The 2nd International Conference on Design Creativity (ICDC2012)

Glasgow, UK, 18th-20th September 2012

"CRITICAL MASS OF IDEAS": A MODEL OF INCUBATION IN BRAINSTORMING

R. Sosa[1] and J. S. Gero[2]

[1]Singapore University of Technology and Design, Singapore.
[2]Krasnow Institute for Advanced Study and Volgenau School of Engineering, George Mason University, USA

Abstract: This paper presents the results of experiments with a computational model of group brainstorming as an environment to study the role of incubation in creativity. In this model, exploration refers to the random search for solutions, exploitation refers to the guided search for new solutions based on existing solutions, and incubation is defined as the re-organization of the search processes used previously to find solutions but with no direct output of actual solutions. This work suggests that the beneficial effects of incubation in ideation could depend on the type of ideation processes carried out in previous stages of the creative process, and it provides insights for understanding the complex nature of incubation. We suggest the concept of "critical mass of ideas" as a plausible mechanism to explain incubation and argue for its inclusion in future studies of creativity.

Keywords: *incubation, brainstorming, multi-agent model*

1. Introduction

Generating and identifying novel ideas is hard. Facilitating ideation teams to generate and identify novel ideas is probably even harder. Key insights from research and practice provide some guiding principles to facilitate creative ideation in design. For instance, research on brainstorming has characterised the differences in ideational productivity of interactive (individuals collaborating in teams) and nominal groups (individuals working alone), suggesting that facilitation of creative teams has a large impact in the fluency of ideas (Isaksen & Gaulin 2005). Facilitation is acknowledged as a key strategy to overcome the well-known shortcomings of brainstorming interactive groups. Yet, there is a lack of systematic evidence and sound explanations of good facilitation practices. The creation of robust facilitation strategies for creative ideation in design is what motivates this work.

Laboratory studies of group brainstorming present considerable challenges such as the criteria to define the task or problem addressed by participants, the criteria to assess the quality of ideas, and subtle differences such as motivation and various societal dynamics that are difficult to account for.

This paper presents a computational model of group ideation that enables the examination of specific variables and their interaction over time in a multi-agent simulation that can be inspected in every detail and run iteratively under different initial conditions to understand the effects of incubation principles. The results of this computational social model cannot be generalised to situations of humans brainstorming, their value is instead as thinking tools to derive guiding principles for future research and practice. In this paper we focus on incubation principles in group brainstorming.

2. Incubation

The idea of 'incubation' in creativity research has been very influential. The term is usually credited to Poincare's anecdotal account of his mathematical discoveries as characterized by the 'four stage model' of Wallas (1926). This model suggests that the creative process iterates through a sequence that begins with an intense period of conscious work (preparation), followed by a period of leaving aside the task for a while (incubation), leading to a sudden flash of insight (illumination) complemented by intense and focused work on the resulting ideas (verification).

Incubation in the 'four stage model' suggests that the individual or team suspends the ideation process either by resting or engaging in other tasks, literally 'sitting on the ideas'. This has been hypothesized to protect the early ideas in the subconscious, possibly providing optimal conditions for understanding and connecting them with other ideas. Dreaming has been linked to creativity due to subconscious random associations between ideas. A recent study examined the role of REM sleep on the Remote Associates Test (RAT), a test where subjects build associations between words that are seemingly unrelated. That study compared conditions of REM sleep with quiet rest and non-REM sleep, concluding that REM sleep does enhance the integration of unassociated information (Caia et al., 2009).

Studying incubation during brainstorming is inherently difficult in laboratory studies. The main approach consists of introducing an unannounced break half-way in the session, during which participants are asked to engage in a different task like solving puzzles unrelated to the brainstorming problem, or to rest quietly (Smith, 1995; Sio & Ormerod, 2009). After this, participants resume brainstorming and their ideation productivity is compared to control groups of no-break condition. Participants in the break conditions have been found to generate more ideas than those in a no-break condition (Paulus et al., 2006). A recent literature review found a set of potential moderators reported, including the problem type, length of the preparation period (explicit and intense ideation), and the incubation task, leading to the possible existence of multiple types of incubation (Smith, 1995). Apparently, taking a break from work on a topic is differentially advantageous, and depends on the type of task undertaken during the break (Ellwood et al., 2009).

A study of expert and novice chess players found that incubation does not always facilitate creative problem solving, but only when the problem solvers' mind is fixated (Sio & Rudowicz, 2008). Similarly, manipulation of the inducement of fixation as well as the presence of breaks during the session confirms that incubation has the effect of increasing the number of ideas and the number of semantic categories of these ideas only when one has become initially fixated during a brainstorming session (Kohn & Smith, 2010). The observed positive effects of an incubation break include reducing the usual decline in quantity and variety in the latter stages of brainstorming (Kohn, 2009). In conclusion, incubation is a complex construct that may have a number of effects depending on given conditions. It has been generally defined as "a stage of creative problem solving in which a problem is temporarily put aside after a period of initial work on the problem" (Smith & Dodds 1999). Therefore one can expect incubation to have different effects depending on the preceding period in the ideation process.

Further research is necessary to understand why and how interruptions during a brainstorming session improve ideation. Interruptions may enable the reorganization of information or the relation between seemingly unassociated ideas, or they may serve to recover from cognitive fatigue, or they may allow people to assimilate more complex ideas and their implications, or de-emphasize and forget dominant or commonplace ideas. In teams they may additionally be helpful to redirect or balance group dynamics, or to regain focus and recover from idea drifting. Further research is also necessary to understand moderating factors such as the nature of the brainstorming problem, the timing of the interruption during an ideation session, the nature of the task performed during the break, and the state of convergence or fixation in the stage previous to the break. The facilitation of ideation groups would greatly benefit from a better characterization of incubation, its expected effects and its appropriate timing during a brainstorming session.

3. Hypotheses

In this paper we build a computational social model of group brainstorming to inspect the fundamental principles of incubation. A multi-agent system is constructed using a modelling framework of creativity and innovation where agents engage in three possible ideation strategies and interact over time producing or 'growing' outcomes of interest. Exploration refers here to the strategy of randomly searching for solutions, exploitation is the guided search for new solutions based on existing solutions, and incubation consists of agents re-organizing their search processes used previously to find solutions with no direct output of actual solutions. The exploration and exploitation mechanisms used here are inspired by the classic notions of divergent or 'horizontal' search to discover new knowledge and convergent or 'vertical' thinking to test the validity of the new knowledge (Nijstad & De Dreu, 2002; Lovell et al., 2012). During brainstorming sessions, one may assume that exploration enables the discovery of new categories or types of solutions, whilst exploitation allows for the generation of alternatives or new instances. The incubation mechanism used in this model is inspired by descriptions of the cognitive mechanisms described in the literature (Smith, 1995; Sio & Ormerod 2009; Paulus et al., 2006; Ellwood et al., 2009; Sio & Rudowicz, 2007). Beyond these modelling abstractions, we do not claim that the results from a computational social model can be generalised to human agents and teams working in real life conditions –a cautious disclaimer usually disregarded in laboratory studies.

The model can be considered open-ended since there is a range of valid solutions depending on the assessment criteria used. Creativity can be measured by the diversity of an agent or a team's solutions, or by applying other criteria that are relevant to the task. The term "ideational productivity" refers in the literature to the fluency of an ideation process usually by distinguishing the total number of ideas produced (gross fluency) from the set of unique and valid ideas (net fluency). Here ideational productivity refers to an aggregate measure of quantity and diversity of solutions without applying an explicit quality criterion. In this study we are working with shapes, so a solution generated by an agent is acknowledged if and only if the topological and geometrical features are not present in previous solutions. Details of the model are provided in the next section. Two hypotheses are explored here, the first hypothesis (H1) is that a combination of exploration and exploitation is likely to produce a significant increase in ideational productivity when compared to the output of exploration alone. The second hypothesis (H2) is that incorporating incubation will produce a significant increase in ideational productivity when compared to the output of exploration and exploitation combined.

4. Experiments

The model of group ideation presented here, called *shapeStorming*, is a model of brainstorming using shape emergence. It is defined using the channels of systemic interaction specified in the IAS framework of creativity: Ideas (I), Agent (A), Society (S) (Sosa et al., 2009). Agents (A) engage in a simple exploratory designing task of two-dimensional geometric composition with emergent shape properties that constitutes the agent-idea channel (Ai). The resulting geometric representations and their topological relations formulated as *design concepts* belong to the set of Ideas (I). Design concepts are shared by agents (Ia) and used as a basis to develop new design concepts (Aa) that are exploited or applied in the guided search of new designs (Ai') and social structures (S) determine the sharing of ideas between teammates (Si) (Sosa et al., 2009).

The random search of geometric compositions in *shapeStorming* is called the *exploration* mode, while the guided search of geometric compositions based on the transformation of available topological rules is called the *exploitation* mode. The construction of topological relations from geometric representations is called the *evaluation* mode. Evaluation is a sub-process of exploration and exploitation where new candidate ideas are inspected for emergent outcomes that support new topological rules. In *shapeStorming*, agents transition between modes in rates defined by the experimenter. The aim for agents in *shapeStorming* is to generate as many original solutions as possible, i.e., geometric and topological compositions that are novel in the system. Every time that exploit or explore modes generate a novel combination of emergent features, the agent in *shapeStorming* evaluates the design and generates a new design concept. Further details on these strategies are provided below. This paper reports on the effects of exploration, exploitation and incubation modes on the number and quality of solutions generated by this model.

4.1. Agents, ideas and teams

Following the IAS framework of creativity (Sosa et al., 2009), *shapeStorming* implements agent-idea interaction as a shape construction process starting from an initial set of *n*-number of two-dimensional shapes of *m*-sides that yields emergent polygons created by the intersection of lines and vertices. Six interaction processes across IAS levels are identified in (Sosa et al., 2009): agent-idea (Ai), idea-agent (Ia), agent-society (As), society-agent (Sa), idea-society (Is) and society-idea (Si). Three functions are aimed at, and are available by, targets within the same level in the IAS framework, namely agent-agent Aa, society-society Ss and idea-idea Ii (Sosa et al., 2009). In the version of *shapeStorming* discussed here, there are two variants of agent-idea (Ai) processes: *explore* and *exploit* modes. In *explore*, agent behaviour is implemented as the random location in a two-dimensional space of connected polylines from which closed geometries of *n*-sides are built. Intersections are sought between all lines of the geometries built. New polygons are created by the superposition of shapes which leads to the identification of new vertices or nodes in the intersections of line segments and thus generates emergent polygons. This shape arithmetic task in *shapeStorming* is illustrated in Figure 1; solutions are compared against each other by the number of emergent polygons and the number of sides of these polygons.

In *exploit* mode, agent behaviour in *shapeStorming* is guided by topological relations derived from previous solutions in an agent process of evaluation of emergent shapes. Evaluation characterizes the number of intersection points and their location inside, outside, in-line or in-vertex with respect to other shapes in the composition. A design concept in *shapeStorming* includes the topological relation of shapes and the number of emergent polygons with their respective number of sides. Such a simple design task adequately models a brainstorming problem: agents are assembled in teams and take turns to generate as many different solutions as possible from an initially defined number of polyline sets. Shape exploration in *shapeStorming* can be considered potentially creative inasmuch as emergent shape semantics "exists only implicitly in the relationships of shapes, and is never explicitly input and is not represented at input time" (Gross, 2001). Further details on the implementation of this model including pseudo-code of key functions is provided elsewhere (Sosa & Gero 2012).

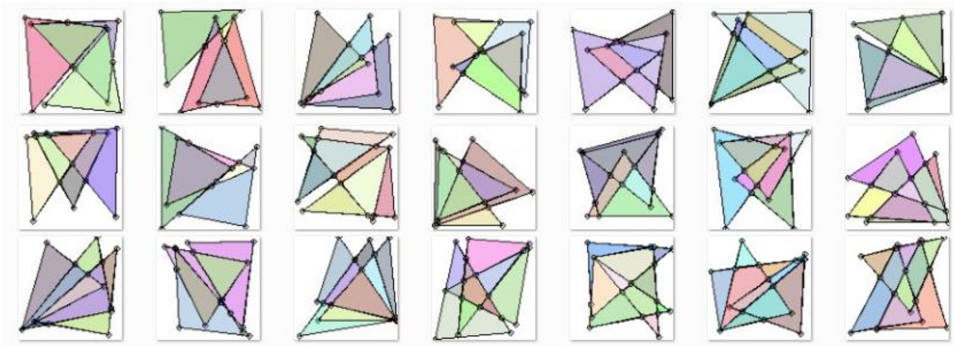


Figure 1: Shape emergence in *shapeStorming*, the output of a team of agents is assessed by the number of solutions and their quality (number of emergent shapes and sides)

In order to assess *shapeStorming* across a number of configurations, a range of results of running four conditions is presented in Table 1: in A, the system is run for 1,000 steps with 4 agents, 2 initial shapes of 3 sides; in condition B, the same setting is run for 10,000 steps; in condition C a third initial shape is introduced and in condition D the system is run for 100,000 steps. Ideational productivity is defined here by the number of design concepts generated by agents during a simulation. We further distinguish between concepts generated in exploration mode and exploitation mode.

Table 1. Total ideation in exploration mode in different configurations of *shapeStorming*

***shapeStorming* conditions**	**Ideational productivity**
A: 1,000 steps, 4 agents, 2 initial shapes, 3 sides	7.23
B: 10,000 steps, 4 agents, 2 initial shapes, 3 sides	9.38
C: 10,000 steps, 4 agents, 3 initial shapes, 3 sides	134.22
D: 100,000 steps, 4 agents, 2 initial shapes, 3 sides	15.35

4.1.1. Experimental settings

This paper shows results from two sets of experiments in *shapeStorming*, Experiment 1 aims to test hypothesis H1 by examining the effects of exploitation mode in ideational productivity at different stages of a brainstorming session in conditions A and B as defined in Table 1. Exploration length φ refers to the ratio of the introduction of exploitation steps to the total simulation steps and is examined here from 0.0 to 1.0 in 0.05 increments. This set of experiments seeks to reveal when is exploitation more likely to give increased ideational productivity and why.

Experiment 2 aims to test hypothesis H2 by examining the effects of varying incubation against different preparation stage lengths. Incubation rate μ stands for the ratio of the time when incubation is activated to the total simulation time and it is inspected here from 0.0 to 0.50 in variable increments in conditions A and B of *shapeStorming*. Experiment 2 seeks to explain the interplay between exploration behaviour and incubation in order to understand the effect of timing of the introduction of incubation in *shapeStorming*, as well as to grasp the fundamentals behind the timing of the incubation stage in *shapeStorming*.

5. Results

Results from Experiment 1 indicate the effects of introducing exploitation of design concepts in *shapeStorming* at a ratio of total simulated time, from exploration length $\varphi = 0$ to 1. When $\varphi = 0$ we artificially seed one base concept at initial time to enable exploitation. An increasing value of φ means that agent behaviour switches to exploitation at later stages of the simulation time, until $\varphi = 1$ when agents only perform exploration during the entire simulation. The effects of introducing exploitation in *shapeStorming* at different times are as follows: in condition A of Table 1, exploration-driven concepts continuously increase as a result of extending the length of exploration stage. Exploitation-driven concepts decrease as exploitation is delayed since the length of the exploitation stage is shortened. Overall ideational productivity in condition A increases as exploitation is delayed up to around 75% of the simulation time ($\varphi = 0.75$) when peak ideational productivity is reached. After this point, the gain of exploration-driven concepts is costly in relation to the sharp decrease of exploitation-driven concepts. Therefore, in conditions like A of short runs (1,000 steps) this advantage is relatively small (from 7.23 to 7.68 or +6% in these experiments).

The advantages of exploitation are more evident in larger simulations such as condition B of Table 1 (10,000 steps). Here, the advantage of exploitation increases considerably (from 9.38 to 18.1 or +93%). Similar to condition A, exploration-driven concepts increase as exploitation is delayed, but in contrast to condition A, exploitation-driven concepts show a significant increase as exploitation is delayed. This could be unexpected given the results of Experiment 1(A). This can be explained by introducing the concept of *critical mass of ideas*, which accounts for the gain in ideational productivity due to positive feedback effects between exploitation and a sufficiently large body of ideas from exploration. In terms of the ‘four-stage model’ of Wallas (1926), this can be interpreted as verification being more productive when coupled with sufficiently rich preparation and incubation stages.

Overall ideational productivity in condition B increases as exploitation is delayed up to around 75% of the simulation time ($\varphi = 0.75$) when peak ideational productivity is reached –a threshold similar to condition A. These results in Experiment 1 illustrate and provide a way to address the following well-known conundrum in facilitation of creative ideation sessions: building on existing categories of ideas is a productive approach until it takes valuable time that can be invested in seeking novel categories of ideas. That exploitation can have positive but differentiated effects on ideational productivity depending on the ability to build on a sufficiently large mass of ideas, provides a background to examine the effects of incubation in Experiment 2.

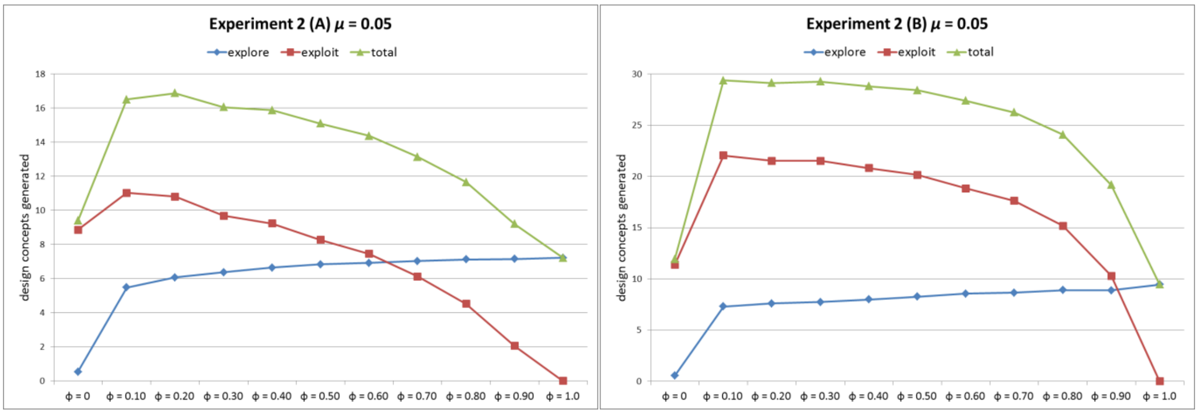
Experiment 2 inspects the timing between exploration, incubation and exploitation stages. Here, exploration length φ and incubation rate μ are varied. A sampling of μ from 0 to 0.50 are tested across all φ’s from 0 to 1 in 0.10 increments. The results, Table 2, indicate that by introducing incubation in condition A of Table 1, the gain in ideational productivity is significant.

Peak ideational productivity in condition A of Table 1 is achieved with a low incubation rate $\mu = 0.05$, that is, agents engaging in incubate mode only 5% of the total simulation time. The increase is a substantial 220%, from the 7.68 solutions generated in exploration-to-exploitation modes as shown in Experiment 1(A) to 16.88 when incubation is included in Experiment 2(A). By traversing the exploration length φ range from 0 to 1 in 0.1 increments, we find that the timing for incubation that produces peak ideational productivity in *shapeStorming* is when agents engage in exploration for a

20% of the total simulation time. Figure 2(a) shows the impact of incubation rate μ = 0.05 for the range of exploration lengths φ from 0 to 1.

Table 2 Peak ideational productivities of incubation rates μ across exploration lengths φ

incubation rate μ	exploration length φ	peak ideational productivity
μ = 0	φ = 0.75	7.68
μ = 0.01	φ = 0.20	15.35
μ = 0.02	φ = 0.20	16.17
μ = 0.03	φ = 0.20	16.42
μ = 0.04	φ = 0.20	16.53
μ = 0.05	φ = 0.20	16.88
μ = 0.10	φ = 0.20	16.5
μ = 0.30	φ = 0.10	15.5
μ = 0.50	φ = 0.10	14.07



(a) (b)

Figure 2. Experiment 2 with condition A and condition B, incubation rate μ = 0.05

This suggests that exploitation in *shapeStorming* is most productive when a combination of sufficient design concepts have been generated –both real concepts produced by exploration and possible concepts produced by incubation. After this threshold defined by 5% incubation plus 20% exploration in condition A of Table 1, it seems that agents waste their turns engaging in less productive incubation or exploration modes, when the larger gains come from focusing on exploitation. Experiment 2 reinforces the notion of *critical mass of ideas* discussed above, and the significant role of incubation in amplifying the value of exploitation, as well as in moving the inflection point from φ = 0.75 in Experiment 1(A) to φ = 0.20 in Experiment 2(A).

Experiment 2(B) replicates these findings when *shapeStorming* is run with condition B of Table 1 for a total of 10,000 simulation steps. With μ = 0.05, the exploration length φ range is varied from 0 to 1 in 0.1 increments. Compared to Experiment 1(B) where only exploration and exploitation modes are used and a mean 18.1 design solutions are generated, when incubation is incorporated in these long simulations, its impact is still considerable. Ideational productivity climbs around 160% reaching 29.38 mean solutions when $\mu = 0.05$ and $\varphi = 0.10$. Incubation even in exhaustive simulation runs have a positive effect in *shapeStorming*, Figure 2(b). This indicates that the effects of incubation may be dependent on the size of the problem space addressed in ideation; as a result, incubation is likely to have higher impacts when applied in shorter sessions in *shapeStorming*.

While incubation in *shapeStorming* doubles ideational productivity, it improves overall performance by two orders of magnitude, since it generates in only 1,000 steps (condition A of Table 1) similar results than those in 100,000 steps without incubation (condition D of Table 1).

6. Introspection

The work presented in this paper confirms via a computational model of group brainstorming the notion that incubation has a positive effect on ideation. It also suggests that the beneficial effects of incubation in ideation depend on a number of factors, and it provides insights for understanding the complex nature of incubation and its interaction with other creativity-related processes.

Our model shows that the combination of guided and random search may be only marginally better than purely random search in short runs, but its advantage increases as simulated time is extended. This points to a close interaction between exploratory and informed search processes over time. A process of ‘building upon ideas’ is more productive when it is activated after a sufficiently long initial period where a larger pool of initial ideas has been generated. According to our model, a significant increase can be obtained through exploitation even with a marginally larger pool of ideas previously generated by exploration. We refer to this as the “critical mass of ideas” (CMI), the principle that a sufficiently rich body or repository of initial ideas is a pre-condition for combinatory processes to generate a high number and variety of creative ideas.

A seemingly paradoxical outcome in creativity research is that the same number of individuals is likely to generate more and better ideas when working in isolation than when interacting in brainstorming sessions as a team (Isaksen & Gaulin, 2005). Although such results are consistent, no definite explanation has been offered until now, particularly since common sense suggests that interacting ideators have a higher potential to combine and build upon their ideas. The principle of “critical mass of ideas” (CMI) may provide a simple working mechanism for these results: in teams, group dynamics may prevent the formation of a sufficiently large body of initial ideas that others can build upon. In contrast, when working in isolation, individuals self-control the transition between exploratory and guided search. It is possible that teams may overcome this limitation by implementing adequate facilitation techniques that enable the formation of a critical mass of individual ideas that can be subsequently combined and improved by other teammates.

The second experiment presented in this paper demonstrates in a simple model of creative computational behaviour and a highly constrained domain representation, that even very low rates of incubation may carry a radical increase in the number of ideas generated in a brainstorming session. With very short incubation periods of only 5% of the total simulation length, when the incubation mode is activated around $1/5^{th}$ through the simulation, it produces the peak results in our model. This captures Edison’s famous dictum that creativity consists of marginal levels of inspiration accompanied by an overwhelming majority of hard work (“Creativity is 1% inspiration and 99% perspiration”). Apparently, incubation represents a cost-effective way of manipulating ideas that were previously generated and they also serve as a pool of possible ideas that can be used later to generate novel ideas. When incubation is activated at the right time and for the right length of time, it seems to catalyse the combined search processes of exploration and exploitation by reaching the highest point of ideation significantly sooner than in equivalent runs without incubation. In other words, when incubation is activated, less randomness may be required in order to generate a sufficiently large pool of initial ideas upon which new solutions can be built. Incubation may thus serve as a type of ‘shortcut’, with the highest advantages seen in shorter time periods.

The notion that a small pool of ideas is unlikely to spark sufficient synergy to reach “the critical mass needed to overcome the overhead associated with (team) interaction” was proposed previously in a different context (Dennis & Valacich, 1993). Here it is suggested that CMI may be useful in understanding differences in ideational productivity between nominal and interacting groups (Isaksen & Gaulin, 2005), as well as the observed effect that “longer preparation periods give rise to larger incubation effects” (Sio & Ormerod, 2009). Our computational model suggests that CMI is a valuable theoretical construct worth analysing in future studies.

Acknowledgements

The authors acknowledge the valuable comments provided by the reviewers of this paper. This research is supported in part by the National Sci-ence Foundation under Grant Nos. NSF IIS-1002079 and NSF SBE-0915482. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Caia, D.J., Mednick, S.A., Harrisona, E.M., Kanadyc, J.C. & Mednick, S.C. (2009) REM, not incubation, improves creativity by priming associative networks. Proceedings of the National Academy of Sciences 106(25), 10130-10134.

Dennis, A.R. & Valacich, J.S. (1993) Computer brainstorms: More heads are better than one. Journal of Applied Psychology, 78(4), 531-537.

Ellwood, S., Pallier, G., Snyder, A., & Gallate, J. (2009) The incubation effect: hatching a solution? Creativity Research Journal, 21(1) 6-14.

Gross, M.D. (2001) Emergence in a recognition based drawing interface, in Visual and Spatial Reasoning II, J. Gero, B. Tversky, T. Purcell, eds., Key Centre for Design Cognition, Sydney Australia, pp. 51-65.

Isaksen, S.G. & Gaulin, J.P. (2005) A reexamination of brainstorming research: implications for research and practice. Gifted Child Quarterly 49(4), 315-329.

Kohn, N.W. & Smith, S.M. (2010) Collaborative fixation: effects of others’ ideas on brainstorming. Applied Cognitive Psychology, 25(3), 359–371.

Kohn, N.W. (2009) An examination of fixation in brainstorming, PhD Thesis Texas A&M University.

Lovell, C., Jones, G., Zauner, K.P. & Gunn, S.R. (2012) Exploration and Exploitation with Insufficient Resources. JMLR: Workshop and Conference Proceedings, 26, On-line Trading of Exploration and Exploitation, 37-61.

Nijstad, B.A. & De Dreu, C.K.W. (2002) Creativity and group innovation, Applied Psychology An International Review, 51(3), 400-406.

Paulus, P.B., Nakui, T., Putman, V.L., & Brown, V.R. (2006) Effects of task instructions and brief breaks on brainstorming. Group Dynamics: Theory, Research and Practice, 10(3), 206-219.

Sio, U.N. & Ormerod, T.C. (2009) Does incubation enhance problem solving? A meta-analytic review. Psychological Bulletin, 135(1), 94–120.

Sio, U.N. & Rudowicz, E. (2007) The role of an incubation period in creative problem solving. Creativity Research Journal, 19(2-3), 307-318.

Smith, S.M. & Dodds, R.A. (1999) Incubation entry in the Encyclopaedia of Creativity, edited by Runco MA. & Pritzker SR. Academic Press San Diego, CA

Smith, S.M. (1995) Fixation, incubation, and insight in memory, problem solving, and creativity, in SM Smith, TB Ward, & RA Finke (eds), The Creative Cognition Approach, MIT Press: 135-155.

Sosa, R. & Gero, J.S. (2012) Brainstorming in Solitude and Teams: A Computational Study of Group Influence, International Conference on Computational Creativity 2012, Dublin Ireland. May 30-June 1 2012, http://computationalcreativity.net/iccc2012/

Sosa, R., Gero, J.S. & Jennings, K. (2009) Growing and destroying the worth of ideas, C&C'09 Proceedings of Conference on Creativity and Cognition, ACM, pp. 295-304.

Wallas, G. (1926) The Art of Thought, J. Cape, London.