A comparative analysis of multimodal communication during design sketching in co-located and distributed environments

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This study extends our understanding of multimodal communication during design sketching. Building on the literature, the theoretical dimension frames gesturing as a communication channel and a thinking medium, and postulates an interplay between gesturing and other channels. The empirical dimension explores the theoretical propositions in the context of co-located and distributed sketching. Quantitative analyses suggest that when gesturing is restricted, graphical communication is leveraged to compensate, and that verbal communication is incessant in both collaboration environments. They also highlight a non-compensatory design phase dependent interaction between gestural and graphical communication. Moreover, they reveal differences in the communication structure used in the two environments. Qualitative analyses identify a behavior termed "cross-gesturing," which informs how gesturing facilitates shared understanding during collaborative sketching.

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Collaborative approaches can be instrumental in accessing expertise during complex product development projects (Dym, Agogino, Eris, Frey, & Leifer, 2005). However, they also pose a challenge for designers by increasing the diversity of information that needs to be communicated and integrated. That challenge is particularly significant in conceptual design, during which vague, preliminary, yet influential ideas are developed within teams. In response, designers leverage accessible and dynamic design representations to mediate collaboration (Visser, 2006). During conceptual design, sketching often acts as a critical representation medium. However, representation usage during the earlier phases of product development is not as well-understood as during the latter phases, which can be attributed to the complexity of creative thought and action. For instance, it has been

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argued that our limited understanding of conceptual design activity explains the lack of support for sketching (McGown, Green, & Rodgers, 1998).

Designing collaboratively implies the utilization of distinct intellectual resources as a team. From a learning perspective, this phenomenon has been referred to as "group cognition" (Stahl, 2006), and has implications for design representation usage. The representation medium acts as a fundamental processing and communication channel, and the "conversations" that take place around that medium through other communication channels further support the expression, negotiation, and integration of viewpoints of individual designers (Nik Ahmad Arif, Badke-Shaub, & Eris, 2012). Moreover, as intellectual and physical resources become more fluid and mobile, the nature of design work is changing, and physical separation between team members is increasing. Complex design projects are often undertaken by distributed teams that function across institutional and national borders. This trend has implications for how design teams leverage representations as well.

Building on this initial framing, our goal is to extend our understanding of collaborative design sketching by analyzing multimodal communication in co-located and distributed environments. Our driving proposition is that availability of multimodal communication channels shapes the structure of sketching activity. We base that structure on temporal relationships of physical communication actions taken by designers. The communication channels of interest are the verbal, textual, graphical, and gestural channels.[1] Although several studies on gesturing have been reported in the design literature, studies focusing on non-gestural communication far outnumber the ones on gestural communication (Visser & Maher, 2011). Thus, we pay specific attention to gestures.

In the following sections, we will articulate our research framework in detail, present an exploratory protocol study we conducted, and report its results in the context of the above proposition.

1 Theoretical framing

1.1 Sketches as design representations that mediate shared understanding

Representations are instrumental in design activity; representation construction has even been argued to define designing (Visser, 2006). Representations can reveal much about how designers structure and process information, and can be categorized according to several differentiating principles. Two principles relevant to this study are the location of the representation, and its intended audience.

When considering the first differentiating principle, a common and useful distinction is the internal vs. external categorization. The internal category