

# Modeling the Transformation of Conceptual Spaces using a Quantum Model of Concept Combination and the Notion of Self-organized Criticality

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Most thoughts and experiences have little effect on our worldviews. However, the occasional thought or experience triggers another, which triggers an ‘avalanche’ of conceptual change, resulting in massive restructuring of conceptual space. The restructuring that occurs during insight is modeled using (1) a theory of concepts of concepts that makes use of a generalization of the formalism of quantum mechanics, and (2) the notion of self-organized criticality.

**Quantum Approach to Concepts.** It is widely believed that concept combination plays a key role in creative insight (Estes & Ward, 2002; Mobley, Doares, & Mumford, 1992; Mumford, Baughman, *et al.*, 1997; Ward, Smith & Finke, 1999). However, concepts, like quantum entities, interact in ways that are non-compositional; *i.e.*, people use conjunctions and disjunctions of concepts in ways that violate the rules of classical logic (Hampton, 1987; Osherson, & Smith, 1981; Aerts, 2009; Kitto, Ramm, Sitbon, & Bruza, 2011). This is true both with respect to properties (*e.g.*, although people do not rate ‘talks’ as a characteristic property of PET or BIRD, they rate it as characteristic of PET BIRD), and exemplar typicalities (*e.g.*, although people do not rate ‘guppy’ as a typical PET, nor a typical FISH, they rate it as a highly typical PET FISH). These effects have made concepts highly resistant to mathematical description. The quantum formalisms were designed to model phenomena that violate the rules of classical logic in the micro-realm: extreme contextuality (the observer effect), and non-compositionality (entanglement). Generalizations of these formalisms do an excellent job of capturing the contextuality and noncompositionality exhibited in studies of how humans use concepts (Gabora & Aerts, 2002, 2009; Aerts & Gabora, 2005a,b; Aerts, 2009; Kitto, Ramm, Sitbon, & Bruza, 2010; Kitto, Ramm, Bruza, & Sitbon, 2011).

**Self-organized Criticality.** Complex systems tend to self-organize into a critical state poised at the cusp of a transition between order and chaos, from which a single small perturbation occasionally has a disproportionately large effect (Bak, Tang, & Wiesenfeld, 1988), a phenomenon referred to as *self-organized criticality* (SOC). A well-known example of this phenomenon in biology is provided by punctuated equilibrium, and similar effects have been identified in earthquakes and stock market dynamics. Noting that large-scale conceptual change and insight often occurs suddenly following a series of minor conceptual changes, it has been proposed that SOC also plays a role in creativity (Ward, Smith, & Vaid, 1997; Gabora, 1998; Schilling, 2005).

**Insight.** Much as most perturbations in SOC systems have little effect, but the occasional one has a very large effect, most thoughts have little effect on the knowledge, experiences, attitudes, and so forth that constitute an individual's internal model of the world, or worldview. However, the occasional thought triggers another, which triggers another, which triggers an 'avalanche' of sequential changes resulting in a massively restructured worldview. Thus insight is modeled as a series of self-triggered 'conceptual collapses'.

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