Multilevel Computational Creativity

Ricardo Sosa
Singapore University of Technology and Design
Singapore 138682
ricardo_sosa@sutd.edu.sg

John S. Gero
Krasnow Institute for Advanced Study
George Mason University
Fairfax, VA, 22030
john@johngero.com

Abstract

Creativity can hardly be understood in isolation from a context where values such as novelty and usefulness are ascribed. This paper presents a multi-level perspective for the study of creativity and formulates a framework for computational creativity that consists of 1) Culture; 2) Society; 3) Groups; 4) Products; 5) Personality; 6) Cognition, 7) Neural processes; and 8) CC processes. This model enables the definition of functional relationships among these levels. As an initial step to illustrate its usefulness, an analysis is made of the ICCC‟12 proceedings in view of this model.

Introduction

The assessment of creativity is increasingly being recognized as an important direction in the research program of computational creativity (Jordanus 2011; Indurkhya 2012; Maher 2010, 2012). One of the main arguments is that creativity is in fact defined via the evaluation or ascription of values such as novelty and utility by third-parties beyond the creator(s). In other words, a creative product, person or process can hardly be understood in isolation from a context where such values are ascribed. Rather than a binary property, we consider that the composite value of creativeness is easier to define as a relative value ascribed by weak-to-strong levels of agreement or consensus to a range of products, persons or processes ranging from non-creative or routine to transformative or disruptive creativity (Gero 1990; Kaufman and Beghetto 2009). Because creativity is defined through the ascription of values (novelty, utility, expectation) in a system where creators and evaluators interact, this paper regards creativity as an eminently psycho-socio-cultural phenomenon; its aim is to frame computational creativity from such perspective.

Computational creativity (CC) has inherited an emphasis on individual processes, performance and products from the mainstream Artificial Intelligence worldview. In that paradigm, the agent architecture consists of autonomous individuals interacting with an external environment (Russell and Norvig 2005). CC has assumed that understanding individual behavior is a sufficient way of modeling creativity. A social-psychology approach to creativity began to illustrate the interaction between individual and external factors (Hennessey 2003). More recently, cultural-psychology creativity seeks to extend that work by shifting the architecture from a view of individual behavior "conditioned" by social factors and towards a more integrated view where interdependent relationships co-constitute a complex creative system (Glăveanu 2010)

This paper presents a multi-level perspective for the study of creativity and formulates a framework for computational creativity (CC). The aims of this work include: to enable new ways of thinking about CC from different disciplines, to support communication between research traditions, and to start mapping the units of analysis, variables and interactions between levels. The paper is organized as follows: Section 2 introduces key concepts and draws from the theoretical bases of this approach; Section 3 presents our framework and explains structural and functional aspects of our model. Section 4 evaluates this model using the 34 papers presented at the previous International Conference of Computational Creativity (ICCC‟12). Section 5 closes the paper presenting modeling strategies and guidelines as well as discussing potential approaches to CC.

Background

Integrating scientific disciplines goes back to Comte‟s hierarchy of sciences according to the scale and complexity of theoretical tools (Mayer and Lang 2011). The role of cultural mediation in the development of cognitive functions has its origins in the tradition of cultural psychology since Vygotsky (Moran and John-Steiner 2003). Ecological models of creative problem solving integrate cognitive, personality, and situational factors (Isaksen et al 1993). Views of creativity as a social construct have been formulated elsewhere (Sawyer 2010; Westmeyer 2009).

Multilevel models that capture the interactions between psychological, social and cultural factors enable two complementary research directions. On the one hand, holistic explanations are possible by going up in the hierarchy drawing upon higher levels that moderate lower effects. On the other hand, reductionistic explanations go down in the hierarchy to inspect lower-level factors that account for high-level phenomena (Koestler and Smythies 1969). For example, accounting for cultural constructs can be essential to understand individual attitudes to altruism (Sheldon et al). Likewise, the characterization of individual cognitive styles helps explain and manage group conflict (Kim et al 2012). Despite the disciplinary divides between psychology, anthropology and sociology, a phenomenon such as creativity may require a cross-disciplinary perspective that includes the interplay between levels of causality (Sternberg and Grigorenko 2001). Computational creativity has the potential to embark on cross-disciplinary modeling.

Contemporary personality research is a relevant example as it provides empirical support for the *irreducibility* postulate: i.e., "no scientific discipline is likely to subsume the others, all are needed" (Sheldon 2004). In the field of personality and well-being, multilevel approaches show the complex interactions and effects among factors located within and between levels of organization -from cultural to social, personality, cognition and neural processes (West et al 2010). Such integrated and interdisciplinary models account for moderator relationships between levels of organization.

The Multilevel Personality in Context (MPIC) (Sheldon et al 2011) and the Cognitive-Affect Personality System (CAPS) (Mischel and Shoda 1995) are two examples of how multiple levels of analysis can be integrated for a more reliable and complete understanding of complex human behavior –such as creativity. The MPIC model specifies the following levels: Culture, Social relations, and four levels of Personality: Self-Narratives, Goals/Motives, Traits/Dispositions, and Needs/Universals (Sheldon et al 2011). Reviewers of the MPIC model further suggest the addition of Situations to account for contextual factors beyond the bio-psychosocial (Mayer and Lang 2011).

In computational creativity, Indurkhya (2012) identifies the interplay between system levels by framing the following dilemma: when non-conscious or unintentional processes generate artifacts deemed as creative by an audience (i.e., works of art by a schizophrenic but also the ubiquitous cases of unexpected successful products), "where is the creativity?". A similar point can be made when considering the attribution of creativity to designs by Nature (McGrew 2012). Understanding the interplay between generative and evaluative processes of creativity has the potential to transcend such apparent paradox where at a given level it may seem like "there is nothing distinctive […] that we can label as creative" (Indurkhya 2012).

Maher (2012) frames the need for evaluation criteria that are independent of the generative process. Jordanus (2011) suggests a standardized approach to evaluation where key components are identified, clear metrics are defined and tests are implemented. The work presented in this paper is aligned to these aims and puts forward a structural and functional framework for an integrated cross-disciplinary study of computational creativity.

Multi-level Computational Creativity

The Multi-level Computational Creativity (MLCC) model builds upon the Ideas-Agent-Society (IAS) framework which maps three dimensions of creative systems: epistemological, individual and social dynamics (Sosa et al 2009). That structural framework synthesizes constructs from five influential theories related to creativity and innovation, i.e.: exemplars, proponents, and communities (Kuhn); innovations, entrepreneurs and markets (Schumpeter); noosphere, strong spirit and culture (Morin); domain, individual and field (Csikszentmihalyi); and logic, genius and zeitgeist (Simonton).

MLCC specifies eight separate levels of analysis: 1) Culture; 2) Society; 3) Groups; 4) Products; 5) Personality; 6) Cognition, 7) Neural processes; 8) CC processes. In addition, MLCC goes beyond the mapping of systemic dimensions and enables the definition of functional relationships among these levels. These relationships can be defined as independent or interdependent, i.e., the former represent processes that occur only within a single level in isolation, whilst the latter represent processes that are connected between levels. Namely, a range of cognitive functions can be studied in a CC system, some of which can be assumed to emerge from explicit lower-level neural processes, others that are defined only within the cognitive level, and a third type that lead to higher-level personality or group processes.

MLCC level	Sample models
1: Culture	Cultural dimensions in creativity (Lubart 2010); Peer-reviewed epositories (Duflou and Verhaegen 2011); IP law (Lessig 2008); Built environment (McCoy and Evans 2002).
2: Society	Gatekeeping (Sosa and Gero 2005a); Creative class (Florida); Migration (Hansen and Niedomysl 2009); Social capital (Fischer et al 2004).
3: Groups	Group conformity (Kaplan et al 2009); Team diversity (Bassett-Jones 2005); Group brainstorming (Sosa and Gero 2012).
4: Products	Rogers (1995) five factors (relative advantage, compatibility, complexity, trialability, observability).
5: Personality	Extraversion and dominance (Anderson and Kilduff 2009); Openness (Dollinger 2004).
6: Cognition	Creative cognition (Finke et al 1996); Bilingüalism (Adesope et al 2010).
7: Neural processes	Neuroanatomy (Jung et al 2010); NN models (Iyer et al 2009).
8: CC processes	Machine creativity (Cohen 1999; Maher et al 2012); Computational models of innovation (Young 2009; Sosa and Gero 2005b); tools and support systems (Liu et al 2004).

Table 1. The eight levels of our multi-level model of computational creativity (MLCC) and exemplary creativity models

MLCC level 1, Culture, refers to processes that either aim to model or draw from knowledge bases and corpora, cultural evolution, cultural dimensions, organizational culture, language and semiotics, economic impacts, taste and traditions, public policy, mass media, intellectual property, creative environments, planned obsolescence, aggregate search trends, market trends and anomalies.

MLCC level 2, Society, captures processes that account for the influence of –or seek to grow effects on– demographics, networks, migration, social influence and authority, roles and occupations, class structure, social capital, crowdsourcing, market segmentation, reputation and popularity, ethnic diversity, gender and aging, diffusion of innovations, crowd behavior.

MLCC level 3, Groups, refers to team dynamics, communities of practice, family and peer support, co-creation, artist collectives, art commission, brainstorming, change management and leadership, deliberation, collaboration/competition strategies, workplace, groupthink, game theory, adopter categories.

MLCC level 4, Product, captures intrinsic properties of creative artifacts largely determined by domain characteristics, techniques and processes, but also by technological or functional features, life-cycle, etc.

MLCC level 5, Personality, personality types, motivation, curiosity, extroversion, mental health, addictions, emotions, risk aversion, well-being, lifestyle, charisma, habit, expertise.

MLCC level 6, Cognition includes all processes related to creative cognition (intuition, insight, incubation, problem framing and solving, memory, concept formation, representation, fixation, association, analogy, divergent thinking, abductive reasoning, visual and spatial reasoning), perception, cognitive and attribution biases, heuristics.

MLCC level 7, Neural processes related to creativity including neuroanatomy (brain asymmetry), neuromodulation (risk, arousal, novelty), brain stimulation, neural network models of creative reasoning.

The final MLCC level refers to CC methods and techniques aimed at solving problems or generating creative solutions with no direct claims to model or being inspired by the other levels.

The MLCC model accounts for multiple levels of studying creativity, none of these levels is strictly new –Table 1 in fact includes references to multiple existing research programs that address creativity from each of the disciplinary traditions that specialize in such scales and units of analysis. The MLCC model brings them together and enables CC researchers to explore top-down and bottom-up connections between these levels.

Directionality of cross-level interactions in the MLCC model opens up a double opportunity in CC: on the one hand, it allows the study of generative processes between levels, i.e., how individuals create in isolation or in teams, how societal and cultural norms provide the bases for change cycles, what neural and cognitive processes help explain creative behavior, etc. On the other hand, it supports the less-explored study of evaluative processes between levels, i.e., how individuals, teams and society attributes creativeness to an artifact or a process, how cultures or subcultures accommodate for new additions or transformations, what neural or cognitive processes help explain the assessment of novel stimuli, etc.

Figure 1 provides a graphical depiction of an MLCC–inspired system showing a conventional organization of levels, i.e.: culture provides a general epistemological background where creators (individuals and teams) generate new artifacts targeted to specific audiences, a process mediated by distributors or promoters of artifacts –which are distinguished from the creators (for example, producers, market and art agents as separate stakeholders from designers and artists).

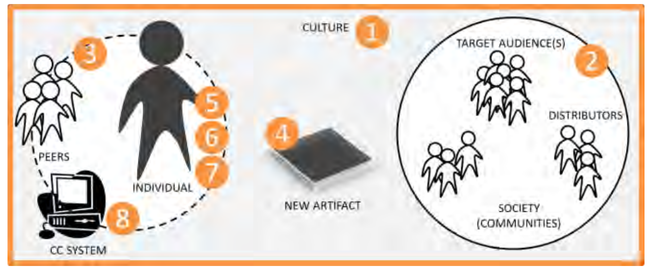

Figure 1. A system architecture to study individual creators and social evaluators interacting in a shared culture

However, the MLCC model supports a wide range of alternative modeling approaches, for example to study the „maker" culture (Anderson 2012) or to focus on the cognitive processes of target audiences –for example how people are primed to rate and comment on the novelty and originality of artifacts in online forums (Sosa and Dong 2013). This flexibility of the MLCC model accommodates various research traditions, including minimal models where interactions between macro cultural and micro neural processes are explored –for example in cellular automata architectures (Sosa and Gero 2004).

CC presents clear advantages as a tool to advance theory building and for the systematic examination of assumptions and extraction of principles in multilevel systems (Fontaine 2006). Nonetheless, associated risks include: loss of clarity in the definition of interactions and causal relationships between levels; misalignment between disciplinary divides (research methods, units of analysis, linguistic traditions); and limited cross-level understanding between specialists.

Is the MLCC a creative artifact? It"s not an entirely novel model –clear precedents were discussed going back as far as the XVII century. However, it does carry some novelty to the CC community. Its usefulness will be defined by its suitability as a modeling framework as determined firstly by the reviewers of the ICCC"13 and ultimately by the entire ICCC community. As an initial step to evaluate its relevance, the following section presents an analysis of the ICCC"12 proceedings using the MLCC model. The aim is to demonstrate its role in the analysis and discovery of trends in the current CC approaches, and identify gaps and connections between recent models of creativity.

Mapping ICCC'12 contributions

The 34 full papers published in the ICCC'12 proceedings were selected for this exercise (Maher et al 2012). They were classified in one or more of the MLCC levels according to their research aims and claims as stated by the author(s), as well as the target research agendas mentioned as part of future work. In addition to the eight MLCC levels, a ninth category was added during the review of these papers, which we named "Tools" and refers to work aimed at developing computational tools to support or enable human creativity (Gatti et al 2012, Hoover et al 2012).

Table 2 presents the 34 papers (rows) and their relation to the MLCC levels (columns). Entries related to generative processes in existing CC systems are marked by ●, while entries related to evaluative processes in existing CC systems are marked by ○. Examples of generative processes include a memetic algorithm "capable of open-ended and spontaneous creation of analogous cases from the ground up" (Baydin et al 2012); an evolutionary art system that generates artwork that "has been accepted and exhibited at six major galleries and museums" (Gabora and DiPaola 2012); and a system "able to generate pleasing melodies that fit well with the text of the lyrics, often doing so at a level similar to that of human ability" (Monteith et al 2012).

A paper may have multiple entries in different MLCC levels, for instance Morris et al (2012) present a "recipe engine" that draws from a corpus of online recipes published online (MLCC level 1), applies CC processes to generate new recipes (MLCC level 8), and these are subsequently analyzed by their typicality to a "recipe genre" (MLCC level 4).

Examples of evaluative processes include plans to include "feedback from journalists, critics, peers and audiences" (Burnett et al 2012); models of the cultural tastes and preferences of audiences (Indurkhya 2012); and plans to study "the cognitive processes of the viewers as they look at […] pictures" (Ogawa et al 2012).

A distinction is made when an entry refers to a future research approach that the authors identify as a valuable way forward –rather than an existing CC system. In such cases a plus sign qualifies the entry, respectively $\bullet^{+}$ and $\circ^{+}$. Table 2 refers to the first author only due to space limitations. Some papers are rather comprehensive, such as Indurkhya (2012) and Maher (2012) which span across five MLCC levels each, but the overall average is 2.18 indicating a reasonable distinction among types of CC models.

Although these results systematic validation, they suggest a focus on generative processes in ICCC‟12 (60 entries, including 43 existing and 17 target processes). Evaluation processes constitute a minority (14 total entries, half of them referring to target processes). These results are consistent with the preceding finding that "only a third of systems presented as creative were actually evaluated on how creative they are" (Jordanous 2011).

MLCC level 8 is the most prevalent: 40% of all papers discuss existing CC processes, and an additional 11% discuss target CC processes. Level 8 refers to methods and techniques aimed at solving problems or generating creative solutions with no direct claims to model or being inspired by the other MLCC levels. Examples include association-based computational creative systems (Grace et al 2012); small-scale "creative text generators" (Montfort and Fedorova 2012); and a music generator "inspired by non-musical audio signals" (Smith et al 2012).

MLCC level 4 is present in 30% of the papers; these present -or discuss approaches to generate- concrete artifacts identified as creative. They include Visual Narrator which constructs short visual narratives (Pérez y Pérez et al 2012); machine-composed music (Eigenfeldt et al 2012); and PIERRE which produces new crockpot recipes (Morris et al 2012).

AUTHORS	1	2	3	4	5	6	7	8	Tools
Agustini				●				●	●
Baydin	●							●	●
Burnett		$\circ^{+}$	○	●					
Charnley				$\bullet^{+}$	$\bullet^{+}$	$\bullet^{+}$			
Colton				●				●	●
Eigenfeldt			○	●					●
Gabora	●			●		$\bullet^{+}$		●	
Gatti									●
Grace				●				●	
Hoover									●
Indurkhya	$\circ^{+}$	$\circ^{+}$		$\bullet^{+}$		$\circ^{+}$		$\bullet^{+}$	
Jennings						●		●	
Johnson			$\bullet^{+}$			$\bullet^{+}$		$\bullet^{+}$	
Jordanus								$\bullet^{+}$	
Jursic									●
Keller									●
Li						●			
Linson						$\circ^{+}$			
Maher	$\bullet^{+}$	$\bullet^{+}$	$\bullet^{+}$			$\bullet^{+}$		$\bullet^{+}$	
Monteith				●				●	
Montfort								●	
Morris	●			●				●	
Noy						●			
O'Donoghue	●					●			
Ogawa	$\bullet^{+}$					$\circ^{+}$			
Pérez y Pérez			○	●				●	
Rank								●	
Ritchie						$\bullet^{+}$		$\bullet^{+}$	
Smith				●				●	
Sosa			●						
Toivanen	●		○					●	
Veale	○							●	
Wiggins						●		●	
Zhu	○								

Table 2. Classification of the ICCC‟12 papers in MLCC levels

More than 30% of all papers address MLCC level 6, cognition. Most of these refer to the cognitive processes involved in the generation of creative artifacts, but a few do suggest the study of cognitive processes related to the evaluation of creativity (Ogawa et al 2012; Linson et al 2012; Indurkhya 2012).

MLCC level 1 is captured in 35% of all papers. In most, culture is used as a source in the creation of creative artifacts (as corpora or as evolutionary models at the cultural level). The remaining entries deal with culture as part of the evaluation of creativity. These include the application of "literary criticism and communication theory […] to develop evaluation methods" (Zhu 2012) and "conceptual mash-ups" evaluated against "semantic structures seeking to replicate the semantic categories" (Veale 2012). Notably, MLCC level 7 –neural models of creativity- is not represented in ICCC"12, although progress is being made elsewhere (Iyer et al 2009).

Evaluation processes are scarce and gravitate mainly around MLCC levels 1 and 3 (Culture and Groups). 11% report assessment by small groups (audiences, experts) and the same number use culture as a metric for validating the results of a CC system (by comparison against or recreation of concrete cultural achievements). Only a couple of papers present potential ways of using societal factors or cognitive studies to understand how an artifact is ascribed creative value.

From an evaluation viewpoint, the ICCC"12 papers do not address the following MLCC levels: products (level 4), personality (level 5), neural processes (level 7) and CC processes (level 8). In this way, the MLCC model helps suggest future research approaches including:

- Models that incorporate explicit CC processes of evaluation of creativity, for example "automated critics" or "automated audiences" capable of replicating the assessment patterns of human judges (different scales and levels of domain expertise), as well as ultimately predicting the creativeness of computer-generated artifacts (Maher and Fischer 2012). Sample research question: "How may a computational system identify a masterpiece from mediocre artworks?"
- Models of neuro-mechanisms behind the creation as well as the evaluation of creativity. Systems that capture the connections between neural and cognitive processes. Sample research question: "How do basic functions such as short term memory or cognitive load moderate the evaluation of creative artifacts?"
- Models of the role of personality and motivation in the creation as well as the evaluation of creativity, for example systems that create or evaluate artifacts based on emotional predispositions, gender distinctions, and other personality dimensions. Models where creative behavior is moderated by environmental cues. Sample research question: "How do extraversion traits such as assertiveness moderate the assessment of creativity?"
- Models of intrinsic artifact properties identified in the evaluation of creativity according to intra and cross-domain characteristics. Sample research question: "What common assessment criteria do people apply when ascribing creativity in music, literature and architectural works?"

Beyond these "missing" levels (or ICCC gaps), this analysis leads to interesting new possibilities and distinctions in CC research:

- Culture can be approached in several ways in both generative and evaluative models: as the source of knowledge and generative techniques; as the standards against which new artifacts are evaluated by the creator and by the evaluators; as the status-quo that prevent or constrain acceptance of new artifacts; as factors exogenous to the domain from which creators can draw from and introduce novelty into their creative process; as rules and regulations that incentivize/inhibit creative processes; as market or cultural outlets and vehicles of promotion of creative value; etc.
- Societal and group levels can equally be considered in several ways: as large collectives or small groups (teams) collaborating in creative endeavors; as opinion leaders that influence both creators and evaluators; as cliques that provide support but may also polarize types of creators; as aggregate structures of behavior that lead to segmentation, migration, institutionalization; as temporal and spatial trends; etc.

As noted before, cognitive modeling may apply both to the generation and the evaluation of creativity. Likewise, although current computational tools are conceived for the creation of creative artifacts, computational tools could also support the individual and collective evaluation of artificial and human-produced artifacts –for example through the automated extraction of evaluation functions provided customer needs and requirements, which can then be used to guide either a computational system or human designers.

Discussion

How do works such as the Mona Lisa by Leonardo become icons of creativity? Elements to consider range from its intrinsic aesthetic and artistic qualities all the way to its distinctive history –including its theft from the Louvre in 1911 and the ensuing two-year international media notoriety (Scotty 2010). This illustrative case exemplifies the "entangled art-market complex" (Joy and Sherry 2003). Two CC scenarios are compared here where MLCC modeling is demonstrated:

1) "The Next Mona Lisa" CC model: a computational generative system is pursued that captures MLCC levels 6, 7 and/or 8 implementing symbolic or neural techniques (inspired or not by human capabilities) which aims to create a work of art comparable to the Mona Lisa, i.e., that receives the kind of appreciation and recognition gaining the status of a global cultural icon. The problem is that not only this approach seems rather implausible based on the current state of CC, it would also require a vast number of exogenous factors outside the reach of the system's authors –and would probably require very long time periods, considering that even *La Gioconda* path to prominence took more than four centuries (Scotti 2010).

2) "The Mona Lisa System" CC model: a multilevel computational system is based on the MLCC levels of choice (two or more from 1 to 8), which aims to capture the creation of a large number of artifacts, some of which (most) fall into complete oblivion, some of which (very few) make it to the equivalent of mediocre galleries, local museums and living rooms of elite audiences, and some of

which (an absolute minority) are preserved, disseminated and capture broad attention and consensus. Some works in this last category may gradually become part of the cultural heritage, may be used as exemplars in specialized domain training and in general education, may fetch high prices in auctions or be considered invaluable in monetary terms, and may ultimately play an influential role in shaping public taste as well as future artifacts within and beyond the domain of origin.

The latter approach opens interesting intellectual paths: What types of processes are capable of generating such diversity of artifacts? What commissioning, distribution and exchange mechanisms are sufficient to account for the observed skewed distributions of evaluation? What connections are possible, in principle, between intrinsic characteristics of artifacts and contextual conditions? What cross-level dynamics apply to creative systems from different domains and times?

Such an MLCC model can include a large number of elements, possibly derived from published studies –for example of art-market dynamics in this case (Debenedetti 2006; Joy and Sherry 2003). The output in such models may not be (only or necessarily) the creative artifact itself, but a deeper understanding of the principles that underlie creative generation and evaluation. This may include two or more MLCC levels, and over time, historical trajectories that are likely to be context and time-dependent. Thus the high relevance of CC approaches for the study of systems based on stochastic processes which can be re-run over sets of initial conditions in order to inspect causal relationships and long-term effects.

Lastly, the following guidelines are provided when building MLCC models, somehow extending the evaluation guidelines proposed by Jordanus (2011).

1) Identify levels to be modeled
   a) Define primary and complementary levels: realistically, empirical validation or data may be relevant only for one or two levels, whilst computational explorations can target other levels of interest.
   b) Identify level variables (experimental and dependent) that represent target factors and observable behaviors or patterns of interest.
   c) Define inputs and outputs at target levels, establishing the bootstrapping strategies of the model.
2) Define relationships of interest between levels
   a) Establish explicit connections above/below primary levels in the model
   b) Define irreducible factors, causal links and whether the model is being used for holistic or reductionistic purposes.
   c) Identify internal/exogenous factors to the system.
3) Depending on modeling aims, define outputs
   a) Define type and range of outputs, identifying extreme points such as non-creative to creative artifacts
   b) Capture and analyze aggregate data, model tuning and refinement
4) Evaluation of a MLCC system
   a) Validity may be achievable in some models where relevant empirical data exists at the primary level(s) of interest, but this may be inaccessible and even undesirable for exploratory models.

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References

Adesope, O., Lavin, T., Thompson, T., and Ungerleider, C. 2010. A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research* 80(2):207–245.

Anderson, C. 2012. *Makers: The New Industrial Revolution*. London: Random House Business Books.

Anderson, C., and Kilduff, G. J. 2009. Why do dominant personalities attain influence in face-to-face groups? The competence-signaling effects of trait dominance. *Journal of Personality and Social Psychology*, 96(2):491–503.

Bassett-Jones, N. 2005. The paradox of diversity management, creativity and innovation. *Creativity and Innovation Management* 14(2):169–175.

Cohen, H. 1999. Colouring without seeing: a problem in machine creativity. *AISB Quarterly* 102:26–35.

Debenedetti, S. 2006. The role of media critics in the cultural industries. *International Journal of Arts Management* 8:30–42.

Dollinger, S. J., Urban, K. K., and James, T. A. 2004. Creativity and openness: Further validation of two creative product measures. *Creativity Research Journal* 16(1):35–47.

Duflou, J. R., and Verhaegen, P. A. 2011. Systematic innovation through patent based product aspect analysis. *CIRP Annals-Manufacturing Technology* 60(1):203–206.

Finke, R. A., Ward, T. B., and Smith, S. M. 1996. *Creative Cognition: Theory, Research, and Applications*. Cambridge: MIT Press.

Fischer, G., Scharff, E., and Ye, Y. 2004. Fostering social creativity by increasing social capital. In Huysman, M. and Wulf, V., eds., *Social Capital and Information*. Cambridge: MIT Press. 55–399.

Fontaine, R. G. 2006. Applying systems principles to models of social information processing and aggressive behavior in youth. *Aggression and Violent Behavior* 11:64–76.

Gero, J. S. 1990. Design prototypes: a knowledge representation schema for design, *AI Magazine* 11(4):26–36.

Glăveanu, V. P. 2010. Paradigms in the study of creativity:

Introducing the perspective of cultural psychology. *New Ideas in Psychology* 28(1):79–93.

Hansen, H. K., and Niedomysl, T. 2009. Migration of the creative class: evidence from Sweden. *Journal of Economic Geography* 9(2):191–206.

Hennessey, B. A. 2003. Is the social psychology of creativity really social? Moving beyond a focus on the individual. In Paulus, P. B., and Nijstad, B. A. *Group Creativity: Innovation through Collaboration*. Oxford University Press. 181–201.

Indurkhya, B. 2012. Whence is Creativity? In *International Conference on Computational Creativity*, 62–66.

Isaksen, S. G., Puccio, G. J., and Treffinger, D. J. 1993. An ecological approach to creativity research: Profiling for creative problem solving. *The Journal of Creative Behavior* 27(3):149–170.

Iyer, L. R., Doboli, S., Minai, A. A., Brown, V. R., Levine, D. S., and Paulus, P. B. 2009. Neural dynamics of idea generation and the effects of priming. *Neural Networks* 22(5):674–686.

Jordanous, A. 2011. Evaluating evaluation: Assessing progress in computational creativity research. In *Proceedings of the Second International Conference on Computational Creativity*, 102–107.

Joy, A., and Sherry Jr, J. F. 2003. Disentangling the paradoxical alliances between art market and art world. *Consumption, Markets and Culture* 6(3):155–181.

Jung, R. E., Segall, J. M., Jeremy Bockholt, H., Flores, R. A., Smith, S. M., Chavez, R. S., and Haier, R. J. 2010. Neuroanatomy of creativity. *Human Brain Mapping* 31(3): 398–409.

Kaufman, J. C., and Beghetto, R. A. 2009. Beyond big and little: The four c model of creativity. *Review of General Psychology* 13(1):1–12.

Lessig, L. 2008. *Remix: Making Art and Commerce Thrive in the Hybrid Economy*. Penguin Press HC.

Liu, H., Tang, M., and Frazer, J. H. 2004. Supporting creative design in a visual evolutionary computing environment. *Advances in Engineering Software* 35(5):261–271.

Lubart, T. 2010. Cross-cultural perspectives on creativity. In Kaufman, J. C., and Sternberg, R. J., eds. 2010. *The Cambridge Handbook of Creativity*. Cambridge University Press. 265–276.

Maher, M.L. 2010. Design creativity research: from the individual to the crowd, In *Design Creativity 2010*, 41–47. London: Springer-Verlag.

Maher, M.L. 2012. Computational and collective creativity: Who"s being creative?. In *International Conference on Computational Creativity*, 67–71.

Maher, M.L. and Fisher, D.H. 2012. Using AI to Evaluate Creative Designs. In *Proceedings of International Conference on Creative Design*, 45–54.

Maher, M.L., Hammond, K., Pease, A., Perez y Perez, R., Ventura, D., and Wiggins, G. (Eds.) 2012. *Proceedings of the Third International Conference on Computational Creativity*. http://computationalcreativity.net/iccc2012

McCoy, J. M., and Evans, G. W. 2002. The potential role of the physical environment in fostering creativity. *Creativity Research Journal* 14(3-4):409–426.

McGrew, S. 2012. Creativity in Nature. In Swan, L;, Gordon, R., and Seckbach, J., eds., *Origin(s) of Design in Nature*. Springer Netherlands. 43–55.

Montfort, N., and Fedorova, N. 2012. Small-Scale Systems and Computational Creativity. In *International Conference on Computational Creativity,* 82–86.

Moran, S., and John-Steiner, V. 2003. Creativity in the making. In Sawyer, R. K., John-Steiner, V., Moran, S., Sternberg, R. J., Feldman, D. H., Nakamura, J., and Csikszentmihalyi, M., eds., *Creativity and Development,* Oxford: Oxford University Press. 61–90.

Rogers, E. M. 1995. *Diffusion of Innovations*. Simon and Schuster.

Russell, S. J., and Norvig, P. 1995. *Artificial Intelligence: A Modern Approach*. Prentice Hall.

Scotti, R. A. 2010. *Vanished Smile: The Mysterious Theft of the Mona Lisa*. Vintage.

Sosa, R., and Dong, A. 2013. The creative assessment of rich ideas. In *Proceedings of the Ninth ACM Conference on Creativity and Cognition*. ACM Press.

Sosa, R., and Gero, J. S. 2004. A computational framework for the study of creativity and innovation in design: Effects of social ties. *Design Computing and Cognition 04*, 499–517.

Sosa, R., and Gero, J. S. 2005a. A computational study of creativity in design: the role of society. *AIEDAM Artificial Intelligence Engineering Design Analysis and Manufacturing* 19(4):229–244.

Sosa, R., and Gero, J. S. 2005b. Innovation and design: computational simulations. In *ICED 05: 15th International Conference on Engineering Design: Engineering Design and the Global Economy,* 1522-1528.

Sosa, R., Gero, J. S., and Jennings, K. 2009. Growing and destroying the worth of ideas. In *Proceedings of the Seventh ACM Conference on Creativity and Cognition*, 295–304. ACM Press.

Westmeyer, H. 2009. Kreativität als relationales Konstrukt. In Witte, E.H., and Kahl, C.H., eds., *Sozialpsychologie der Kreativität und Innovation*, 11–26. Lengerich: Pabst Science Publishers.

Young, H. P. 2009. Innovation diffusion in heterogeneous populations: Contagion, social influence, and social learning. *The American Economic Review* 99(5):1899–1924.