Investigating design cognition in the construction and enactment of team mental models

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When discussing the performance of design teams, researchers repeatedly stress the role of design cognition. A major challenge in this research is assessing the collective cognitive structures and processes of a design team. Based on the construct of the team mental model, we present advances to two complementary research methods, latent semantic analysis and reflective practice analysis, to provide a way to model design team cognition over time so as to identify which aspects are relevant to design performance. Together these methods characterize: (1) the emergence of sharedness of the team mental model; (2) the accuracy of the team mental model in relation to a dynamic referent model; and, (3) the enactment of the team mental model as goal-directed behavior.

Keywords: design cognition, reflective practice, research methods, teamwork

By now, the causal importance of the structures and processes of cognition in explaining designers' behaviors and, hence, the performance of designers, is well accepted. More broadly, there is general agreement that team cognition is important to the performance of multi-disciplinary teamwork (McDonough III, 2000). One construct, which describes how knowledge is constructed and shared by a team to enable goal-directed actions, is the team mental model construct (Mohammed, Ferzandi, & Hamilton, 2010). Mental models constitute an organized understanding of the world, which influences human behavior (Johnson-Laird, 1983). Although they are simplified, representations of the world, mental models are deeply rooted in knowledge, or what one knows or thinks to be true (Cannon-Bowers, Salas, & Converse, 1993; Ma, Lee, & Jeng, 2003; Mohammed & Dumville, 2001), and in beliefs and assumptions people hold (Senge, 1990). On the group level, a *team mental model* refers to the knowledge of a team (Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994), which is hypothesized to support coordinated team performance. Badke-Schaub, Neumann, Lauche, and Mohammed (2007) theorize that the task-related content in team mental

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www.elsevier.com/locate/destud
0142-694X $ - see front matter *Design Studies* **34** (2013) 1–33
doi:10.1016/j.destud.2012.05.003

models captures the linkages between cognitive content and structures and design activities. That is, mental models about the aims, outcomes, and requirements of a project provide a construct to study how the knowledge structures (what the members know about their domain) and belief structures (what the members desire in their creative output) of the team members are associated with the outcomes of their creative work. We emphasize that the team mental model is not the same as collective team knowledge; a team mental model represents various types of knowledge such as declarative and procedural knowledge (Rouse, Cannon-Bowers, & Salas, 1992), that is, desired states that are preferred or expected (Mohammed, Klimoski, & Rentsch, 2000). The team mental model is a model of the team's collective knowledge; it is not the entirety of team knowledge itself.

In this paper, we will focus on the measurement of a task-related team mental model, because task-related content in team mental models has been shown to be more predictive of team performance than team-related content about mutual interdependencies (DeChurch & Mesmer-Magnus, 2010). We will refer to task-related team mental models simply as team mental models. The team mental model theory holds that team members draw on their own knowledge to realize actions that are consistent and congruent with their teammates', and this behavioral outcome is causally related to cognitive processes (Cannon-Bowers & Salas, 2001; Klimoski & Mohammed, 1994; Mohammed et al., 2000; Orasanu, 1990; Rouse et al., 1992; Townley, Beech, & McKinlay, 2009). The theory is that the quality of the team mental model has an effect upon the likelihood of the quality of performance-based outcomes causally related to cognitive-behavioral processes. Two main concepts have been proposed in the literature as indicators for the quality of a team mental model: (1) the *level of sharedness* (Cannon-Bowers & Salas, 2001), i.e. having a 'shared cognition'; and (2) the *accuracy* of a team mental model (Rentsch & Hall, 1994). Sharedness refers to the extent to which team members have overlapping, or shared, knowledge and belief structures; accuracy refers to the relation between the team's mental model and a referent expert mental model. In various research settings, support was found for the relation between both the sharedness and the accuracy of the team mental model and the team's performance, e.g. by Edwards, Bell, Day, and Arthur Jr (2006) in the context of aviation training, and by Lim and Klein (2006) in the context of military training.

Although some research has shown that a design team's mental model is related to the quality of the designed work (Badke-Schaub & Frankenberger, 1999; Badke-Schaub, Lauche, & Neumann, 2007), to date, this research is still in an explorative stage. This is mainly due to the lack of established methods that allow for measuring the team mental model of design teams over time while they are engaging in activities rather than after they have completed their activities. Due to the lack of in-process measures of process quality,