

Designers' perception during sketching: An examination of Creative Segment theory using eye movements



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As a visual thinking tool, sketching strongly supports the conceptual stage of product design. Designers perceive their sketches and discover new ideas. Creative Segment theory models sketching process as a Creative Segment tree, and reveals the Creative Segment-centered pattern of sketching activities. However, the perception of sketches is important during sketching, whether designers' perception is in accord with this theory has not been examined. This article reports an experiment that recorded participants' eye movements to analyze their perception. Participants displayed unique eye movement features during Creative Segments, their fixations changed during the generation of Creative Segments and differed when generating Creative Segments on the three-level branches of the tree. These results provide evidence for the Creative Segment theory.

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Conceptual sketching is a visual thinking process; designers sketch their ideas, inspect their sketches and perceive new possibilities, generating more creative ideas. Various articles have studied how designers benefited from sketching processes and ambiguous sketches (Goldschmidt, 1991; Temple, 1994). Researchers segmented the sketching process and tracked the development of design ideas (Kavakli & Gero, 2002; Suwa, Purcell, & Gero, 1998), and compared activities between novices and experts to reveal better sketching strategies (Cross, 2004).

The sketching process could be modeled using Creative Segment theory (Sun, Xiang, Chai, Wang, & Huang, 2014). This theory defines Creative Segment as the loop involving idea generation, idea expression and visual feedback, and arranges Creative Segments in a Creative Segment tree. In this way, the Creative Segment tree displays the evolution paths of ideas to final outcomes, providing possibilities for valuable understanding of sketching. Sun et al. (2014) have conducted experiments that analyzed the sketching activities to validate this theory, but have not examined the visual feedback of sketches. The visual feedback, namely the perception of sketches, is a critical part during

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sketching that triggered new thoughts (Goldschmidt, 1991), and needs to be further analyzed in order to examine the Creative Segment theory.

Designers' eye movements provide an effective data source for the analyses of perception during sketching. The fixations display items of interest (Findlay & Gilchrist, 2003). Participants move their eyes according to demands of the task (Schütz, Braun, & Gegenfurtner, 2011), and fixate on critical regions during problem solving (Hodgson, Tiesman, Owen, & Kennard, 2002); fixations also serve to guide thoughts and stimulate solutions (Thomas & Lleras, 2007). Apart from fixations, other eye movement data, such as fixation duration and pupil diameter, indicate participants' concentration level (Miall & Tchalenko, 2001; Minassian, Granholm, Verney, & Perry, 2004).

In this article, we optimized the Creative Segment theory and employed eye-tracking techniques to examine designers' perception. Designers focus on multi-level factors involving design goals, functions, and structures during sketching; the Creative Segments could be arranged according to their goals, functions, and structures. A digital sketching experiment was conducted, participants' eye movements were recorded, and the ideas during sketching were recognized and arranged as three-level Creative Segment trees. The eye movements as the tree grew and the eye movement data among Creative Segments on the three-level branches were analyzed to examine the Creative Segment theory.

1 Previous studies

1.1 Sketching as a visual thinking process

The early stage of industrial design faces ill-structured problems (Restrepo & Henri, 2004). A typical design process for this problem is solution-based (Dorst & Cross, 2001). The solutions are generated for current problems, and new problems are discovered based on the solutions, stimulating new solutions. This co-evolution gradually set boundaries to the problems and lead to proper solutions.

Sketching supports the reflective and ambiguous process of conceptual industrial design (Cross, 2006; Temple, 1994). Concepts can be stored and organized visually (Kan, Barsalou, Solomon, Minor, & Thompson-Schill, 2003). Sketch as a quick visual representation records the solutions in real time, enabling a flexible recall of the functional issues (Römer, Pache, Weißhahn, Lindemann, & Hacker, 2001; Suwa, Gero, & Purcell, 1998). From the perspective of knowledge management, sketches support knowledge creation, knowledge sharing, and knowledge documentation (Eppler & Pfister, 2011).

Sketching builds conversation between the internal mental and external materializing activities (Schutze, Sachse, & Romer, 2003). Taura et al. (2011)

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