Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design

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Conventional Computer Aided Design tools lack intuitivity for being used in conceptual architectural design process. This paper identifies the impact of using a haptic based VR 3D sketching interface for integrating novice designers' cognitions and actions to improve design creativity. This study employs protocol analysis for comparing the collective cognitive and collaborative design protocols of three pairs of novice architectural designers in both 3D and manual sketching sessions. Results show that the simple and tangible haptic based design interface improved designers' cognitive and collaborative activities. These improvements also increased their engagement with 'problem-space' and 'solution-space' that led towards more artefact maturity. Research findings from this study can help the development of cutting-edge haptic-based collaborative virtual environments in architectural education and associated professions.

Keywords: architectural design, design cognition, virtual reality, protocol analysis, collaborative design

The early conceptual phases of the design process are often characterized by fuzziness, coarse structures and elements, and a trial-and-error process. Craft and Cairns (2006) mentioned that during the early conceptual design stages the chances of correcting errors are the highest, and the use of low-expenditure sketches and physical models is crucial. Cross (1999) asserted that the thinking processes of the designer hinge around the relationship between internal mental processes and their external expression and representation in sketches. Cross (2007, p. 33) further acknowledged that designers have to have a medium "which enables half formed ideas to be expressed and to be reflected upon: to be considered, revised, developed, rejected and returned to".

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Using current CAD tools can have detrimental effect on designers' reasoning procedures, thereby hampering their cognitive activities (Ibrahim & Pour Rahimian, 2010). Existing literature highlights that the intangible and arduous user interfaces of current CAD systems are the two major issues which hamper designers' creativity during conceptual design phase (e.g. Bilda & Demirkan, 2003; Kwon et al., 2005; Pour Rahimian, Ibrahim, & Baharuddin, 2008). In addition, Kwon et al. (2005) noted that Virtual Reality (VR) offers a better insight of 3D objects by providing direct drawing and editing through 3D interaction media. They support Fiorentino et al.'s (2002) idea that VR can offer the ideal interface for 'free' artistic visualization through linking creative experimentation and accurate manufacturing-oriented modelling. Although, VR 3D sketching interfaces have already been used in some other design fields such as industrial design (Ding, Zhang, Peng, Ye, & Hu, 2005), the idea is still new in architectural design studies. This paper reports on a feasibility study of a tangible VR 3D sketching interface as an alternative solution to replace conventional CAD systems during the conceptual design phase.

This paper reports a conducted empirical experiment for reaffirming efficiency of the proposed system in the conceptual architectural design phase, and presents the results of a comparison study on design activities between a VR based simple and tangible interface and a traditional pen and paper sketching interface. Here the traditional sketching method is selected as a baseline for comparison with a proposed 3D sketching design interface. The purpose was to reveal the cognitive and collaborative impacts of the proposed design system. Five pairs of 5th year architecture students experienced with the traditional design and CAD systems were selected as participants for this experiment. During the experiment, protocol analysis methodology (Dorst & Dijkhuis, 1995; Ericsson & Simon, 1993; Foreman & Gillett, 1997; Lloyd, Lawson, & Scott, 1995; Schön, 1983) was selected as the research approach and data acquisition method.

1 VR 3D sketching and cognitive approach to designing

Kan (2008) defined design (as a noun) as a series of decisions which expose the relationship of geometries, materials and performance. Kan clusterd some of design activities as: thinking and knowing (Cross, 2007), free-hand sketching and interactions (Lawson, 1997), social construction of design solutions (Minneman, 1991) and designing-by-making (Jones, 1970). Goldschmidt and Porter (2004) defined designing as a cognitive activity which entails the production of sequential representations of a mental and physical artefact; and Tversky (2005) noted that when constructing the external or internal representations, designers are engaged in spatial cognition process in which the representations serve as cognitive aids to memory and information processing. Schön (1992) asserted that with execution of action and reflection, each level of representation makes designers evolve in their interpretations and ideas for