Reframing Convergent and Divergent Thought for the 21st Century

Liane Gabora

Running head: REFRAMING CONVERGENT AND DIVERGENT THOUGHT

(A slightly earlier version of this paper has been submitted to a peer-reviewed journal. This is not a final draft of a published paper.)

Address for correspondence:

L. Gabora
Department of Psychology, Fipke Centre for Innovative Research
3247 University Way, University of British Columbia
Kelowna, BC, V1V 1V7, CANADA
REFRAMING CONVERGENT AND DIVERGENT THOUGHT

Abstract

Convergent thought is defined and measured in terms of the ability to perform on tasks where there is a single correct solution, and divergent thought is defined and measured in terms of the ability to generate multiple different solutions. However, this characterization of them presents inconsistencies, and despite that they are promoted as key constructs of creativity, they do not capture the capacity to reiteratively modify an idea in light of new perspectives arising out of an overarching conceptual framework. Research on formal models of concepts and their interactions suggests that different creative outputs may be projections of the same underlying idea at different phases of this kind of ‘ honing’ process. This leads us to redefine convergent thought as thought in which the relevant concepts are considered from conventional contexts, and divergent thought as thought in which they are considered from unconventional contexts. Implications for the assessment of creativity are discussed.

Keywords: Alternate Uses Task, concepts, context, convergent thinking, divergent thinking, potentiality, quantum model, Remote Associates test
Creativity is central to what makes us human. Other species perceive, make decisions, and take action, but our ability to adapt ideas to our own needs, tastes, and perspectives, and express ourselves through language, art, technology, and other means, is exceptional. Thus, understanding creative thinking is central to understanding our humanness.

In creativity research, as in other areas of cognition, there is a long history of dual process theories, which assert that there are two kinds of thought, or that thought varies along a continuum between two extremes (Chaiken & Trope, 1999; Evans & Frankish, 2009; James, 1890/1950, Johnson-Laird, 1983; Sloman, 1996). In creativity research the distinction is most often made between convergent and divergent thinking. Convergent thought is defined and measured in terms of the ability to perform on tasks where there is a single correct solution, while divergent thought is defined and measured in terms of the ability to generate multiple different solutions (Guilford, 1967). A widely used test of convergent thinking is the Remote Associates Test (RAT) (Mednick, 1968). A typical RAT question is: What is the common associate of TANK, TABLE, and HILL? The answer is: TOP. A widely used divergent thinking test is the Alternate Uses task, which asks questions like ‘think of as many uses as you can for a brick’ (Christensen, Guilford, Merrifield, & Wilson, 1960). Responses are most often rated in terms of fluency, the total number of ideas generated in a given time. Often they are additionally rated in terms of originality, the number of unusual or statistically infrequent ideas. Fluency and originality are considered to reflect the quantity and quality of ideation performance, respectively. Occasionally they are also rated in terms of flexibility, the number of different categories of ideas. On rare occasions answers are rated for elaboration: the amount of detail given, or evidence that the individual has followed an associative pathway for some distance.

Although these characterizations of convergent and divergent thought have stuck for half a century, as formulated, they present inconsistencies. For example, it is often said that a creatively demanding problem requires both convergent and divergent thought (e.g., Beersma & De Dreu, 2005; Gibson, Folley, & Park, 2009; Kerr & Murthy, 2004). However, given that convergent and divergent thought are defined in terms of the number of correct solutions, this makes no sense. A problem either has one correct solution or it has many; it cannot have both one and many. Moreover, the way convergent and divergent thought have been defined and measured is inconsistent how people think about creativity; for example, although divergent thinking is thought to be the most promising candidate for the foundation of creative ability (Plucker & Renzulli, 1999; Runco, 2007), performance on the RAT would seem to be a better indicator of creativity than many tasks that would be classified as a divergent thinking task, such as ‘list as many things as you can that are red’. Finally, it is often noted that earlier responses on a divergent thinking task are less creative than latter ones (Beaty & Silvia, 2012), but if divergent thinking is characterized in terms of the number of possible responses, this is the opposite of what one should expect, because with each response one gives, the number of remaining possible responses decreases by one. Thus, the conventional view would predict that, as one proceeds, one should start thinking more convergently, not more divergently.

More fundamentally, as noted elsewhere (Piffer, 2012), divergent thinking research, and creativity research in general, emphasizes the generation of multiple ideas over what is sometimes called honing—recursively reflecting on a question or idea by viewing it from different perspectives with the output of each such reflection providing the input to the next.

1 Sometimes the distinction is between associative and analytic thought (e.g., Chrusch, C. & Gabora, L., 2013), or executive versus generative (e.g., Ellamil, Dobson, Beeman, & Christoff, 2012). See (Sowden et al., 2014) for how convergent and divergent thinking relate to other dual process theories.
(Gabora, 2017). One thereby comes to a deeper, more nuanced understanding of it. Honing differs from elaboration in that it does not include additions or modifications to the idea that are tacked on willy-nilly; it refers specifically to modifications that arise in response to an overarching conceptual framework that is shepherding the creative process. The structure of this overarching framework reflects the individual’s worldview: their self-organizing web of understandings about their world and their place in that world (in other words, the creator’s mind as experienced ‘from the inside’). Like other self-organizing systems, a worldview continually interacts with and adapts to its environment to minimize internal entropy, a measure of uncertainty and internal disorder. Thus, honing continues until what has been called psychological entropy (Hirsh, Mar, & Peterson, 2012) decreases to an acceptable level. In Piagetian terms, during honing the individual assimilates each new understanding of the idea, and the individual’s worldview changes to accommodate this new understanding. Insight is then explained in terms of self-organized criticality (SOC) (Gabora, 1998, 2017; Schilling, 2005), a phenomenon wherein, through simple local interactions, complex systems tend to find a critical state poised at the cusp of a transition between order and chaos, from which a single small perturbation occasionally exerts a disproportionately large effect (Bak, Tang, & Weisenfeld, 1988). Thus, while most thoughts have little effect on one’s worldview, an idea we call insightful is one for which one thought triggers another, which triggers another, and so forth in an avalanche of conceptual change.

Surely, whether one is writing a novel, or composing a symphony, or inventing a new kind of solar panel, this kind of honing process is central to the creative act. Moreover, the ability to hone an idea may have little to do with the ability (or patience) to engage in a futile exercise like coming up with uses for a brick, or things that are red. A refinement on conventional measures of divergent thinking, in which participants indicate what they think are their two most creative answers, and these answers are rated on a 5-point scale, shows good reliability and high predictive validity without the fluency confound (Silvia et al., 2008). However, one could still score highly on this version of the test without having engaged in honing.

Our conception of convergent and divergent thinking may be distorted by our everyday experience in the physical world; because objects in the world exist in different places and have distinct, definite boundaries, it may be difficult to wean ourselves from the intuition that ideas in the mind do as well. Elsewhere, on the basis of evidence from research on the attributes of associative memory, my colleagues and I have argued that the common assumption that creativity involves searching through a space of discrete, separate possibilities, selecting the best, and tweaking it, is misleading (Gabora, 2010, 2018; Gabora & Ranjan, 2011). This is also what is suggested by research in the formal structure of concepts and their interactions. The goal of the rest of this paper is to, without going into any mathematical details, show how this research points to a new conception of convergent and divergent thinking that resolves the above inconsistencies, and potentially catalyzes a deeper understanding of how the creative process works. The approach to concepts that I will draw upon is sometimes referred to as the quantum approach (Aerts, Sozzo, & Veloz, 2016; Aerts, Broekaert, Gabora, & Sozzo, 2016; Aerts, Gabora, & Sozzo, 2013; Aerts & Gabora, 2005a, 2005b; Blutner, Pothos, & Bruza, 2013; Busemeyer & Bruza, 2012; Busemeyer & Wang, 2018; Gabora & Aerts, 2002; Pothos, Busemeyer, Shiffrin, & Yearsley, 2017). It is called this not because it has anything to do with

---

2 This word is chosen deliberately because it implies that the process is neither entirely top-down nor entirely bottom-up.
quantum particles, but because quantum mechanics is where the underlying mathematical structures were originally developed and applied.

**Potentiality, Context, and Creative Thought**

The gist of the new view of creative thought suggested by concepts research is conveyed by the photograph below of a woodcutting with light shining on it from three different directions, yielding three differently shaped shadows: that of a G, an E, and a B (Figure 1). Though each shadow is distinctly different, they are all projections of the same underlying object. We could say that the woodcutting has the potentiality to actualize different ways, and to actualize in one of these ways requires an observable or context, in this case, light shining from a particular direction. We can refer to the state of the woodcutting when no light is shining on it as its ground state.

![Figure 1](image)

**Figure 1.** Photograph of ambiguous woodcuttings taken from the front cover of ‘Gödel, Escher, Bach: An Eternal Golden Braid’ by Douglas Hofstadter (1979). The above ‘triplet’ (as he calls them) is not simply a rotated version of the one below; it is an altogether different shape. (Used with permission.)

While it is tempting to assume that a bout of creative thought entails the generation of multiple distinct, separate ideas, there may be a single underlying mental representation that, like the woodcuttings, is ill-defined, and affords some degree of ambiguity in its interpretation. Just because the different sketches of a painting, or prototypes of an invention, take different forms when expressed in the physical world, that doesn’t mean they derive from different underlying ideas in the mind. Just as the three shadows of each of the two woodcuttings in Figure 1 are projections of the same underlying object, the sketches or prototypes may be different external realizations of the same underlying idea at different stages of a creative honing process. Midway through a creative thought process one may have an inkling of an idea but not yet know whether, or exactly how, it could work. Because it is ‘half-baked’, it may be more vulnerable to interpretation, meaning that it could appear quite different when looked at from a different perspective. Note that the two woodcuttings in Figure 1 have two different shapes, yet they yield the same three shadows. To distinguish the shape of the woodcutting above from the
woodcutting below would require that light be shown on them from still more angles, casting shadows that would not look like any particular letters we know. Similarly, the more complex one’s unborn creative idea, the more honing steps required to discern its underlying form and whittle it down as needed. We can say that it is a state of potentiality.

In the quantum approach to concepts, this kind of potentiality is described as a *superposition state* represented by a vector in a complex Hilbert space. Concepts act as *contexts* for each other that alter how they are experienced; for example, the concept TREE might make you think of a deciduous tree (one with leaves), but in the context CHRISTMAS, you might think of a coniferous tree (one with needles and cones). Each possible context may actualize the potentiality of the concept differently, and these possible actualizations are represented by *basis states*. The actual, existing context is treated as an *observable* that determines how the concept changes in light of this context. It might change in such a way as to alter the weights of certain properties. (For example, ‘talks’ and ‘lives in a cage’ are not considered properties of BIRD but they are considered properties of PET BIRD (Hampton, 1987); thus, the context PET is influencing the properties we ascribe to BIRD.) A context can also alter the typicalities of certain exemplars. (As a canonical example, *guppy* is not considered a typical exemplar of PET, nor of FISH, but it is considered a typical exemplar of PET FISH (Osherson & Smith, 1981).) In the absence of any observable—i.e., when a concept is not being viewed from any particular context, or thought about at all—the concept is said to be in a *ground state*. In its ground state there are no properties associated with the concept, but also, there are no properties that are, a priori, excluded from it; thus, you could say it is a state of infinite potentiality. Conceptual change due to the impact of a context is modeled as *collapse* of the vector representing the concept to one of its basis state (Figure 2).

![Figure 2](image)

**Figure 2.** (a) Graphical depiction of a vector |Ψ⟩ representing the concept TREE. In the default context, TREE may be more likely to collapse to projection vector |d⟩ which represents DECIDUOUS TREE (tree with leaves) than to collapse to projection vector |c⟩ which represents CONIFEROUS TREE (tree with needles and cones). This can be seen by the fact that subspace a₀ is smaller than subspace a₁. (b) In the context CHRISTMAS (shown in gray), the concept TREE, now denoted |Ψ_C⟩ is likely to collapse to the orthogonal projection vector |α_c⟩, representing CONIFEROUS TREE, as shown by the fact that b₀ is larger than b₁. (After collapse, the projected vector is the same length as the original due to renormalization).

This general modeling approach has enabled us to cope with some of the non-compositional ways in which people use concepts—famously said to be the biggest challenge facing cognitive science (Fodor, 1998)—by describing them in terms of effects such as...
entanglement and interference (Aerts et al., 2013, 2017; Aerts, Broekaert, Gabora, & Veloz, 2012; Aerts & Sozzo, 2011, 2014; Busemeyer & Bruza, 2012). The approach can be applied to concept combinations and more complex compounds of concepts such as decisions (e.g., Busemeyer, Wang, & Townsend, 2006; Yukalov & Sornette 2009) jokes (Gabora & Kitto, 2017), and even worldviews (Gabora & Aerts, 2009), as well as to creativity (e.g., Gabora & Carbert, 2015). For example, working with data from a study in which participants were asked to rate the typicality of exemplars of a concept for different contexts, and introducing a state-transition threshold, we built a model of how exemplars of a concept arise in divergent versus convergent modes of thought (Veloz, Gabora, Eyjolfson, & Aerts, 2011). By lowering a threshold of allowable deviation from the default context, seemingly atypical exemplars appeared as new possibilities. Honing an idea can be modeled as reiterated collapse, resulting in a change of state of the idea, which induces the conceptual framework to subject the idea to a new context, which in turn brings about a new collapse, and so forth, until the idea is sufficiently robust in the face of new contexts that they no longer cause it to undergo a change-of-state (Gabora, 2017). In short, it is becoming possible to move beyond crude conceptions of creative cognition to a more refined understanding that is aligned with and informed by advances in the adjacent area of concepts research.

Redefining Convergent and Divergent Thought

Let us now see how this can pave the way to a new conception of convergent and divergent thought. There is a relationship between the weights on the properties of a concept in a particular state, and its susceptibility to collapse to any particular new state. For example, if you think about TREE in terms of only its most typical properties such as ‘grows in the ground’, your next thought may be about something else that grows in the ground, such as a FLOWER. However, if you think about TREE in a way that encompasses not just typical properties such as ‘grows in the ground’ but also atypical properties, and in particular those implied by the context, your next thought may be about something semantically distant from TREE; for example, a poet might think of a word that rhymes with TREE such as BEE. Recall how, in its ground state, there are no properties associated with a concept, but also, no properties excluded from it. This means that, for any concept there exists some context that could come along and make any given property become relevant. The more exotic the context, the more atypical the properties that are evoked, and thus the more unconventional the subsequent thought.

This suggests that in convergent thought an idea is refined by considering the relevant compound of concepts in their conventional contexts. Because one is not concerned about all the remote ways in which the object of thought could be related to other things, but instead working with it in its most compact form, mental energy is left over for complex operations. This then is why convergent thought is conducive to unearthing relationships of causation, or thinking analytically, as well as simply carrying out rote tasks.

Conversely, in divergent thought one reflects on an idea by considering a particular compound of concepts from unconventional contexts. This is conducive to unearthing relationships of correlation, i.e., forging new connections between seemingly unrelated areas, as in analogical thinking. Note that the more unconventional the contexts one calls up, the

---

3 Entanglement is a phenomenon first encountered in particle physics wherein the state of one entity cannot be described independently of the state of another, and any measurement performed on one influences the other.

4 Interference is the annihilation of the crest of one wave by the trough of another when they interact.
REFRAMING CONVERGENT AND DIVERGENT THOUGHT

seemingly less sensible the next thought may be, and therefore the more honing that may be required to coax it into a form that eventually makes sense. It is for this reason that the products of divergent thought (as redefined here to mean thinking of ideas from unconventional contexts) may require extensive honing.

Implications for Assessment

On the basis of this view of convergent and divergent thinking, let us now re-examine the tests used to assess these constructs. Although the RAT (Mednick, 1968) is used to assess convergent thinking because each question only has one correct answer, to determine the common associate of TANK, TABLE, and HILL you have to think of at least one of these words in a context that is not its default context. For example, unless you are a retailer in the business of selling tank tops you likely interpret the word TANK in terms of its meaning as a military vehicle. Therefore, if we go with the redefinition of convergent thinking as mental operations wherein the contents of thought are viewed from conventional contexts, convergent thought is insufficient to solve the RAT. The RAT is actually more appropriately used as a test of divergent thinking. This is consistent with the RAT’s wide usage as a test of creativity despite that convergent thought is contrasted with divergent thought and divergent thought is frequently equated with creativity.

Since in divergent thinking tasks such as the Alternate Uses task people only reflect upon an idea from unconventional contexts after they have generated conventional responses, these tasks only test for divergent thinking during the latter part of the task. Thus it makes sense that, as noted by Beaty and Silvia (2012), this is when the most creative responses occur.

Neither the RAT nor conventional divergent thinking tests assess the capacity to hone an idea in a reiterated manner such that uncertainty decreases to an acceptable level and the idea transitions from ill-defined to well-defined. Amobile’s (1982) consensual assessment technique, which involves asking multiple experts to evaluate the creativity of a work, is better in this regard, but it undoubtedly measures not just divergent thinking but what is sometimes called contextual focus: the capacity to spontaneously shift between convergent and divergent as needed, in response to the situation one is in (Gabora, 2003). What is required is a new approach to creativity testing in which each step in a creative process is broken down into a series of states and contexts, and the type and magnitude of conceptual change from one step to the next are analyzed so as to better understand the interplay of convergent and divergent thinking. Steps in this direction are underway using studies of artmaking (Choi & DiPaola, 2013) and computational models (Bell & Gabora, 2016; DiPaola, 2017; DiPaola, & Gabora, & McCaig, 2018; McCaig, DiPaola, & Gabora, 2016), as well as technologies such as functional magnetic resonance imaging (Jung & Vartanian, 2018).

Conclusions

The constructs of convergent and divergent thought have been around for half a century, and the way they are defined and measured has changed little in that time. Meanwhile, we have made headway in understanding the dynamics of the compounds of concepts that constitute ideas, and in modeling how they interact as one thought gives way to the next. Given the presence of inconsistencies in how convergent and divergent thought are conventionally defined and measured, it seems appropriate to revise our understanding of them in light of recent advances in understanding the internal workings of these processes. This paper has shown how
formal research on concepts can pave the way to a new way of defining, measuring, and thinking about convergent and divergent thought.

I close by noting that this is not the only potentially fruitful avenue for research yielded by a joining of forces between research on concepts and research on creativity. For example, there are hints that the above-mentioned presence of interference and entanglement effects in empirical studies of conceptual change are related to creativity, but to date this has not been systematically explored. Another direction for future research concerns the role of incubation: the idea that setting a creative task aside for a while, or incubating on it, can promote insight. One could model this as letting the idea return to its ground state such that it sheds its coterie of typical properties (and contexts), and taps into its reservoir of infinite potentiality (in the sense that no properties are definitively present nor absent).

Another intriguing prospect this line of inquiry leads to is the following. Creative people are more subject to adoration, as well as social disapproval and even bullying, and it is generally assumed that this is because they violate social norms (Sternberg & Lubart, 1995). However, this may not be the whole story. I have suggested that the creative mind is in the process of honing ambiguous mental forms, and indeed it has long been thought that creative people are particularly comfortable with ambiguity (e.g., Tegano, 1990; but see also, Merrotsy, 2013). This may include ambiguity with respect to how they themselves come across, which in turn may make them more vulnerable to other people’s projections. In other words, they may be more subject to misinterpretation, appearing as Gods or Goddesses to some, and as devils to others.

It is hoped that this paper has provided a glimpse of how formal models of concepts can play a key role in the development of a 21st Century understanding of this most human of abilities, the ability to create.

Acknowledgements
The author acknowledges funding from grant 62R06523 from the Natural Sciences and Engineering Research Council of Canada.

References
Aerts, D., Aerts, J., Beltran, L., Distrito, I., de Bianchi, M. S., Sozzo, S., & Veloz, T. (2017). Context and interference effects in the combinations of natural concepts. In P. Brézillon, R. Turner, & C. Penco (Eds.), Modeling and using context (pp. 677–690). Springer International Publishing.
Aerts, D., Broekaert, J., Gabora, L., & Sozzo, S. (2016). Generalizing prototype theory: A formal quantum framework. Frontiers in Psychology, 7. https://doi.org/10.3389/fpsyg.2016.00418
Aerts, D., Broekaert, J., Gabora, L., & Veloz, T. (2012). The guppy effect as interference. In J. R. Busemeyer, F. Dubois, A. Lambert-Mogiliansky, & M. Melucci (Eds.), Quantum Interaction (pp. 36–47). Springer Berlin Heidelberg.
Aerts, D., & Gabora, L. (2005a). A theory of concepts and their combinations I: The structure of the sets of contexts and properties. Kybernetes, 34(1/2), 167–191. https://doi.org/10.1108/03684920510575799
Aerts, D., & Gabora, L. (2005b). A theory of concepts and their combinations II: A Hilbert space representation. Kybernetes, 34(1/2), 192–221. https://doi.org/10.1108/03684920510575807
Aerts, D., Gabora, L., & Sozzo, S. (2013). Concepts and their dynamics: A quantum-theoretic modeling of human thought. Topics in Cognitive Science, 5(4), 737–772. https://doi.org/10.1111/tops.12042
Aerts, D., & Sozzo, S. (2011). Quantum structure in cognition: Why and how concepts are entangled. In D. Song, M. Melucci, I. Frommholz, P. Zhang, L. Wang, & S. Arafat (Eds.), Quantum Interaction (pp. 116–127). Springer Berlin Heidelberg.

Aerts, D., & Sozzo, S. (2014). Quantum entanglement in concept combinations. International Journal of Theoretical Physics, 53(10), 3587–3603. https://doi.org/10.1007/s10773-013-1946-z

Aerts, D., Sozzo, S., & Veloz, T. (2016). New fundamental evidence of non-classical structure in the combination of natural concepts. Philosophical Transactions of the Royal Society A, 374(2058), 20150095. https://doi.org/10.1098/rsta.2015.0095

Bak, P., Tang, C., & Weisenfeld, K. (1988). Self-organized criticality. Physical Review A, 38, 364.

Beaty R. E. & Silvia P. J. (2012). Why do ideas get more creative across time? An executive interpretation of the serial order effect in divergent thinking tasks. Psychology of Aesthetics, Creativity, and the Arts, 6, 309–319.

Beersma, B., & De Dreu, C. K. (2005). Conflict’s consequences: Effects of social motives on post-negotiation creative and convergent group functioning and performance. Journal of Personality and Social Psychology, 89(3), 358–374.

Bell, S. & Gabora, L. (2016). A music-generating system inspired by the science of complex adaptive systems. In Proceedings of the 4th International Workshop on Musical Meta-creation. Palo Alto: Association for the Advancement of Artificial Intelligence (AAAI) Press. ISBN: 978-0-86491-397-5.

Blutner, R., Pothos, E. M., & Bruza, P. (2013). A quantum probability perspective on borderline vagueness. Topics in Cognitive Science, 5(4), 711–736. https://doi.org/10.1111/tops.12041

Busemeyer, J. R., & Bruza, P. D. (2012). Quantum models of cognition and decision. Cambridge University Press.

Busemeyer, J. R., & Wang, Z. (2018). Hilbert space multidimensional theory. Psychological Review, 125(4), 572–591. https://doi.org/10.1037/rev0000106

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. Journal of personality and social psychology, 43, 997–1013.

Busemeyer J. R., Wang Z., Townsend J. T. (2006). Quantum dynamics of human decision making. Journal of Mathematical Psychology, 50, 220–41. doi: 10.1016/j.jmp.2006.01.003

Chaiken, S., & Trope, Y. (1999). Dual-process theories in social psychology. New York: Guilford Press.

Christensen, P. R., Guilford, J. P., Merrifield, P. R., Wilson, R.C. (1960). Alternate uses. Sheridan.

Choi, S.K., & DiPaola, S. (2013). How a painter paints: An interdisciplinary understanding of embodied creativity. Proceedings of a Conference on Electronic Visualisation and the Arts (pp. 127-134). London: British Computer Society.

Chrusch, C. & Gabora, L. (2014). A tentative role for FOXP2 in the evolution of dual processing modes and generative abilities. In P. Bello, M. Guarini, M. McShane, & B. Scassellati (Eds.), Proceedings of the 36th Annual Meeting of the Cognitive Science Society (pp. 499–504). Austin TX: Cognitive Science Society.

DiPaola, S. (2017). Exploring the cognitive correlates of artistic practice using a parameterized non-photorealistic toolkit. Leonardo 50, 531–452.
DiPaola, S., & Gabora, L. & McCaig, G. (2018). Informing artificial intelligence generative techniques using cognitive theories of human creativity. *Proceedings of the Annual International Conference on Biologically Inspired Cognitive Architectures*.

Evans, J., & Frankish, K. (Eds.). (2009). *In two minds: Dual processes and beyond*. New York: Oxford University Press.

Fodor, J. A. (1998). *Concepts: Where cognitive science went wrong*. Oxford University Press.

Gabora, L. (1998). Autocatalytic closure in a cognitive system: A tentative scenario for the origin of culture. *Psychology, 9.*

Gabora, L. (2003). *Contextual focus: A cognitive explanation for the cultural revolution of the Middle/upper Paleolithic*. Proceedings of the 37th annual meeting of the Cognitive Science Society (pp. 758-763). Austin TX: Cognitive Science Society.

Gabora, L. (2003). Revenge of the “neurds”: Characterizing creative thought in terms of the structure and dynamics of memory. *Creativity Research Journal, 22*(1), 1–13. https://doi.org/10.1080/10400410903579494

Gabora, L. (2017). Honing theory: A complex systems framework for creativity. *Nonlinear Dynamics, Psychology, and Life Sciences, 21*(1), 35–88.

Gabora, L. (2018). The neural basis and evolution of divergent and convergent thought. In O. Vartanian & R. Jung (Eds.) *The Cambridge Handbook of the Neuroscience of Creativity* (pp. 58–70). Cambridge MA: Cambridge University Press.

Gabora, L., & Aerts, D. (2002). Contextualizing concepts using a mathematical generalization of the quantum formalism. *Journal of Experimental & Theoretical Artificial Intelligence, 14*(4), 327–358. https://doi.org/10.1080/09528130210162253

Gabora, L., & Aerts, D. (2009). A model of the emergence and evolution of integrated worldviews. *Journal of Mathematical Psychology, 53*(5), 434–451. https://doi.org/10.1016/j.jmp.2009.06.004

Gabora, L., & Carbert, N. (2015). Cross-domain influences on creative innovation: Preliminary Investigations. *Proceedings of the 37th annual meeting of the Cognitive Science Society* (pp. 758–763). Austin TX: Cognitive Science Society.

Gabora, L., & Kitto, K. (2017). Toward a quantum theory of humour. *Frontiers in Physics* (Section: Interdisciplinary Physics), 4(53). doi: 10.3389/fphy.2016.00053

Gabora, L., & Ranjan, A. (2011). How insight emerges in a distributed, content-addressable memory. In A. Bristol, O. Vartanian, & J. Kaufman (Eds.) *The Neuroscience of Creativity* (pp. 19–43). Cambridge, MA: MIT Press.

Gibson, C., Folley, B. S., & Park, S. (2009). Enhanced divergent thinking and creativity in musicians: A behavioral and near-infrared spectroscopy study. *Brain and cognition, 69*, 162–169.

Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: Routledge.

Hampton, J. A. (1987). Inheritance of attributes in natural concept conjunctions. *Memory & Cognition, 15*(1), 55–71. https://doi.org/10.3758/BF03197712

Hirsh, J. B., Mar, R. A., & Peterson, J. B. (2012). Psychological entropy: A framework for understanding uncertainty-related anxiety. *Psychological Review, 119*, 304-320.

Hofstadter, D. R. (1979). *Gödel, Escher, Bach*. New York: Basic Books.

James, W. (1890/1950). *The principles of psychology*. New York: Dover.

Johnson-Laird, P.N. (1983). *Mental models*. Cambridge MA: Harvard University Press.
Kerr, D. S., & Murthy, U. S. (2004). Divergent and convergent idea generation in teams: A comparison of computer-mediated and face-to-face communication. Group Decision and Negotiation, 13, 381–399.

McCaig, G, DiPaola, S., & Gabora, L. (2016). Deep convolutional networks as models of generalization and blending within visual creativity. In Proceedings of the 7th International Conference on Computational Creativity (pp. 156-163). Palo Alto: Association for the Advancement of Artificial Intelligence (AAAI) Press.

Mednick S. A. (1968). The remote associates test. Journal of Creative Behavior, 2, 213–214.

Merrotsy, P. (2013). Tolerance of ambiguity: a trait of the creative personality? Creativity Research Journal, 25(2), 232–237.

Neisser, U. (1963). The multiplicity of thought. British Journal of Psychology, 54, 1–14.

Osherson, D., & Smith, E. (1981). On the adequacy of prototype theory as a theory of concepts. Cognition, 9(1), 35–58. https://doi.org/10.1016/0010-0277(81)90013-5

Piffer, D. (2012). Can creativity be measured? An attempt to clarify the notion of creativity and general directions for future research. Thinking Skills and Creativity, 7, 258–264.

Plucker, J. A., & Renzulli, J. S. (1999). Psychometric approaches to the study of human creativity. In R. J. Sternberg (Ed.), Handbook of creativity (pp. 35–61). New York: Cambridge University Press.

Pothen, E. M., Busemeyer, J. R., Shiffrin, R. M., & Yearsley, J. M. (2017). The rational status of quantum cognition. Journal of Experimental Psychology: General, 146(7), 968–987. https://doi.org/10.1037/xge0000312

Runco, M. A. (2014). Creativity theories and themes: Research, development, and practice. Amsterdam: Elsevier.

Sowden, P., Pringle, A., & Gabora, L. (2015). The shifting sands of creative thinking: Connections to dual process theory. Thinking & Reasoning, 21(1), 40–60.

Sternberg, R. J., & Lubart, T. I. (1995). Defying the crowd: Cultivating creativity in a culture of conformity. Free Press.

Tegano, D. W. (1990). Relationship of tolerance of ambiguity and playfulness to creativity. Psychological Reports, 66(3), 1047–1056.

Vartanian, O. & R. Jung (Eds.) (2018). The Cambridge Handbook of the Neuroscience of Creativity. (pp. 58–70). Cambridge MA: Cambridge University Press.

Veloz, T., Gabora, L., Eyjolfson, M., & Aerts, D. (2011). Toward a formal model of the shifting relationship between concepts and contexts during associative thought. In D. Song, M. Melucci, I. Frommholz, P. Zhang, L. Wang, & S. Arafat (Eds.), Quantum Interaction (Vol. 7052, pp. 25–34). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-24971-6_4, 381–399.

Yukalov V., & Sornette D. (2009). Processing information in quantum decision theory. Entropy, 11, 1073–120. doi: 10.3390/e11041073