

Brainstorming in Solitude and Teams: A Computational Study of Group Influence

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Abstract

Early studies of creative ideation showed that individuals brainstorming in isolation tend to generate more and better ideas than groups. But recent studies depict a more complex picture, reinforcing the need to better understand individual and group ideation. Studying group influence is one way to address the complex interplay between ideas in different brainstorming scenarios. We define group influence as the degree to which individuals are influenced by ideas coming from other team members. This paper presents results from a multi-agent simulation of the role of group influence in brainstorming groups. The results from the simulations indicate that the findings from previous laboratory studies tend to be misinterpreted, and that both isolation and teamwork present opportunities and challenges for creativity.

Introduction

Is it better to generate new ideas in solitude or in teams? Creativity research has shown that this distinction is not trivial. Early studies showed that individuals working in privacy tend to generate superior results along three criteria: total number of ideas, number of unique ideas, and quality of ideas [1]. But a more complex picture is portrayed by subsequent studies, reinforcing the need to better understand the interplay between individual and group ideation as well as the importance of facilitation dynamics [2].

The term ‘brainstorming’ refers to the method of problem solving based on timed sessions where participants are instructed to address a problem by freely generating a large number of ideas irrespective of their apparent value [3]. The aim of brainstorming sessions is to generate as many different alternative solutions to a given problem as possible. Whilst many variants of brainstorming have been proposed, the basic premises are: a) to maximize the number and the originality of ideas, b) to combine or improve ideas suggested, and c) to avoid critical evaluation of ideas [4].

Individual brainstorming consists of engaging subjects in idea generation sessions isolated from others. Group or team brainstorming refers to the more typical scenario where individuals interact to generate and evaluate possible solutions to a common problem. Following the literature, we use the term *nominal group* to refer to the former and *interactive group* to refer to the latter condition [2].

Recent studies of idea fluency in brainstorming show that nominal groups outperform non-facilitated interactive groups both in gross and net fluency of ideas; but are considerably outperformed by facilitated interactive groups [2]. As with other factors related to team dynamics, such as diversity and leadership, group influence as a construct and its effects on creative ideation are yet to be fully understood. This is a relevant topic in the still incipient research stream on multi-level approaches to team creativity [5].

The general process by which individuals in isolation consistently surpass group creativity has been explained as ‘ideational productivity loss’ and appears to have a series of likely cognitive and group-level causes [6]. Cognitive factors that may interfere with ideational productivity include production blocking, interruptions, forgetting ideas, and distraction by task-irrelevant processes. A higher cognitive load is also often cited as a source of ideational loss, typically caused by attending to other’s ideas.

Group factors that may account for productivity loss include team structure and diversity, turn-taking, awareness of public evaluation, disposition to converge with others’ judgments, lower motivation due to shared responsibility, and a tendency to free-ride [7]. Multi-level approaches are required to understand, for instance, what is the appropriate degree of accessibility to others’ ideas when brainstorming in teams in order to ensure that individuals are able to both build upon their own ideas as well as upon the ideas of their teammates.

Teamwork in creativity enables the important process of sharing ideas; however this freedom may have two different effects on creative ideation: one possibility is that teammates generate a wide range of diverging ideas thus obstructing the connection and refinement of coherent

‘trains of thought’. The noise generated in this imagined scenario would more likely produce incomplete and incompatible ideas of low quality not to mention dissatisfaction from the participants. A second possibility is that teammates rapidly converge in agreement around one or just a few dominant ideas without exploring other alternatives.

Group influence can be one way to address this interplay between ideas in brainstorming. We define group influence in this paper as the degree to which individuals are influenced by ideas coming from other team members. Here, group influence is a group-level rather than an individual construct. Groups with high influence levels are those where all ideas by all participants are always available to every group member. Groups with low influence levels are those where individuals are only exposed to their own ideas. Between these extremes, group influence indicates the ratio of ideas available to brainstormers.

In this paper we present results from a multi-agent simulation of the role of group influence in brainstorming groups. Our aim here is to model the interactions between agents engaged in a simple task of divergent reasoning in order to inspect the beneficial and detrimental effects of different team structures in idea generation. In defining this model, we follow the distinctions between ideas, agents and societal factors of the IAS framework for the computational modeling of creativity and innovation as explained below [5]. The rest of this paper is organized as follows: the next section presents precedent work on the computational modeling of group brainstorming, the following section introduces our own modeling approach to group influence in brainstorming, then the simulations results are presented and the paper concludes with a discussion of the results and their implications in computational creativity research.

Models of Group Brainstorming

This paper presents an approach to the study of creativity using computational social science [7] in order to inspect the mechanisms behind the apparent paradox of ideational productivity loss in brainstorming groups. Computational social science utilizes multi-agent simulations that are useful to explore hypotheses, test assumptions and understand fundamental issues in complex social systems. These systems are also useful to generate predictions for future laboratory experiments or case studies.

Semantic and Social Models

Iyer et al [8] propose a connectionist framework of idea generation in order to inspect experimental data from laboratory studies on ideation and idea priming. In particular they explore the interaction between ‘irrelevant primes’ and context familiarity; irrelevant cues are defined as sets of ideas of which only a fraction are related to the task at hand, while context familiarity is given by the pre-existing classification of ideas defined in the system.

With this model, the researchers emulate the laboratory results and provide hypotheses as to why even irrelevant primes can increase idea quality and fluency. By manipulating the degree of familiarity between contexts, they show that when irrelevant primes are used between two completely unfamiliar contexts, there is no benefit, whilst irrelevant priming is useful only when partial information about semantic relationships is shared between search contexts. In this vein, the authors suggest future experimental studies on the creative capacity to create ‘short-cut linkages’ between features, concepts or semantic categories that are typically not related.

In an extension of this work, Paulus et al propose an approach to modeling group creativity by vertically integrating neural and social networks [9]. They define agents as simplified versions of the connectionist model described above, and account for individual differences in semantic contexts, idea association, domains, cognitive strategies and responses to cues. Through what they define as a *parameterized interaction protocol* (PIP), their proposed model accounts for turn-taking between agents and, more relevant to our approach, the accessibility of ideas by either the entire group or a selected few. With this model still under development and testing, the authors aim to address a range of research questions, including the efficiency of certain interaction structures and scheduling protocols for group ideation.

Group Influence in a Design Task

From the perspective of computational social science, creative systems are modeled by multiple generators and evaluators of ideas linked in a social system. In such systems, creativity is explained as an emergent outcome, i.e. a global effect that ‘grows’ from simple local interactions [10]. The model presented here is defined using the channels of interactions specified in the IAS framework (ideas, agents, society) [10]. Agents (A) engage in a simple designing task that constitutes the agent-idea channel (Ai) where the resulting designs belong to the set of Ideas (I); social structures (S) determine the availability of ideas (Si); ideas are used by agents (Ia) to build design concepts (Aa) that are further applied in the design of new ideas (Ai').

In this model, Ai is implemented as a shape search process starting from an initial set of polygons and affine transformations, I is the set of final shape representations produced by the agents, S is the arrangement of agents in groups, Si is the experimental variable of group influence, Ia is a transmission mechanism of ideas to agents, and Aa is modeled as an inference process of design concepts. At the moment, this model is limited to only four of the nine channels of interaction in the IAS framework, namely: Ai , Si , Ia and Aa . In the future, we plan to integrate and examine more IAS processes in this model including leadership styles (As), compliance to group majority (Sa), group agreement to adjust idea influence (Is), etc.

A description of the simplified design task implemented in this system can be formulated as: “within a fixed time

period, generate as many different shape compositions as possible by combining a set of initial shapes". Shape compositions are defined as arrangements of n final shapes created from the combination of less than n initial shapes. New shapes are created by the superposition of existing shapes which lead to the identification of new vertices in the intersections of line segments. This enables the emergence of new shapes as the set of paths $\{LM\}$ from between the start and end points of figures L and M that lead through each intersection point, traversing each segment no more than once [11]. This shape arithmetic task provides a relative quantitative measure to compare two or more sets of results. A quality criterion is defined for this task as a function of the total number of new shapes created and their number of sides.

Figure 1 illustrates one composition created by this generative program. Further details on the complexity of this type of tasks are found elsewhere [13]. This two-dimensional shape representation is used to model divergent visual reasoning and is similar to those typically used in brainstorming research [6]. Whilst this design task is fairly straightforward to implement in a computer system, the results are varied enough to capture some of the key properties of design situations such as open-ended problem formulations with many appropriate solutions, and incremental development of solutions. A measure of task difficulty is defined by the number of initial shapes and the number of sides of these initial shapes. In this paper we present results using two initial shapes of three sides each.

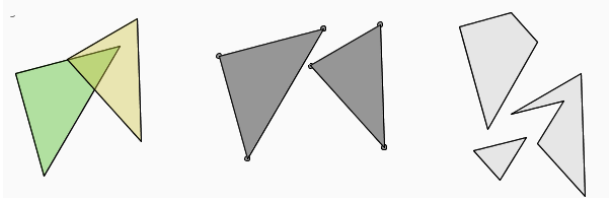


Figure 1 A random composition of 2 initial shapes where overlapping triangles are detected forming 3 emergent subshapes of 3, 4 and 5 sides, respectively. Shape compositions with more sub-shapes and subshapes with more sides are ranked higher.

The task is used to study group brainstorming by implementing a multi-agent system where agents are automated shape generators that search for new solutions, derive design concepts and interact in this process over a fixed time period. Agent behavior in this simplified model of brainstorming consists of the following behaviors: exploration function (random shape drawing and transformation), evaluation function (concept formation from topology relationships of shapes), and exploitation function (shape drawing and transformation by application of learned concepts).

Shape exploration in this program 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" [12].

A design concept is defined here as a topology relationship between the initial shapes associated to the fitness of the final shape composition. More details are provided below. After a designer agent has generated one or more concepts, it can use them to generate new shapes. Exploitation strategies consist of random variations to existing design concepts. New compositions can then be obtained as a result of applying the modified rule and evaluating whether its outcome yields a new shape composition.

The following pseudo-code shows the algorithm to generate initial shapes and new emergent subshapes in this task (exploration function):

```
for(initialShapes) {
    select n random (x,y) points
    connect all pairs of points with lines
    build a polygon with resulting lines
}
for(every polygon) {
    for(every line i of every polygon) {
        find intersection point(linei-linen)
        store all vertex in a set
    }
}
for(all vertex in set) {
    build all subshapes via graph search (dijkstra)
    store new subshape in a set
}
eliminate duplicate subshapes
```

The following pseudo-code shows the algorithm to assign a qualitative measure to shape compositions (first part of evaluation function):

```
for(finalShapes) {
    fitness += (sides of subshape * finalShapes)
}
```

The following pseudo-code shows the algorithm to build design concepts in this task (second part of evaluation function):

```
for(all initialShapes s) {
    s.insideVertex += (vertex is within boundaries of shape s+1)
    s.outsideVertex += (!vertex is within boundaries of shape s+1)
    s.inLine += (vertex intersects line of shape s+1)
    s.coincidentVertex += (vertex is coincident with vertex of shape s+1)
}
designConcept = { {insideVertex, outsideVertex, inLine,
    coincidentVertex}, fitness}
store designConcept in a set
```

The exploration and exploitation mechanisms used here are inspired in the classic notions of divergent or 'horizontal' and convergent or 'vertical' thinking processes [3]. During brainstorming sessions, one may assume that exploration

enables the discovery of new types of solutions, whilst exploitation allows for the generation of alternatives or new instances – a kind of tradeoff in a multi-armed bandit problem.

In this system, designer agents start with exploration and transition to exploitation given a variable defined by the experimenter. The following pseudo-code shows the algorithm for selecting between exploration and exploitation:

```

for(designerAgents){
  if (timeStep < exploreLength) strategy = "exploration"
  else {
    strategy = "exploitation"
    select a random designConcept from set of concepts
    switch (designConcept){
      case (insideVertex): initialShapes(insideVertex)
      case (outsideVertex): initialShapes(outsideVertex)
      case (inLine): initialShapes(insideVertex)
      case (coincidentVertex): initialShapes(coincidentVertex)
    }
  }
}

```

Group influence γ is defined as a sharing ratio of concepts: in the extreme case where $\gamma = 0$, agents have no access to the concepts generated by other agents; for cases $\gamma > 0$, agents have access to a fraction of the concepts generated by other agents up to $\gamma = 1$, where all agents have access to all concepts generated in the group. This experimental variable γ enables the modeling of both nominal and interactive groups in the brainstorming research literature, as well as scenarios similar to computer-mediated brainstorming where the researcher can control the level of interaction between participants [2].

Group influence γ is implemented in two sections of the code. First, agents store new design concepts in a shared team pool of concepts with a probability γ . Second, γ is also used in turn-taking on each simulation step. This is to account for the differential conditions in which nominal and interactive teams operate: when individuals work alone there is a type of allocation of turns in parallel, while teammates work in sequential turns. In this paper we inspect four γ scenarios: $\gamma = 0, 0.33, 0.66$ and 1.0 .

Exploration length ε is defined as a ratio of total simulation time during which agents activate exploration behavior. This variable is used to model the timing at which brainstorming participants switch from exploration to exploitation behaviors. Although we acknowledge that such transition may take more complex patterns in real brainstorming sessions, in this paper we adopt a parsimonious approach as a foundation for future models. Exploration lengths $\varepsilon = 0.2$ to 1.0 are inspected in this paper in 0.2 increments.

In this paper we present and discuss results of four and sixteen-member groups where both group influence γ and exploration length ε are the experimental variables and both quantity and quality of generated ideas is the dependent variable. Gross fluency refers to the total number of

design concepts generated during a simulation, while net fluency refers to the number of original or unique design concepts produced.

The impact of varying the level of group influence in idea fluency at different stages of a brainstorming session is likely to provide a possible explanation of the mechanisms behind the well-documented yet poorly understood phenomenon of ‘ideational productivity loss’ in group brainstorming.

Results

All results are mean values of 30 runs for every experimental condition. Control random-generator seeds are used in order to compare the effects of the independent variables. The trend is clear: as the scope of influence of ideas increases, fluency decreases across all exploration lengths. Table 1 shows the results for all 20 experimental conditions in gross and net fluency in four-member teams. When $\gamma = 1$, agents are activating the exploration strategy during 100% of the simulation; therefore no advantage from exploitation behavior is possible.

Table 1. Results in gross and net fluency from varying group influence γ in teams of 4 agents across a range of exploration lengths ε .

Exploration length ε	Group γ	Gross fluency	Net fluency
$\varepsilon = 0.2$	$\gamma = 0$	40.9	19.63
	$\gamma = 0.33$	53.86	19.46
	$\gamma = 0.66$	41.23	16.9
	$\gamma = 1$	18.4	9.2
$\varepsilon = 0.4$	$\gamma = 0$	48.46	22.76
	$\gamma = 0.33$	63.46	23.4
	$\gamma = 0.66$	47.66	19.23
	$\gamma = 1$	23.26	11.63
$\varepsilon = 0.6$	$\gamma = 0$	56.96	25.9
	$\gamma = 0.33$	69.46	25.43
	$\gamma = 0.66$	47.16	19.6
	$\gamma = 1$	29.13	14.56
$\varepsilon = 0.8$	$\gamma = 0$	57.56	25.03
	$\gamma = 0.33$	64.86	23.03
	$\gamma = 0.66$	44.9	18.26
	$\gamma = 1$	27.6	13.8
$\varepsilon = 1.0$	$\gamma = 0$	44.36	14.93
	$\gamma = 0.33$	44.43	14.13
	$\gamma = 0.66$	33.9	13
	$\gamma = 1$	22.06	11.03

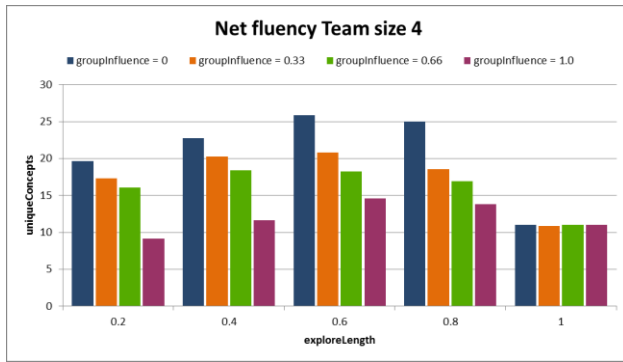


Figure 2. Group influence γ has a negative effect on net fluency across all exploration lengths ε . The differential effects of γ are higher when ε is low, and net fluency is higher across all γ when ε is medium. With high ε , the effects of γ are less significant.

Group influence γ has a clear effect on the generation of unique design concepts or net fluency, Figure 2. In this model, agents brainstorming in isolation do produce more original ideas than the *same* agents brainstorming in teams. These results are consistent across different team sizes from 4 to 16 members in our model, Figure 3.

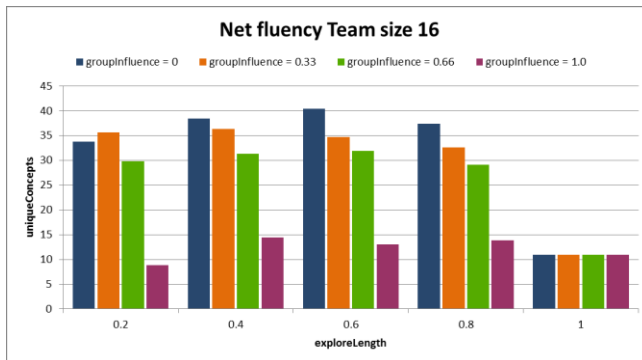


Figure 3. In large teams ($N = 16$), group influence γ has a more significant effect on net fluency across all exploration lengths ε .

When group influence is zero, agents contribute no solutions to the common pool of team concepts, and they only store and have access to their own concept pool. Gross fluency is the total sum of individual concepts, while net fluency is the count of original concepts in this set. Consistently across different team sizes, when group influence is zero, net fluency is highest indicating that agents in isolation generate more unique solutions than when they share solutions with others.

Although this outcome is consistent with the brainstorming literature, it still seems counter-intuitive; how can teams of agents in this model be less efficient than same-size groups of separate individuals? This result may seem paradoxical particularly when we consider the amplifying effects that the exploitation strategy has in this model, as evidenced by scenarios where agents explore the entire simulation time span ($\varepsilon = 1.0$). If exploitation is so productive (particularly when balanced with similar rates of exploration in this model), where does the advantage of iso-

lated agents come from despite the fact that they have access to smaller solution sets during exploitation? In other words, one could expect that teams of agents in this model would be more productive given that each individual agent has access to a larger pool of concepts from which it can retrieve a higher diversity of solutions in order to build more concepts. In contrast, we observe that as group influence increases and agents contribute more and have more access to a larger pool of solutions, both gross and net fluency decrease. The gap between net fluency of nominal and interactive groups varies in this model as a function of exploration length, i.e., how early or late is exploitation activated during the simulated brainstorming session.

In larger groups the effects of group influence are more significant. Agents in large teams appear rather inefficient in high group influence conditions: their net fluency is equivalent to that of teams four times smaller. In this respect, it would be tempting to conclude that working in isolation is more efficient for creative ideation.

However, there is a fundamental distinction that is made clear in this model, which has largely remained implicit across studies that compare the performance of nominal versus interactive teams: the total output of these two types of groups is incommensurable. The key is turn-taking; the comparison is inadequate when measured in number of turns rather than in minutes or hours. The difference is that in isolation, although in theory the same number of individuals are generating and recording ideas, in fact the number of turns is n times higher than in interactive groups since turn-taking occurs in parallel. In principle, no idle time exists for individuals in nominal groups. In contrast, teams follow some type of sequential order (skewed or not) by which all team members except one are idle at every turn or intervention. Therefore, this natural 'bottleneck' in team interaction (*production blocking*) is a sufficient cause for the relative poor performance of teams when compared to the aggregate results of individuals in isolation.

In order to account for this inequality, turn adscription is manipulated in our model to ensure that all agents in nominal and interactive groups have access to an equal number of turns over the simulated time. The result is an increase in gross fluency as group influence increases, Figure 4.

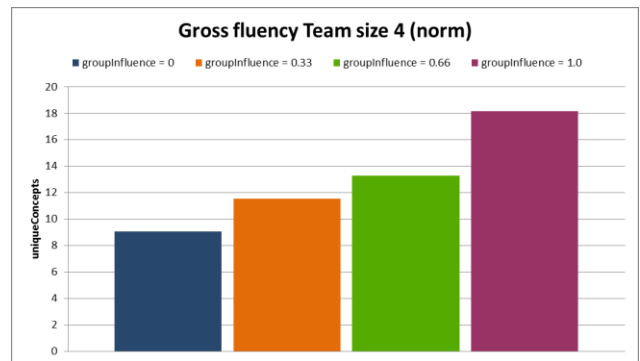


Figure 4. Teams outperform same-number of individuals in gross fluency as group influence γ increases ($\varepsilon = 0.2$).

Discussion

Is it better to generate ideas in solitude or in teams? The work presented in this paper suggests that each condition may present certain advantages and judging performance merely by measuring output is a limited approach. Although no definite answer can be expected from this simple model of brainstorming, it does capture interesting observations related to one of the key causes associated to ideational productivity loss, i.e. production blocking in groups. Within its limitations, this model supports a number of insightful hypotheses to consider:

- The balance between divergent and convergent thinking in a brainstorming session is important, and the time at which ideation is switched between these two modes of thinking is likely to have important an effect in the productivity of brainstorming groups.

- Individuals brainstorming in isolation are more productive than teams over similar time periods as a result of their increased *intensity* of participation. Teams present a ‘bottleneck’ in the form of sequential turn-taking, which is avoided by individuals in isolation who are –in principle– constantly active in generating new ideas and building up on previous ideas.

- The increased fluency of isolated brainstormers over teams may be a feature of easy tasks. It is possible that in difficult tasks, group diversity is more advantageous than individual ideational intensity. If this is the case, then transformative creativity may be more appropriate for brainstorming in solitude, whilst combinatorial creativity may be a more suitable objective of teams.

- Turn allocation can be optimized via facilitation techniques or technological means so that an adequate balance exists between having access to others’ ideas and avoiding interruptions. This balance may turn out to be a key factor in the performance of brainstorming groups.

The work presented here focuses on the effect of influence over ideas; it is natural to expect a more complex picture that includes individual diversity and other situational conditions. Nonetheless, our results can be cautiously compared to those from laboratory studies. For instance, a widely-cited study of 4-person groups in the same two assessment conditions shows a productivity gain of around 60% from interactive to nominal groups [14]. On the other hand, another study where the total number of ideas is considered in 4-people groups but in a simpler task, reports a mean difference of 38% between nominal and interactive groups [15]. In our system these differences range between 40% and 100% depending on certain task factors.

Nevertheless, the aim of this system is not to replicate a particular task or set of results, but rather to demonstrate the nature and effects of production blocking in teams or interactive groups. In addition, these findings provide a possible explanation as to why people may enjoy more working in groups than in isolation [16, 17]. Apart from a number of social reasons, in terms of idea generation, our experiments suggest that individuals find it easier to operate in groups as they have access to a large number of ideas

generated by others. Namely, significantly less individual effort is required to generate solutions.

If the results of this experiment were able to be generalized, then facilitators of brainstorming sessions should consider the aim of the session in relation to the type of demands imposed over the search of solutions, the degree of transformative or combinatorial creativity required, the social influence of the group (as a sum of paired influences between team members), and the resulting hierarchical interactions between brainstormers.

Brainstorming has been treated in general as a ‘black box’ method of problem solving. People are allocated into teams and they are expected to come up with solutions in a period of time with the general rule that they generate ideas without constraints. The importance of these simple computational experiments is that they show that the results of brainstorming sessions can be qualitatively different between independent individuals and groups, and also between different types of groups. Further modeling will be necessary in order to formulate and evaluate research-based instructions for adequate brainstorming sessions [18]. Future work with this model will account for individual agent diversity.

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References

1. Taylor, D. W., Berry, P. C., and Block, C. H. 1958. Does group participation when using brainstorming facilitate or inhibit creative thinking. *Administrative Science Quarterly*, 3, 23–47.
2. Isaksen, S. G. and Gaulin, J.P. 2005. A Reexamination of Brainstorming Research: Implications for Research and Practice. *Gifted Child Quarterly*, 49 (4): 315-329.
3. Osborn, A. F. 1957. *Applied Imagination*, Scribner, New York.
4. West, M.A. 2002. Sparkling fountains or stagnant ponds: an integrative model of creativity and innovation implementation in work groups, *Applied Psychology An International Review*, 51(3): 355-424.
5. Reiter-Palmon, R., Herman, A. E., and Yammarino, F. J. 2008. Creativity and cognitive processes: Multi-level linkages between individual and team cognition. In Michael D. Mumford, Samuel T. Hunter, Katrina E. Bedell-Avers, eds., *Multi-Level Issues in Creativity and Innovation*, Emerald, 203-267.
6. Paulus, P. B. and Nijstad, B. A. 2003. *Group Creativity: Innovation through Collaboration*, Oxford University Press, Oxford.
7. Paulus, P. B. and Brown, V. 2003. Ideational creativity in groups: Lessons from research on brainstorming. In PB Paulus and B Nijstad, eds., *Group Creativity: Innovation Through Collaboration*, Oxford University Press, New York, 110-136.
6. Brown, V. and Paulus, P. B. 2010. A Simple Dynamic Model of Social Factors in Group Brainstorming, *Small Group Research*, 27(1): 97-114.
7. Gilbert, G. N. and Conte, R. 1995. *Artificial Societies: The*

Computer Simulation of Social Life, UCL Press, London.

8. Iyer, L. R., Minai, A. A., Brown, V. R., Paulus, P. B. and Doboli, S. 2009. Effects of Relevant and Irrelevant Primes on Idea Generation: A Computational Model. *Proceedings of International Joint Conference on Neural Networks*, Atlanta, Georgia, USA, June 14-19, 2009.
9. Paulus, P. B., Levine, D.S., Brown, V., Minai, A. A., and Doboli, S. 2010. Modeling Ideational Creativity in Groups: Connecting Cognitive, Neural, and Computational Approaches. *Small Group Research* 41: 688-724.
10. Sosa, R., Gero, J. S. and Jennings, K. 2009. Growing and destroying the worth of ideas, *C&C'09 Proceedings of Conference on Creativity and Cognition*, ACM, 295-304.
11. Gross, M.D. 1996. Emergence in a recognition based drawing interface, *Visual and Spatial Reasoning II*, J. Gero, B. Tversky, T. Purcell, eds., Key Centre for Design Cognition and Computing, Sydney Australia, 51-65.
12. Gero, J. S. and Jun, H. 1995. Getting computers to read the architectural semantics of drawings, in L. Kalisperis and B. Kolarevic (eds), *Computing in Design: Enabling, Capturing and Sharing Ideas*, ACADIA, 97-112.
13. Stouffs, R. and Krishnamurti, R. 2006. Algorithms for classifying and constructing the boundary of a shape, *Journal of Design Research* 5(1): 54-95.
14. Diehl, M. and Stroebe, W. 1987. Productivity loss in brainstorming groups: Toward the solution of a riddle, *Journal of Personality & Social Psychology*, 53(3): 491-509.
15. Paulus, P. B. and Dzindolet, M. T. 1993. Social influence processes in group brainstorming, *Journal of Personality & Social Psychology*, 64(5): 575-586.
16. Nijstad, B. A. and De Dreu, C. K. W. 2002. Creativity and group innovation, *Applied Psychology An International Review*, 51(3): 400-406.
17. Paulus, P. B., Dzindolet, M. T., Poletes, G. and Camacho, L. M. 1993. Perception of performance in group brainstorming: The illusion of group productivity, *Personality & Social Psychology Bulletin*, 19(1): 78-89.
18. Paulus, P. B. and Dzindolet, M. 2008. Social influence, creativity and innovation. *Social Influence*, 3(4): 228-247.