Attention-Experience Disparities and the Influence of Idea Visibility on Idea Integration in Electronic Brainstorming: A Computational Model

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Abstract

Despite the pervasive use of electronic media for group brainstorming, research and practice show that electronic brainstorming systems (EBSs) may have created an illusion of productivity as they seem to offer limited benefits in terms of quantity or quality of the ideas generated by individuals during brainstorming. An underpinning thesis for losses during electronic brainstorming is associated with the lack of idea integration and use. This paper introduces and computationally examines a model of idea integration that formulates the joint influence of (1) idea visibility as an electronic media feature, (2) attention to partners' ideas as a cognitive attribute, and (3) individual's experience with idea integration as a decision-making factor on idea integration in EBS. Idea visibility and attention influence the opportunity for idea integration and individual's experience influences motivation for performing idea integration. From the best of our knowledge, this study is the first that examines the interacting effects of the above three factors on idea integration, and the model provides a theoretical basis for future empirical research. Results from our computational experiments suggest that the influence of idea visibility cannot be expressed in terms of simple effects of either attention or experience. Rather, the effect of visibility on idea integration is moderated by partners' attention-experience disparities.

1. Introduction

Electronic brainstorming is widely used in organizations. While electronic brainstorming provides many benefits such as enhanced information exchange and reduced production blocking, processing and use of the ideas shared by others is diminished in electronic brainstorming compared to verbal brainstorming [5, 6, 23]. Research has also uncovered that electronic brainstorming may suffer from reduced saliency of the ideas and reduced idea integration [6]. Idea integration depends on information saliency but little is known about the interplay between the two and how idea integration and saliency may be facilitated by user interface features in EBSs. It is important to note that EBSs may be used for variety of brainstorming forms but the scope of this study is limited to EBSs used for idea generation where ideas will be exchanged in form of text. And the communication mechanism is limited to computer screen.

Saliency in the current paper is operationalized by idea visibility (on the screen). Idea visibility in the EBS context is also a manifestation of what is referred to as exposure to partners' ideas by scholars of group creativity [38]. Whether or not exposure to partners' ideas positively influences the creativity process is still unclear [5, 6, 24, 38]. Creativity in the current paper is realized through idea integration; this is based on the assumption that no one individual has sufficient knowledge to create the best idea. Idea integration, thus, becomes a key to realizing more fully the value of the individually generated ideas [22, 30]. Idea integration is defined here by explicit reference and use of the evidence presented in partners' ideas and is closely related to information adoption & use [6, 9, 35]. It is important to note that partners' ideas will also implicitly influence one's ideation by providing cues for probing memory and through activating related concepts in associative memory [1] and by affecting transition among categories [3].

In addition to exposure to partners' ideas, idea integration requires attending to those ideas [6]. As a creative process, idea integration is influenced by prior belief on its outcome derived from idea integration experiences [17]. Examining idea integration from a data limited vs. resource limited view of processes, attention influences the amount of processing effort allocated to idea integration, and experience influences individuals' perception of the quality of the information contained in partners' ideas and gained from integration [19]. This paper examines the influence of visibility on idea integration contingent on individuals' attention, and individuals' experience with idea integration.

1.1. Related Work

In addition to the brainstorming literature, the current study also borrows ideas from research on creativity support tools [28]. Creativity support tools help individuals express themselves creatively and become creative thinkers. Individuals' goal is to be creative thinkers in their organizational context and software and user interfaces are to supports users to become more productive and innovative. The focus of this paper is however idea integration. Idea integration is considered the most fruitful process in brainstorming [6, 30, 20, 22, 38]. To date, however, the dominant focus in IS research on electronic brainstorming is on idea sharing, without much consideration of the ultimate goal for the shared ideas to be integrated and used by others. Although idea sharing and idea integration are closely coupled, idea sharing does not guarantee idea integration and use [36].

Building upon the premise of the importance of visibility or saliency of ideas [6], attention [3], and motivation [17], we set the stage for deeper understanding of idea integration with respect to IS interface features, and attention-experience disparities within groups. Attention disparity means that individuals are different with respect to their attentiveness; and experience disparity means that individuals are different with respect to their experience with idea integration. Similar to performance implications of other within-group disparities such as informational diversity [11] attention-experience disparities are shown to influence our key performance indicator, idea integration [30].

For integration, individuals must perceive different dimensions (differentiation) and be motivated to create the connections among the differentiated dimensions (integration) [10, 15, 30]. An attentive individual will experience more opportunity for idea integration than a less attentive individual (Figure 1). Motivation in our study is linked to uncertainty associated with idea integration outcome [17]. Considering that idea integration has a finite set of possible outcomes (e.g., ideas are good or not good) and assuming that individuals in the groups are Bayesian decision makers, experienced individuals form a concentrated prior distribution as opposed to a diffuse distribution for inexperienced individuals. Consequently, beliefs derived from a concentrated prior distribution for experienced individuals are less uncertain than those derived from a diffuse prior distribution of their inexperienced partners. Uncertainty associated with idea integration may also be examined as an exogenous factor linked to partners' ideas' perceived merit and value. The exogenous facet of uncertainty can be readily investigated in laboratory experiments. These are promising research areas that we plan to pursue in future research.

1.2. Current Study

This paper models the impact of idea visibility on idea integration in EBSs, and how the impact is contingent on attention to partners' ideas and experience with idea integration (Figure 1). The model is a concrete example of confluence of individual's cognitive and behavioral characteristics and IS design [13, 26, 31] in studying of EBS performance [7, 23]. The model is examined by computational experimentation because accounting for the interactive effects of all combinations of individual's characteristics and choices in laboratory experiments is complicated, and often intractable. Although simulation is limited in scope, it provides useful information for understanding the mechanism [12, 34].

Our experiments indicate that in groups with attention disparity, idea visibility has more of an effect on increasing the rate of idea integration, especially when there is experience equality in the group compared to when there is experience disparity. It also indicates that, in groups with experience disparity, increase in idea visibility has a stronger effect on increasing the rate of idea integration when there is attention equality in the group compared to when there is attention disparity. In the computational study report, the rationale for choosing these contingencies and their importance to the study of idea integration in electronic brainstorming groups and the results are described.

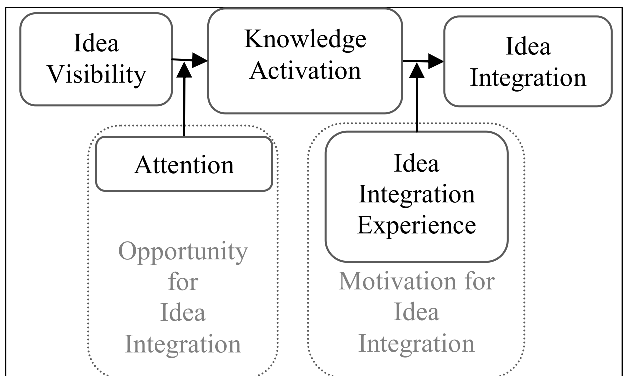

Figure 1: A Model of Idea Integration

2. Summary of the Model

This paper's developed mode (Figure 2) consists of two sub-layers. The first sub-layer involves the modeling of the search for evidence, and the second sub-layer models idea generation and idea integration. A brief overview of the model follows (see Figure 2):

-Individuals search for evidence.

-Evidence that is collected by individuals is activated based on the frequency and recency of the processes performed on them. Activation is boosted when evidence is visited during the search process or if it is used in idea generation or if it is viewed on the screen. Activation of the evidence via viewing on the screen depends on the saliency that is defined based on the visibility on screen.

-When individual decides to generate an idea, only a subset of evidence that is highly activated, i.e., the activation is greater than a threshold, will be available for idea generation. The subset of evidence with activation above the threshold is called the activation window.

-Some evidence in the activation window have been discovered by partners and have never been used by the individual. Using that subset of evidence in generating ideas is referred to as integration.
Individuals' experience formed based on the outcome of idea integration in the past plays a role in realizing integration when individuals make decision for idea integration. The idea integration is successful when the created idea is perceived as a good idea; and it failed if the idea is perceived as a bad idea. Each of the above steps will be described in detail in the following sections.

3. Idea Integration in Groups

An idea is a basic element of thought that consists of at least one testable proposition [33]. For the purpose of this paper, an idea is defined as a set of evidence, in which evidence is at the lowest granularity level. Individuals search for and collect evidence in their background knowledge maps, and articulate subsets of evidence and the connection among them as ideas. The concept of evidence is similar to that of facts in hidden profile tasks [6] (Figure 3). The pieces of evidence, however, are not provided to individuals but are discovered and retrieved by them during the brainstorming process [24].

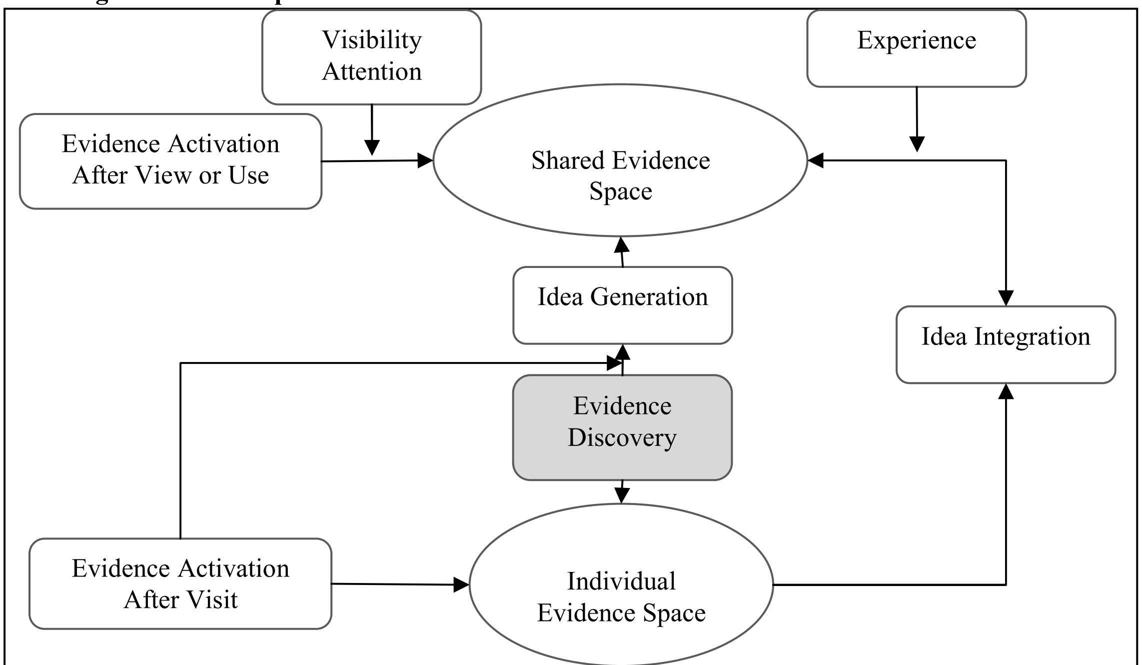

Figure 2: Processes and Components of the Model

3.1. Search in Evidence Space

Search in background knowledge maps in our model is identified as *search in evidence space.* Evidence space is defined as the space in which clues and evidence are distributed [24]. Evidence space influences availability and saliency of the evidence throughout the ideation process. Search for evidence in the evidence space is modeled by a random walk (e.g., in a two-dimensional space) process with reinforcement learning. Individuals start at some point in the space and traverse the space for discovering more evidence which are represented by numbers (1,2,3,…) in Figure 4.a; the numbers indicate the order by which evidence are discovered. When individuals generate and share ideas, which are represented by circles in Figure 4.b, all the evidence encompassed in those ideas, are automatically shared. The shared pieces of evidence comprise a common space from which subset of evidence can be borrowed and utilized by other individuals for generating new ideas (Figure 4.c). To allow for informational diversity within groups [11], the evidence space is populated randomly at the start of each trial and the initial position in the evidence space is also determined randomly. The initial position in the evidence space influences the number of evidence and the order by

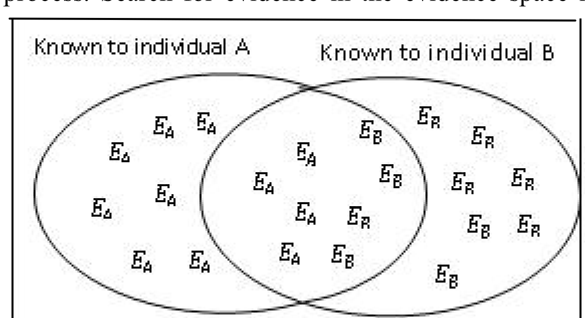

Figure 3: Shared and unshared evidence (Dennis 1996)

which they are discovered during the search process (Figure 3.a) [8].

As soon as subsets of evidence are articulated as ideas and ideas are shared, the visibility of the ideas will play a key role in further activating the evidence; this effect will be explained in the next section. For the sake of tractability, the evidence space is two-dimensional in our study as illustrated in Figure 4. Without loss of generality, the evidence space is randomly populated at the beginning of the simulation. Individual's walk in different directions follows a Dirichlet distribution. Dirichlet distribution is the multinomial extension of Beta distribution which is used here for representing a simple Bayesian learning. If evidence is discovered in some direction, individual is more likely to take that direction in the future. This asymmetric random walk with reinforcement learning for choosing direction is a simplified representation of the spreading activation of evidences, in which evidences that are discovered are dependent on what has been discovered in the past.

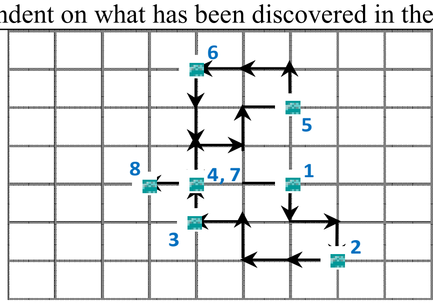

Figure 4.a: Individual's random walk in a 2-dimensional evidence space

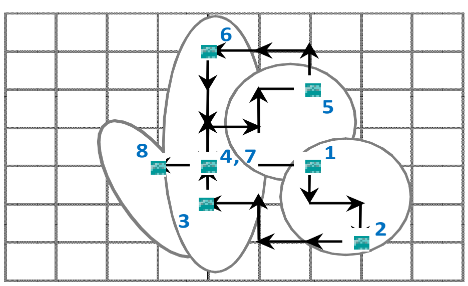

Figure 4.b: Ideas as sets of evidence

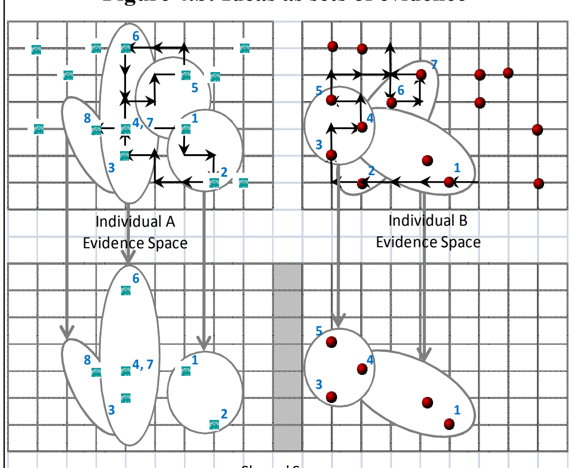

Figure 4.c: Idea sharing leads to the sharing of the evidence

As the number of steps of the walk increases, the likelihood of discovering new pieces of evidence decreases. This diminishing return on the number of steps is consistent with the saturating nature of idea generation in groups where the number of ideas increases at the beginning and stays steady when the upper bound of solution space is approached [27, 37].

4. Idea Visibility, Activation, and Idea Integration

As described in this study's model of idea integration (Figure 1), idea visibility and attention influence the ability for idea integration through the mediating effect of knowledge activation. As described in the previous section, the search for cues related to the subject of brainstorming is modeled by the search in the evidence space. In other words, knowledge activation in our model is operationalized by evidence activation (Figure 5). The role of attention is critical in studying the influence of visibility on idea integration because attention enables information processing that boosts activation and consequently increases individual's ability of knowledge integration.

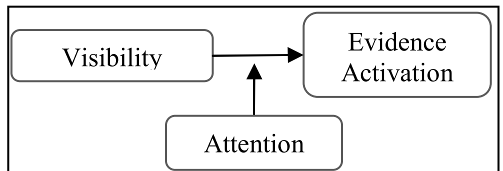

Figure 5: Visibility, attention and evidence activation

The probability by which evidence will be used is characterized by a measure of activation, which is sensitive to the recency and frequency of its previous uses. This is based on theories of short-term memory [1]. Specifically, if the current time is T and the evidence is processed at times $t_1, t_2, \dots, t_n$, then the activation will be:

$$\text{Evidence Activation}=\sum_{k=1}^{n}(T-t_k)^{-d} \quad \textbf{(1)}$$

Where d is the decay parameter representing the rate by which the evidence is weakened in the individual's memory. As d increases, pieces of evidence processed in previous periods become less active and the probability of them being used in a new idea is diminished. The activation varies based on the operation being conducted by the individual. When an individual discovers the evidence, or shares an instance of that evidence in an idea, the activation of that evidence boosts. Also when individual views an instance of an evidence framed in an idea generated by others, the activation is boosted but with a different rate. For instance, if evidence E_{A_1} is mentioned by individual A at times $t_1, t_2, \dots, t_k$, then its activation will be boosted based on its occurrence for individual A. If evidence, E_{B_1} is mentioned by individual B at times $t_1, t_2, \ldots, t_l$, evidence E_{B_1}'s activation for individual A will be discounted. Below is the time period in which each of the evidence has been processed:

$$\hbar istory\ of\ processing\ of\ E_{A1} = \{t_1^{A1}, \ldots, t_k^{A1}\}$$

$$\hbar istory\ of\ processing\ of\ E_{B1} = \{t_1^{B1}, \ldots, t_l^{B1}\}$$

Where $t_1^{A1}, \ldots, t_k^{A1}$ are all the times at which evidence E_{A_1} has been visited or used by individual A and $t_1^{B1}, \ldots, t_l^{B1}$ are all times at which evidence E_{B_1} has been viewed by individual A; the activation then will be:

Table 1: Activation of evidence for individual A

Evidence E	Activation, $act_A(E)$ is boosted by	Activation $act_A(E)$ T: Current time t: Time of processing
Discovered by B but not shared	-	-
Discovered by B and shared	View	$visibility \times \varphi_A \times (T - t_i)^{-d_A}$
Discovered and shared by B and used by A	Use	$(T - t_i)^{-d_A}$
Discovered by A but not shared	Visit	$(T - t_i)^{-d_A}$
Discovered by A and shared	Use	$(T - t_i)^{-d_A}$
Discovered and shared by A and used by B	View	$visibility \times \varphi_A \times (T - t_i)^{-d_A}$

$$act_A(E_A) = \sum_{i=1}^{k} (T - t_i^{A1})^{-d_A}$$

$$act_A(E_B) = \sum_{i=1}^{l} \varphi_A \times (T - t_i^{B1})^{-d_A} \quad \textbf{(3)}$$

Where φ_A is the attention parameter or the discount rate for the decay where evidence processed is only viewed by individual A and is not used. Similarly, if E_{A_1} is shared with individual B, activation of evidence E_{A_1} for individual B will be discounted by φ_B. Now if individual B mentions E_{A_1} again in an idea created by own then E_{A_1} 's activation for individual B will not be discounted. This occurrence, however, will boost activation of E_{A_1} for individual A discounted by φ_A.

Based on evidence activation, activation window is defined. At each point of time, activation window includes a subset of pieces of evidence with activation above a threshold assuming that the activation follows the power law formula described above plus a logistic noise and follows the rules described in Table 1.

$$inclusion\ of E_i\ in\ act_W = \begin{cases} 1\ if\ activation(E_i) > \tau \\ 0\ if\ activation(E_i) < \tau \end{cases}$$

Where act_W represents activation window and τ is the threshold meaning that evidence with activation above τ maybe included in the idea generated at time t. Pieces of evidence in the activation window are those available for idea generation.

Table 1 summarizes the three different processes by which activation of the evidence is boosted: visit, use, and view. The activation varies based on the process type and based on whether the evidence is discovered by own or by others.

5. Individual Experience, Idea Generation Outcomes and Individual Decision Making for Idea Integration

According to our model (Figure 1), an individual's ability for knowledge integration is influenced by visibility and attention. Previous research studies, however, suggests that not all the facts available to the individuals are used by them [e.g., 36] and sometimes individuals disregard the evidence provided by others. One reason can be that partners' ideas are not salient and/or not being attended to [6]. Another reason can be that the individual believes that using the evidence provided by partners is not rewarding [32].

Individual's choice thus contributes to the difference among individuals' performances concerning idea integration. An individual's choice for idea integration is assumed to be influenced by factors similar to those affecting a firm's decision of whether to innovate or not (Mansfield 1968 in [17]): **(1)** the extent of quality gain from integration compared to not integrating; **(2)** the extent of the uncertainty associated with integration outcome that is contained in the individual's prior distribution of the outcome. A diffuse prior, for instance a Beta with parameters (1, 1), is indicative of greater uncertainty than a concentrated one, such as a Beta with parameters (100, 100) (Mansfield 1968 in [17]). In our model, uncertainty is derived from experience with idea integration; and **(3)** the cost associated with integration, which may be defined as the cost of mindfulness [14] and cost of creating conceptual connection among different ideas. While uncertainty associated with idea integration is included in our model, gains from and cost associated with idea integration are left out because of lack of empirical or theoretical research studies for modeling them.

Uncertainty associated with idea integration is modeled by a Bayesian belief updating. Idea integration as a creative process inevitably involves an element of chance [4] and may result in failure or success. Success implies that the generated idea is perceived as a good idea, and failure means that the idea is bad. The assumption in our model of electronic brainstorming is that individual can rate each others' idea in real time (which is consistent with the practice) and the aggregate subjective evaluations by partners contribute to individual's perception of the success or failure. Our model, however, makes no attempt to characterize the process by which individual's perception is formed based on the partners' feedback. The premise is that individuals are capable of forming that belief using mechanisms provided to them by the electronic system. Those mechanisms are used as the best available real-time proxy for ideas' values and may not correspond to the actual quality of ideas. As such, perceived success or failure of idea integration is modeled by a biased coin toss [4] that allows for individual's Bayesian learning from past experience [17].

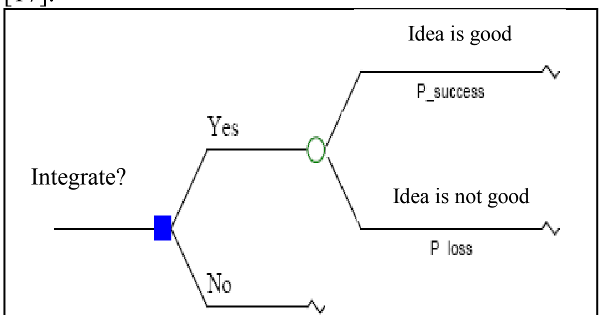

Figure 5. Bayesian updating of individual's belief on the outcome of idea integration

The first parameter of the Beta distribution of the priors, s, accumulates successful integration trials and the second parameter, l, accumulates failures. $s + l$, the sum of the two parameters measures the total amount of information. Initial beliefs of individuals are indicated in the initial parameters. $s + l$, therefore indicates the precision of the resulting estimate. The precision depends on the extent of previous experience (initial parameters) and frequency and outcome of integration at each trial. A second beta distribution stores information on failure or success of idea integration with no integration.

6. Computational Experiment and Summary of the findings

The model developed above is simulated to examine the effect of visibility on integration in groups of two with different attention-experience compositions. The computational experiment was developed using R statistical package.

Ideas are organized in pages on the screen and each page includes a certain number of ideas. Visibility increases when the number of ideas per page increases. Visibility based on position on screen is a stage function, drops a level when page number increases. Attention is represented by the decay discount rate for the evidence that is shared by partner [3]. Inexperience is represented by diffuse priors as in $\beta(1,1)$ and experience is represented by concentrated priors as in $\beta(100,100)$ [17]. It is assumed that both individuals are experienced with idea generation in general, meaning that they both have concentrated priors for idea integration. When individuals are given the choice to perform idea integration, they first compare the success prospects for idea generation and integration, and then make the decision based on that comparison.

6.1. Computational Experiment Setup and Hypotheses

The parameters of the model, their description and their values are depicted in Table 2. The ranges of parameters are chosen based on previous literature on reinforcement learning and on associative memory [1].

Table 2: Parameter description and their values

Parameter	Description	value
GSize	Group Size	2
Dim1, Dim2	Dimensions of the evidence space	30, 30
Brainstorming duration	Time units spent on brainstorming	1200
Visibility	Number of ideas per page	Low: 5 High: 12
φ_i	Attention	Low: 0.1 High: 0.3
d_i	The rate by which evidence activation is decayed for individual i	[0.1-0.5] Set to 0.1, and 0.3

Dependent variable is the total number of idea integration performed by individuals over the total number of ideas generated in the group.

$$Integration\ Ratio\ (IR) = \frac{\sum_{individual\ i's\ in\ group\ g}(\#\ of\ idea\ integration\ by\ \ individual\ i)}{\sum_{individual\ i's\ in\ group\ g}(\#\ of\ ideas\ generated\ by\ \ individual\ i)}$$

The number of idea integration is divided by the number of ideas because the total number of ideas generated by each group in each trial of the computational experiments varies. The first contingency examined is for groups with attention disparity with two different compositions of experience equality and disparity to examine hypothesis 1:

Hypothesis 1: In groups with attention disparity, visibility has more of an effect on the rate of idea integration increase when there is experience equality in the group than when there is experience disparity.

The second contingency is for groups with experience disparity with two different compositions of attention equality and attention disparity:

Hypothesis 2: In groups with experience disparity, visibility has more of an effect on the rate of idea integration increase when there is attention equality in the group than when there is attention disparity.

The rationale for choosing the above three attention-experience contingencies among the four possible contingencies is two-fold. First it is obvious that from Attention Equality-Experience Equality condition to where attention or experience of one individual is higher (lower), there will be a gain (loss) in idea integration because either opportunity or motivation for integration are increased (decreased) (Figure 1). Secondly there can be no meaningful comparison of Attention Equality-Experience Equality and Attention Disparity-Experience Disparity (both different) condition because there may exist particular attention-experience disparity conditions (specific values of the parameters) that lead to gain in integration and some other combinations that lead to loss in idea integration. Therefore propositions including Attention Equality-Experience Equality contingency will have little value either because they are obvious or because they cannot be generalized.

Table 3: Attention-Experience Contingencies and Hypotheses

Hypothesis	Attention-Experience Contingencies	Independent Variables Values
H1	Attention Disparity-Experience Equality vs. Attention Disparity-Experience Disparity	Attention*: $\varphi_{i=0.3}, \varphi_{j=0.1}$ Prior: $\beta_1(1,1), \beta_2(1,1)$ Attention: $\varphi_{i=0.3}, \varphi_{j=0.1}$ Prior: $\beta_1(100,100), \beta_2(1,1)$
H2	Experience Disparity-Attention Equality vs. Experience Disparity- Attention Disparity	Prior: $\beta_1(100,100), \beta_2(1,1)$ Attention: $\varphi_{i=0.1}, \varphi_{j=0.1}$ Prior: $\beta_1(100,100), \beta_2(1,1)$ Attention: $\varphi_{i=0.3}, \varphi_{j=0.1}$

*φ_i is the attention parameter which represent the rate for which evidence shared by others is attended to by individual *i* and thus is activated. The higher the φ_i the more the ideas of partners are attended to.

6.2. Computation Experiments for Groups

The point estimate of the dependent variable, *IR*, was calculated by its average for 10 simulation runs. The descriptive statistics for the three attention-experience contingencies (second column in Table 3) in low and high visibility conditions are shown in Table 4.

The output variable *IR* from low visibility to high visibility conditions is collected for each of the three contingencies in 150 runs. The 2-way ANOVA for the factorial design of visibility: [low, high] and attention-experience contingencies: [equal-different, different-equal, different-different] is available in Table 5. Also the average IR for binary comparison of the three attention-experience contingencies is included in discussion for each hypothesis.

Hypothesis 1: In groups with attention disparity, visibility has more of an effect on the rate of idea integration increase when there is experience equality in the group than when there is experience disparity.

Average IR for [attention disparity – equal experience] increased from 0.07 to 0.19 while it changed from 0.23 to 0.24 [attention disparity – experience disparity]. To interpret the results based on *Hypothesis 1*, it is important to first note that visibility and attention will influence individual's opportunity via influencing evidence activation (Figure 1). This implies that the number of times that individuals face the decision for idea integration increases as visibility and attention to partners' ideas increase. In groups with attention disparity thus integration opportunity is lower for the less attentive individual. If less attentiveness is accompanied by less experience, it means that the less attentive individual with will be more sensitive to failure instances of idea integration efforts. Also the more attentive partner who has more experience will face more integration opportunity while being less sensitivity to failure instances of idea integration instances. Over time then, the more attentive partner who has more experience performs more idea integration. This increased idea integration performance in turn decreases the opportunity for the less attentive partner who is also sensitive to failures. Hypothesis 1 suggest that because of this dual-disparity, an increased opportunity for both individuals caused by increased visibility will have less effect when groups with dual disparity compared to groups with attention disparity- experience equality. In other words, the only possible pathway for the less attentive individual to continue idea integration is when partners have comparable (here, equal) experience. With equal experience, instance of idea integration will equally influence partners' motivation for idea integration thus making the influence of visibility much more tangible for the group (Table 5).

Hypothesis 2: In groups with experience disparity, visibility has more of an effect on the rate of idea integration increase when there is attention equality in the group than when there is attention disparity.

Table 4: Descriptive Statistics for the Total Number of Ideas and Idea Integrations

	Visibility low				**Visibility high**			
		C1*	C2*	C3*		C1	C2	C2
Idea generation	Mean	30.7	29.8	30.6	Mean	32.1	31.7	33.2
	Standard Deviation	20.1	21	16.2	Standard Deviation	20.1	27	25
	Minimum	16	14	18	Minimum	17	13	17
	Maximum	169	168	163	Maximum	173	167	169
Idea Integration	Mean	8.6	28.2	14	Mean	28.6	19.74	21.4
	Standard Deviation	6.8	17.04	7.54	Standard Deviation	20.6	9.31	16.1
	Minimum	2	6	7	Minimum	2	4	3
	Maximum	45	64	31	Maximum	65	75	57

* C1 : Attention Disparity-Experience Equality; C2 : Attention Disparity-Experience Disparity; C3: Experience Disparity-Attention Equality, Count=150

Table 5. 2-Way ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Visibility	0.05	1	0.05	6.52	0.012	3.95
Disparities	0.21	2	0.1	12.37	1.95E-05	3.1
Interaction	0.12	2	0.06	7.35	0.001	3.1
Within	0.71	84	0.008			
Total	1.1	89				

Columns contain the data for each of the three contingencies, the attention-equality; experience equality condition was also included in. C1: Attention Disparity-Experience Equality; C2: Attention Disparity-Experience Disparity; C3: Experience Disparity-Attention Equality, Count=90, 15 for each contingency at low and high visibility.

Average IR for [experience disparity – equal attention] increased from 0.11 to 0.18 while it changed from 0.23 to 0.24 [experience disparity – attention disparity]. To interpret *Hypothesis 2*, it is important to first note that individuals' choices for integration and its outcome at earlier stages of idea generation will influence individual's motivation for idea integration (Figure 1) at later stages by influencing decision choices through the Bayesian belief update. That is the number of idea integration efforts, the observed outcomes (failure or success), and the sequence of those outcomes influence individual's motivation for idea integration in future. The motivation, however, is independent from other underpinning processes of activation and depends only on individual's experience and idea integration outcomes and their sequence. For more experienced individuals, failure has less of an effect on motivation for idea integration. In groups with experience disparity, therefore, when a partner is more attentive, increased motivation for idea integration is accompanied by increased opportunity for idea integration (Figure 1). This dual advantage leads to an increased number of idea integration for the partners with attention-experience advantage, which in turn decreases opportunity of idea integration for the less experienced partner. This decreased opportunity accompanied by less motivation, causes a decrease in idea integration efforts by the disadvantaged partner. This counterbalancing effect undermines the gain from the increased visibility for the group. In other words, if the level of attention and experience differs, then one partner stays in integration train and the other in the negative loop of not integrating because of either less opportunity or weak belief on idea integration success.

These finding from our computational study are also consistent with that of prior research studies in that exposure to others' ideas is not universally beneficial (Potter & Balthazard 2004). The effect illustrated by Hypotheses 1-2 resembles that observed in long leaps in random walk. That is the persistent difference among frequency of the individuals' idea integration may arise even if the outcome of idea integration process is similar to that of a coin toss (Denrell 2004); and this persistence difference in idea integration efforts in groups with dual-disparity significantly reduces the gain from increased visibility.

7. Discussion, Conclusion and Summary

This computational study builds on theoretical and empirical research on electronic brainstorming and creativity. Our goal is to build a theory of idea integration [3, 6, 17] based on the simulation results. The developed theory links the effectiveness of IS artifact user interface in enhancing idea integration to human cognition and decision making behavior. The computational experiment presented in this paper suggests that tweaking visibility may not play a significant role in groups with both attention- and experience- disparities. The findings also suggest that in groups with attention or experience disparity only, increased visibility leads to increased idea integration. In other words, groups with dual disparity may not gain much from greater exposure to each others' ideas and groups with attention or experience disparity only, will gain much from greater exposure to each others' ideas during the brainstorming process. An implication of our study for group designer and facilitator is that when idea integration is a crucial performance indicator, groups with people who have different attention skills and experience may not warrant an optimal composition. Attention skills may be inferred from individual's previous activities in terms of attending to ideas and information shared by others. Experience may also be inferred from the extent to which an individual have been able to effectively use ideas of others and combined them to create better ideas in the context of organizational problem solving or other related activities (e.g., in [29])

Our study provides a theoretical foundation based on which laboratory experiments can be conducted in which attention and experience parameters and other parameters of model may be estimated. The rationale for choosing computation experiments in the current study is based on unavailability of theories to guide design and build of such laboratory experiments. It is important to note that task- and context- specific factors have not been included in this study. Groups with similar group compositions may behave differently when work on different tasks, or using different communication modes, or when social structure or anonymity is altered. Thus our study poses some limitation in that regard.

The current model may be modified in any of the following ways. (1) Assumptions: evidence space may be characterized differently, and the Dirichlet-based random-walk in the evidence space may be replaced by more precise representation of spreading activation. Such representation may include the distance in the evidence space as a proxy for the extent of association among concepts. The predictions of the model are expected to be robust with respect to the above alteration since the current assumptions are consistent with theories that this study is built upon. (2) Independent and dependent variables: other user interface features such as font size and color [18], cognitive factors such as learning by doing, and learning from others [32], and other forms of belief updating models such as those of believers in law of small numbers and outcome autocorrelations [2, 25] may be part of future endeavors to further enlighten this area of research. Also other dependent variables such as timing of idea integration may be examined for more precise predictions of effect of the interacting effect of user interface features, and cognitive and behavioral factors. Apart from the above incremental improvements, future extension of this work may include combining explicit and implicit idea integration, characterizing the cost of mindfulness or being attentive and the cost for idea integration [14, 33].

While we are aware of the limitation of our study with respect to validation, we believe this study is a starting point for more comprehensive approaches to IS design which takes into account cognitive and behavioral factors. The conceptualized link between user interface and human-cognition provides a foundation for tailoring user interface for the required level of idea integration in different settings which leads to design of interfaces that better fit the task. The quest for finding a better fit by articulating the link between user interface features and the cognitive requirements of the task provides a new pathway for research and practice on IS artifact design for cognitively intensive tasks in general and electronic brainstorming in particular [26]. Our study of idea integration in EBS is also consequential for creativity research because electronic media is the prevalent platform for brainstorming within groups in many organizations [16] and the speed of idea generation and sharing is sharply surpassing that of idea integration and use.

References

1. Anderson, J. R. (2005). Cognitive Psychology and Its Implications (6th ed.), W.H. Freeman, NY.

2. Barberis N, Shleifer A, Vishny R. (1998). A model of investor sentiment. *Journal of Financial Economics* 49(3): 307-343.
3. Brown, V., Tumeo, M., Larey, T. S., & Paulus, P. B. (1998). Modeling cognitive interactions during group brainstorming. *Small Group Research*, 29(4): 495-526.
4. Campbell, D.T. (1960). Blind Variation and Selective Retentions in Creative Thought as in Other Knowledge Processes, *Psychological Review*, 67(6): 380-400
5. Davidson, G., Dornburg, C., Stevens, S., Hendrickson, S., Bauer, T., & Forsythe C. (2007). Sandia Research Team Studies Best Way to Solve Wicked Problems, Sandia NationalLaboratories: http://www.sandia.gov/news/resources/releases/-2007/wickedproblems.html
6. Dennis, A. R. (1996). Information Exchange and Use in Group Decision Making: You Can Lead a Group to Information, But You Can't Make it Think, MIS Quarterly, 20(4), 433-457.
7. Dennis, A. R., and Valacich, J. S. (1999). Research Note, Electronic Brainstorming: Illusions and Patterns of Productivity, *Information Systems Research*, 10(4), 375-377.
8. Denrell J. (2004). Random walks and sustained competitive advantage. *Management Science,* 50(7): 922-934
9. Ferran, C. & Watts, S. (2008). Videoconferencing in the Field: A Heuristic Processing Model, *Management Science*, 54(9): 1565-1578.
10. Gruenfeld, D. H., & Hollingshead, A. B. (1993). Sociocognition in Work Groups – The Evolution of Group Integrative Complexity and its Relations to Task-Performance, *Small Group Research*,24(3), 383-405.
11. Homan AC, van Knippenberg D, Van Kleef GA, De Dreu CKW. (2007). Bridging faultlines by valuing diversity: Diversity beliefs, information elaboration, and performance in diverse work groups. Journal of Applied Psychology 92(5): 1189-1199
12. Harrison, J. R., Lin, Z., Carroll, G. R., & Carley, K. M. (2007). Simulation modeling in organizational and management research. *Academy of Management Review*, 32(4): 1229-1245.
13. Huber, G. P. (1992). How to Deal with Cognitive-Style - Response. Mis Quarterly, 16(2): 153-154.
14. Levinthal, D. & Rerup, C. (2006). Crossing an apparent chasm: Bridging mindful and less-mindful perspectives on organizational learning. Organization Science, 17(4): 502-513.
15. Litchfield R. C. (2008). Brainstorming reconsidered: A goal-based view. *Academy of Management Review*: 649-668.
16. McAfee, A. P. (2006). Enterprise 2.0: The Dawn of Emergent Collaboration, *MIT SloanManagement Review*, 47(3): 20-29.
17. McCardle KF. (1985). INFORMATION ACQUISITION AND THE ADOPTION OF NEW TECHNOLOGY. *Management Science* 31(11): 1372-1389
18. McNab, A. L. (2009). Designing Interfaces for Faster Information Processing: Examination of the Effectiveness of Using Multiple Information Cues, *Proceedings of fifteenth Americas Conference on Information Systems*, San Francisco, CA.
19. Norman, D.A. and Bobrow, D.G. (1975). On data-limited and resource limited processes. Cognitive Psychology, 7:44-64.
20. Okhuysen, G. A., and Eisenhardt, K. M. (2002). Integrating knowledge in groups: How formal interventions enable flexibility, *Organization Science*, 13(4), 370-386.
21. Orlikowski, W. J. & Iacono, C. S. (2001). Research commentary: Desperately seeking the "IT" in IT research - A call to theorizing the IT artifact. Information Systems Research, 12(2): 121-134.
22. Osborn, A. F. (1953). Applied imagination; principles and procedures of creative thinking, Scribner, New York, NY.
23. Pinsonneault, A., Barki, H., Gallupe, R. B., & Hoppen, N. (1999). Electronic brainstorming: The illusion of productivity. *Information Systems Research*, 10(2): 110-133.
24. Potter, R. E., & Balthazard, P. (2004). The role of individual memory and attention processes during electronic brainstorming. *MIS Quarterly*, 28(4), 621-643.
25. Rabin M. (2002). Inference by believers in the law of small numbers. *Quarterly Journal of Economics* 117(3): 775-816
26. Rao, H. R., Jacob, V. S. & Lin, F. (1992). Hempispheric-specialization, cognitive differences, and their implications for the design of decision support systems. MIS Quarterly, 16(2): 145-151.
27. Reinig BA, Briggs RO, Nunamaker JF. (2007). On the Measurement of Ideation Quality, *Journal of Management Information Systems*, 23(4): 143-161.
28. Resnick M., Myers B., Nakakoji K., Shneiderman B., Pausch R., Selker T. and Eisenberg M. (2005). Design Principles for Tools to Support Creative Thinking, Workshop on Creativity Support Tools, ftp://ftp.cs.umd.edu/pub/hcil/CST-NSF/Papers/designprinciples.htm
29. Rich, E. (1979). User Modeling via Stereotypes, *Cognitive Science*, 3: 329-354.
30. Robert, L. P., Dennis, A. R., & Ahuja, M. K. (2008). Social capital and knowledge integration in digitally enabled teams, *Information Systems Research*, 19(3), 314-334.
31. Robey D. (1992). More Ado About Cognitive-Style and DSS Design – Response, *Mis Quarterly* 16(2): 151-153
32. Siemsen, E., Balasubramanian, S., & Roth, A. V. (2007). Incentives that induce task-related effort, helping, and knowledge sharing in workgroups. *Management Science*, 53(10), 1533-1550.
33. Simon, H. A. (1976). Administrative behavior; a study of decision-making processes in administrative organization, Macmillan Co, NY.
34. Stasser, G. (1988). Computer-Simulation As a Research Tool- The DISCUSS Mode of Group Decision Making, *Journal of Experimental Social Psychology*, 24(5): 393-422.
35. Sussman, S. W. & Siegal, W. S. (2003). Informational influence in organizations: An integrated approach to knowledge adoption. Information Systems Research, 14(1): 47-65.
36. Thoemmes, F. J. & Conway, L. G. (2007). Integrative complexity of 41 US presidents, *Political Psychology*, 28(2): 193-226.
37. Valacich, J. S. & Dennis, A. R. 1994. A Mathematical Model of Performance of Computer-Mediated Groups during Idea Generation, *Journal of Management Information Systems*, Vol. 11: 59-72: M.E. Sharpe Inc
38. Zhou, J, and C. Shalley (2007). Handbook of Organizational Creativity, Lawrence Erlbaum Associates Inc, US.