

Investigating the cognitive behavior of generating idea sketches through neural network systems

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Design can be regarded as a seeing—moving—seeing process, where designers repeatedly see and generate ideas that are based on what they have done. The crucial point of design thinking is how designers recognize ambiguous shapes from sketches and then transfer them into different shapes. This study attempts to conduct cognitive experiments to elucidate the sketching process and to simulate two types of sketching behavior used by neural network systems. When exhibiting the first type of sketching behavior, designers are able to transform their original sketches to satisfy requirements. Simulating this type of visual cognitive behavior by neural networks could help computers modify shapes to meet design requirements, as human designers do. When demonstrating the second type of sketching behavior, designers are able to see an ambiguous shape as different complete shapes so as to associate divergent design ideas. Another set of neural networks investigated in this study could also associate different shapes by adjusting the TSL and produce different idea sketches from the same shape.

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Keywords: drawings, computer supported design, visual reasoning, neural network

Design behavior is one kind of particular activity that includes many types of ambiguous behaviors, divergent judgments for design problems, and intuitive processes (Akin, 1986). Because of its complexity and uncertainty, scholars regard design behavior as a ‘black box’ behavior. Although design is a creative activity, which is generated by certain complex mental operations in a designer’s brain, it also involves various kinds of rational and logical thinking processes. As a consequence, several studies have been conducted in an attempt to define what design behavior is.

According to Schön and Wiggins (1992), design is one kind of ‘seeing—moving—seeing’ process, where both ‘seeing’ and ‘moving’ are equiponderant for developing design ideas. They considered the design process to be a conversation with materials conducted in drawings, which is crucially dependent on seeing. Designers generate sketches on paper, observe the drawn

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www.elsevier.com/locate/destud
0142-694X \$ - see front matter *Design Studies* 29 (2008) 70–92
doi:10.1016/j.destud.2007.06.002
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product of their work, and employ different kinds of seeing; therefore, this is a process of discovery. In terms of visual cognition, many scholars discovered the visual phenomena based on general visual theories (Kosslyn, 1973; Reed, 1974; Kosslyn et al., 1983). During the process of seeing, not all of the objects that were presented on the retina were seen simultaneously. Therefore, a small area or one of these objects could be attended (Palmer et al., 1993).

Designing is the process of visual thinking, the production of thought via visual imagery. To investigate the visual thinking behavior exhibited in the design process, Goldschmidt (1991, 1992, 1994) analyzed the protocol. The purpose of visual thinking in early sketching activity is primarily to enable the designer to identify clues for forming and emerging design ideas by addition, deletion, and modification. Goldschmidt proposed that designers occasionally use imagery to generate new sketches based on their original drawings. She also found that visual thinking occurs more frequently in creative thought or in problem solving that requires insight.

The crucial point of visual thinking in the design process is how designers recognize shapes from sketches and transfer them into different forms. Many researchers also discovered that the behavior of idea sketching is the most important and creative part of design behavior (Kavakli et al., 1998; McGown et al., 1998; Suwa et al., 1998; Verstijnen et al., 1998). When Scrivener and Clark (1994) recorded sketching processes and inspected them by replaying the video, they determined that the process of idea sketching occurs part by part. Moreover, Kavakli et al. (1998) advanced the process of idea generation, in which designers first deconstructed the design subject and then drew the sketches in sequential order. Meanwhile, Verstijnen et al. (1998) proposed that a complex junction was combined by components. Each component fixes the others by essentially transforming them. In addition, Goel (1995) claimed that there are two major activities in the sketching process: (1) lateral transformation, a transformation from one idea to another; and (2) vertical transformation, in which designers develop a more detailed sketch than the previous one. Lateral transformation occurs during the preliminary stage of idea generation, in which the idea is fragmented; vertical transformation is generated during the detailed-design stage.

In the field of cognitive science, some studies concluded that the human thinking process is a flexible, nonlinear, and paralleled process. On the other hand, studies in the field of computer science, based on the theory of propagating information by neurons from neurophysiology, found that the neural network (NN) could simulate some possible cognitive behavior as well as humans. Even though the NN system was developed before 1980, research was hampered by limitations associated with hardware and related theories until the appearance of parallel distributed processing (PDP) in 1986 (Rumelhart et al., 1986). The PDP system could simulate higher-level cognitive behavior,

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