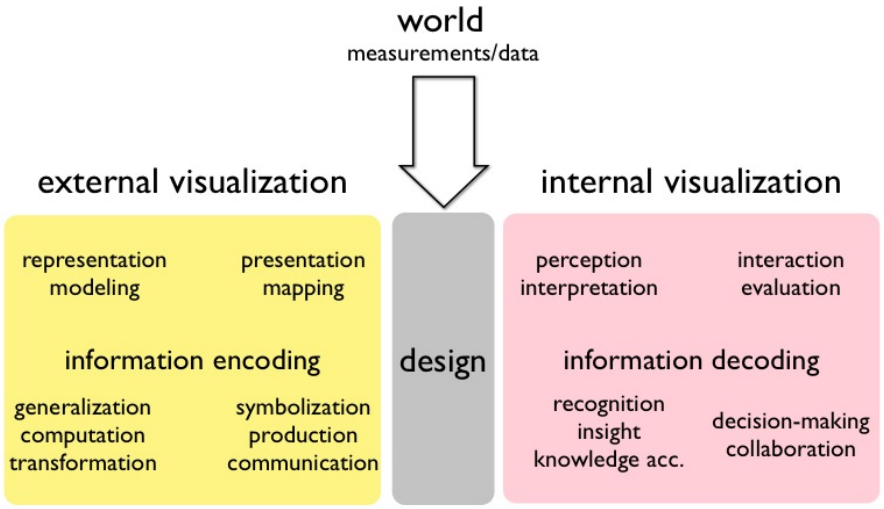
Hegarty (2004) suggests three possibilities regarding the interplay between internal cognition (e.g., mental representations such as images) and external visualization (e.g., graphics) in an educational/learning context:

1. External visualizations might act as a cognitive prosthetic for people with limited internal visualization capabilities. If this is true, people with low cognitive spatial visualization skills might benefit from well-designed external visualizations(Hegarty, 2004).
2. Use of external and internal visualizations might depend on internal visualization. That is, a base capacity to internally visualize may be needed to take advantage of

external visualizations. If this is true, people without internal visualization ability may not be able to take advantage of external visualizations.

3. External visualizations might augment internal visualization for all people, regardless of a person's individual cognitive skill base (Card et al., 1999;Thomas and Cook, 2005).

The question remains as to how these three possibilities transfer into the GIS and design, spatial analysis, learning, and spatial knowledge construction domains. The potential role of design as an interface to and mediator between internal and external visualization (and their design components) is depicted below.



In related work together with colleagues have identified three design areas, based on empirical findings, in which core geographic concepts such as location, distance, region, and scale etc. need to be considered for the construction of spatialized views: 1) the visuo-spatial structure employed to represent the world of information; 2) the representation of meaning encapsulated in the database for knowledge discovery; and 3) the potential experiential effects spatialized views have on information seekers when exploring semantic spaces to satisfy a particular information need (Fabrikant and Buttenfield, 2001). A theoretically sound representational framework of spatialization grounded on ontological and semantic principles can, once established, arguably also be transferred to the explicit geographic domain as a basis to reduce current limitations of how geographic space is represented within GISystems and understood by their users.