Behavioral analysis of analogical reasoning in design: Differences among designers with different expertise levels

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This paper explores the impacts of the expertise level of designers during analogical reasoning. In study 1, participants were asked to select source examples and explain their selections. It was found that experts were more likely to consider Experience and Esthetics as reasons for their selections. Third-year students were more inclined to draw inspiration from Symbolism, whereas first-year students considered more about Function. Another group of participants took part in study 2, performing analogical design. The behaviors of participants during design process were coded and the behavioral frequencies as well as durations were analyzed. We conclude that experts and third-year students pay more attention to the completeness of the design, while first-year students put more efforts on the functionality of design.

Keywords: analogical reasoning, design behavior, design cognition, design education

Analogy involves accessing and transferring elements from familiar categories or prior knowledge (named the source) to construct a novel concept (named the target), e.g., in an attempt to solve a problem or elucidate a situation (Gentner, 1998; Holyoak & Thagard, 1989, 1997). In a number of studies, analogical reasoning has been proved to be critical to problem solving (Gick & Holyoak, 1980, 1983; Holyoak, 1985; Melis & Veloso, 1998), decision making (Schwenk, 1988), scientific discovery (Dunbar & Blanchette, 2001; Nersessian, 2008), creative thinking (Cubukcu & Cetintahra, 2010), and design (Cagan, 2008; Casakin & Goldschmidt, 1999; Goel, 1997; Goldschmidt, 2001; McAdams & Wood, 2002; Nagel et al., 2008). In recent years, the behavioral differences between novice and expert designers had become a heated study. However, notably few studies have focused on the behavioral differences between novice and expert designers during analogical reasoning. In this paper, we conducted two studies to learn how analogies support different designers. Study 1 examined the

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www.elsevier.com/locate/destud
0142-694X *Design Studies* **36** (2015) 3–30
http://dx.doi.org/10.1016/j.destud.2014.07.001

pre-stage of analogical reasoning by analyzing the source example selections of different designers for a same target. Study 2 examined behavioral frequencies and durations of different designers during analogical reasoning. Findings of this study should be useful in providing guiding principles for design education.

1 Background

1.1 Visual analogy

Analogical reasoning can occur with pictures, words, and sentence clues (Malaga, 2000; Schwert, 2007; Smith, Ward, & Schumacher, 1993). Because visual features frequently assist designers more than other forms (Bilda, Gero, & Purcell, 2006; Goldschmidt & Smolkov, 2006), visual analogies are largely employed by designers to solve design problems. Anecdotal examples of master architects, e.g., Le Corbusier, successfully using visual analogies to build notable architectures illustrates that establishing mappings via structural or surface relations could lead to meaningful outcomes. Empirical studies on the use of visual analogy in design (Casakin & Goldschmidt, 1999, 2000; Çubukçu & Dündar, 2007; Goldschmidt & Smolkov, 2006; Verstijnen, Wagemans, Heylighen, & Neuckermans, 1999) indicated that visual analogy impacts the quality of design solutions. Casakin and Goldschmidt (1999) conducted a study to provide some understanding of the way experts and novices apply visual analogical thinking to design. They found that both novices and experts were able to reason by visual analogy and establish successful analogies. Compared to experts, novices did not add constraints to the design problem, but produced a large number of solutions. Purcell and Gero (1992) reported the roles of image familiarity on creative output for a product design task. They found that familiar pictorial images tend to produce design fixation and increase design variety, while unfamiliar pictorial images were shown to have no such effect.

It has been suggested that the level of abstraction for the representation of prior knowledge and a current design problem both affect analogical problem solving (Linsey, Murphy, Markman, Wood, & Kurtoglu, 2006; Linsey, Wood, & Markman, 2008), that is general semantic representations in memory allows for a higher chance of using a previously encountered product as a source analogy later. Moreover, studies have also confirmed that the level of abstraction of the representations is closely related to designers' response. The study by Christensen and Schunn (2007) revealed that the exposure to different forms of sources, i.e., sketches and physical prototypes, impacts analogical strategies. Participants mainly adopted within-domain analogies while being exposed to physical prototypes. When exposed to sketching, they adopted between-domain analogies (defined in Section 1.2). Cardoso and Badke-Schaub (2011) contended that realistic source examples would cause fixation by the participants, while abstract source examples could lead participants to