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그룹 아이디어 제너레이션을 위한 시뮬레이션 알고리즘의 개발

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Group Idea Generation and Simulation

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■ Abstract ■

Electronic brainstorming (EBS) to improve the process and outcomes of group decision making is an artifact of Information Systems legacy. Despite three decades of research with EBS in an effort to become a key resource of organizational performance, its performance when compared to that of nominal is inconclusive because of the recent debate over its usefulness in terms of productivity. Subsequent researchers have directed our attention to the re-examination of cognitive stimulation, which is considered the major benefit in computer-based idea generation, to explain the performance singularity in computer-based groups. While both cognitive and motivational factors that moderate and mediate the group-interaction process remain unexplored, individual differences that are tightly linked to creative behavior have been largely ignored to account for the discrepancy in performance. Since simulations have been widely used in situations where an outcome does not meet the assumptions, the notion of a group simulator and detailed simulation mechanisms are introduced to examine the potential effects of individual differences on the performance of computer-based idea generation groups. In addition, two prior studies that empirically explored cognitive mechanisms with the group simulator are showcased along with six propositions to initiate future research.

Keywords : Computer-Mediated Idea Generation, Human-Computer Interaction, Simulation

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1. Introduction

In today's fast-paced society, the value of creativity that exploits intellectual capital (i.e., information and knowledge) to generate novel ideas to cope with a complex and dynamic environment is indispensable [2, 77, 122]. Since idea generation is tightly linked to creativity [69], identifying and developing better techniques to enhance ideation effectiveness has received substantial research attention. Among numerous structured techniques (e.g., Brainstorming [80], Delphi [15], Nominal Group [117, 118], and Electronic Brainstorming [78]) introduced, the performance comparison between computer-based groups [78] and nominal groups [117, 118], which both have consistently outperformed face-to-face groups [80], has a history of debate (cf., [18] vs. [90]). With the support of rich structural features, such as parallel input, group memory, and anonymity, computer-based groups are expected to perform superior to nominal groups. However, evidence demonstrating an overall favorable performance of computer- based groups is thus far marginal when compared to that of nominal groups [1, 85, 86, 89, 97].

There is certainly no harm in utilizing computer-based groups because they are no less productive than are baseline groups (i.e., face-to-face groups). However, given that paper-and-pencil-based nominal groups' performance is no worse than that of computer-based groups (see [1]) and the cost of setting up and maintaining Groupware is high, the net benefit of Groupware to the organization is questionable [82]. Thus, despite the recognition and successful utilization of Groupware as a key resource in the workplace [3], organizations are suggested not to invest in Groupware without noticeable productivity gain. In the next section, we review prior idea generation literature and identify factors that constrain the performance of computer-based groups. We then offer a group simulator as one approach to examine individual differences to account for the performance discrepancy followed by experimental showcases. The paper concludes with implications for future research.

2. Literature Review

The effectiveness of an individuals-based ideation (i.e., non-interacting nominal) versus a group-based ideation (i.e., interacting face-to-face or computer-based) has a long history of investigation. Over the years, a variety of idea-generation techniques have been developed (see, for example, [119]) to enhance ideation creativity and performance. Empirical findings have shown that non-interacting individuals (i.e., nominal) whose ideas are pooled outperform interacting (face-to-face) groups [70, 73]. Among three factors (production blocking,[1]) evaluation apprehension,[2]) and free riding[3])) identified to explain performance discrepancy, Diehl and Stroebe [23; see also 109] concluded that production blocking is the main cause of poor performance in face-

1) Production blocking occurs when a group member has the floor. As a result, other members may forget or suppress their ideas (a.k.a. attenuation blocking), concentrate on remembering their own ideas (a.k.a. concentration blocking), or constantly listen to others when speaking (a.k.a. attention blocking) [78].

2) Socially anxious individuals may experience evaluation apprehension in interacting groups [8].

3) Free riding (or social loafing) refers to the reduction of individual physical or cognitive effort in a collective setting [58, 62, 111].

to-face groups. While others have explored the potentials of the use of trained facilitators [61], additional brainstorming rules [91], and leadership style [105] to narrow the performance discrepancy gap, Information Systems researchers have investigated how electronic communication through computing and networking technologies could be used to overcome production blocking in interacting groups [115]. The results have shown that computer-based groups outperform non-supported (face-to-face) groups for a broad range of group sizes and a variety of tasks [37]. However, with various contextual factors examined, such as group, task, context, and technology, computer-based idea generation is yet to prove its superiority over nominal because of the debate over its usefulness in terms of productivity [18, 90].

Despite the positive potential of computer-based groups, there are many remaining process losses that hinder the performance of computer-based groups. Examples include insufficient cognitive stimulation [13], attention blocking to stimuli [108], dual-task interference [46], cognitive interference via information overload [106], production time underutilization [36], and social comparison and matching [97]. Prior studies have tended to focus more intensely on facilitating process gains, such as multiple dialogues [20], overlooking ways to mitigate process losses. Because avoiding or eliminating process losses that undermine creativity may be more effective in enhancing group productivity than in reinforcing the process gains, this study focuses specifically on the issue of insufficient cognitive stimulation. Numerous prior studies have suggested a much less significant influence of cognitive stimulation (i.e., the value of seeing the ideas of others that is believed to be the major benefit of computer-based idea generation [21; see also 18] on the ideational performance of computer-based groups (e.g., [1, 13, 23, 24, 38, 87]).

Connolly et al. [13] encouraged the examination of various psychosocial factors to better understand why individuals in computer-based groups are not necessarily obtaining large stimulation benefits (cognitive and social) from the interaction process. One of the fundamental reasons is derived from the taken-for-granted methodological choice in composing groups, i.e., randomization. Although this method facilitates causal inferences by reducing the likelihood of bias (i.e., sampling error), random group composition in the context of idea generation tends to induce social loafing and negative productivity matching (i.e., the tendency of individuals to match their efforts to a baseline level [83] for high performers. As Roy et al. [97; see also 95] suggested, an elimination of low performers is one way to increase idea-generation performance, the goal of idea generation, i.e., to generate as many quality ideas as possible, depends largely on the competencies of high performers [22, 43]. Given that high performers have fewer overlapped cognitive domains than do low performers [65], which pre-conditions the generation of diverse, novel ideas, other prior studies (e.g., [22, 63, 64, 65, 114, 116]) provide strong evidence to suggest that high performers are more likely to be motivated when they are with the same or above-level performers.

Despite these reasonings, a major challenge has been how to separate individuals from their groups and how to examine various individual differences in the group-interaction process.

Brown and his colleagues [5, 6] have suggested the use of a computer-simulated environment as one possible approach to explore these issues. As a result, we have seen a surge of simulated studies in recent years (e.g., [38, 50, 98, 116]). However, studies are silent on how the mechanism of the group simulator would operate, which is critical in benefiting other researchers. Thus, this study delineates one possible approach to construct a simulation mechanism.

3. Simulation

Researchers typically choose one of three scientific methods (i.e., laboratory experiments, surveys, and field studies) to test their theoretical predictions. As McGrath [68, see p. 74 in particular] notes "the three-horned dilemma" of methodological choices, in which each method serves its own purpose to maximize one of three measurement dimensions : precision, generalizability, and realism. Of these three methods, the purpose of laboratory experimentation is to maximize precision by controlling error variance; therefore, it has been the most popular choice among group and social psychologists to measure a causal relationship between predefined variables despite its artificiality [39, 48].

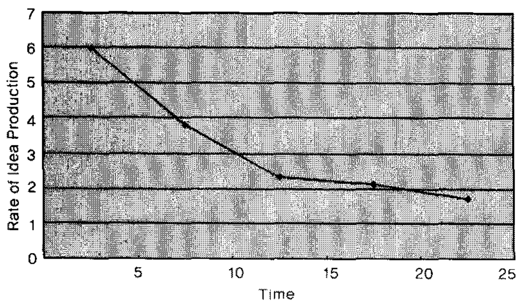
As an alternative and/or an extension to laboratory experimentation, experimental simulations have also been used across disciplines in situations where an outcome does not meet the assumptions of analytical models to further understand a phenomenon at hand. Good examples under management science are (1) Monte Carlo simulation, which estimates the distribution of an outcome variable that depends on several probabilistic input variables and (2) systems simulation, which explicitly models sequences of events that occur over time (e.g., inventory tracking and queueing models) [29, see p. 6 in particular]. Schultz and Sullivan [101] suggest that when simulations involve human participants (such as the group simulator in this study), it can "transcend mathematical, verbal, and other symbolic (including computer) models in their ability to include many more variables-environmental, physical, cognitive, emotional, social, etc. Their nonprogramming nature (i.e., using real "chance" events) allows them to go beyond previous assumptions in the evolution of the system process and model form, as well as in the questions and possibilities they raise" [p. 9-10]. Hartmann [44] further argues that simulations can formulate a theory of science and can provide a new methodology that transcends the three-horned dilemma.

3.1 Phase I : The First-Generation Simulator and Limitations

3.1.1 Design

The outcomes of group idea generation are contingent upon the interaction of a myriad of group, task, context, and technology factors that differ from situation to situation [78]. Thus, error variance is inevitably large in interacting groups. A group simulator can accurately control the idea-stimulation manipulation and allow for a more accurate (and controlled) measure of individual performance because all participants receive uniform stimuli. Garfield et al. [38] describe a group simulator as an electronic environment that "looks and acts like a groupware system, but instead of sharing ideas among participants, the simulator presents participants with comments that appear to be from other participants but which are, in fact, drawn from a database of preset ideas" [p. 327].

The major limitation of the group simulator used in Satzinger et al. [98] and Hilmer and Dennis [50] is that the stimuli were presented from the simulator "at the same time intervals" [50, p. 100]. It was also reported that approximately 20 percent of the subjects noticed they were working with artificial systems rather than with real groups [50]. As a result, a significant number of subjects were excluded from the data analyses. It is speculated that this is due largely to a limited ability to mimic the sequence of a real group idea-generation session in a way that ideas are presented. The sequence is a downward curvilinear relationship, represented by many ideas in the early stage and fewer responses toward the later stages, running out of ideas in the end (see <Figure 1> below). <Figure 2> shows one such logic to mimic a downward curvilinear relationship.



<Figure 1> Number of Ideas Generated per 5-Minute Intervals by Interactive Four-Member Groups [5]

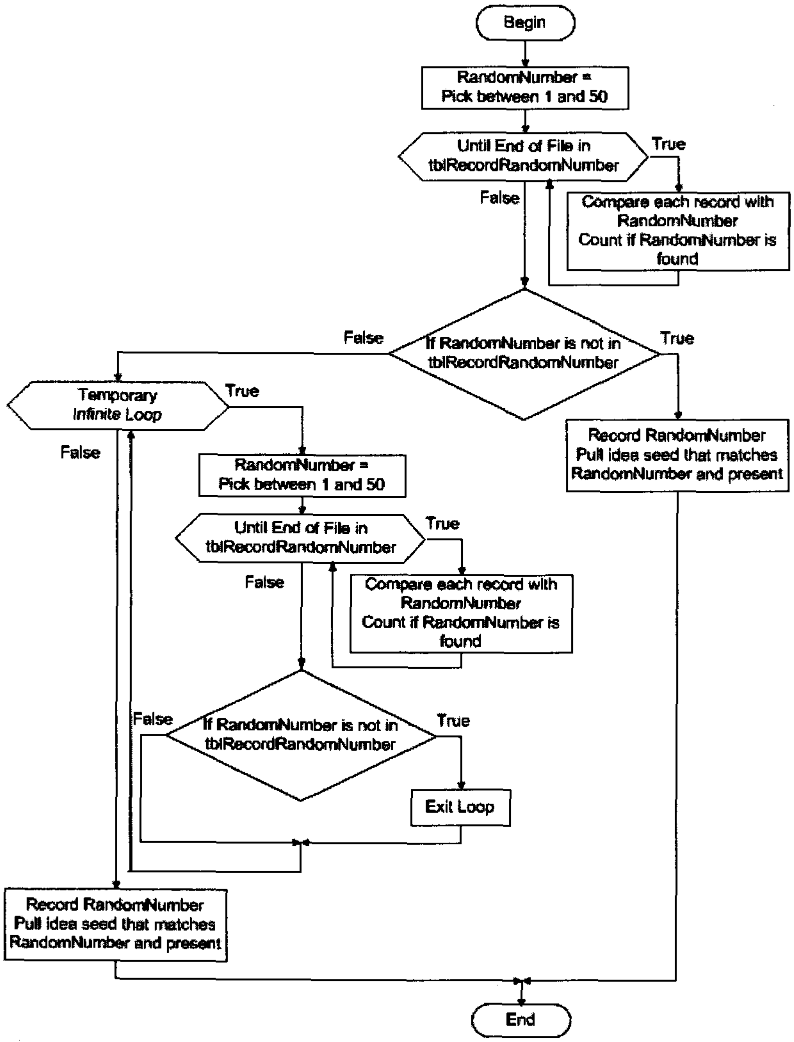
This logic starts with a pool of idea numbers from one to fifty. The logic activates the randomize method to pick numbers from the pool while recording used numbers. Since the randomize method generates the same random numbers more than once, when a number is generated, it is compared with a list of used numbers. If a randomly generated number is already on the list of used numbers, the logic goes through a temporary infinite loop to produce an unused number. This creates a mechanism of the downward curvilinear relationship.

3.1.2 Experimental Procedure

After creating this mechanism, we conducted several actual group idea-generation sessions to collect a large pool of ideas with an experimental task (e.g., Campus Parking Task). For these sessions, the group size was five members. After removing redundancies, 193 unique ideas were identified by all pilot groups. Three experts, senior employees from the campus Department of Parking Services, were then asked to rate the magnitude of impact of the proposed items using the 7-point Likert scale (anchored by 1, "a very poor solution", and 7, "a very good solution"). The mean of the three ratings was used as an index of the quality of each idea. Since group members generated on average 50 ideas in a fifteen-minute session and the outcomes of group idea generation are typically a mixture of low- and high-quality ideas, from the precoded master list, we randomly selected 50 ideas : 25 high-quality ideas (M = 4.813) and 25 low-quality ideas (M = 1.147). Any ideas assessed as "ridiculous" by the experts were discarded from further consideration. A Cronbach's inter-rater reliability of these expert ratings was adequate at 0.93.

3.1.3 Results

A series of pilot studies with a total of 58 par-



〈Figure 2〉 Flowchart to Create a Downward Curvilinear Relationship

ticipants were used to verify that the simulator accurately mimicked the sequence and interactions of real group idea-generation sessions. To test whether or not the simulator accurately reproduced the sequence and interactions of "real" group idea-generation sessions, a post-session question asked each participant "How many people do you think you were working with on this task?" On average, participants reported 4.29 members (SD = 0.988). Thus, it appears that participants believed that they were working in an interactive group, validating this approach for enforcing greater experimental control and for examining individual-level factors in groups.

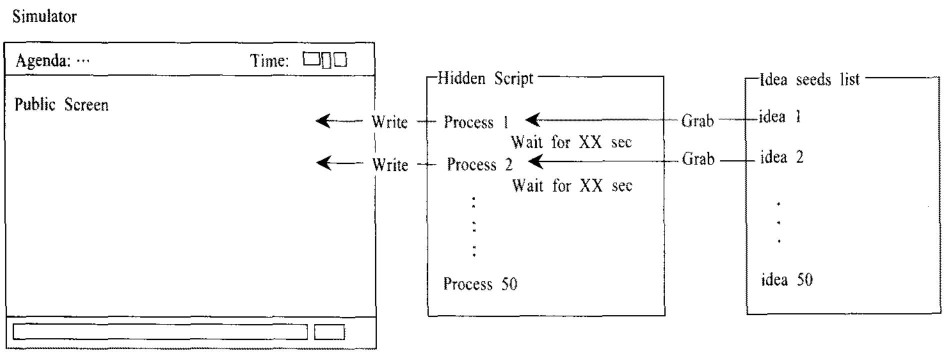
3.1.4 Limitations

In order to examine individual differences, each participant needs to have a unique connection to the simulator. If there are 50 participants, there need to be 50 copies of the simulator to create unique instances. When we thoroughly tested how many instances a normal computer server could handle, the result showed that the server could handle around 20 subjects simultaneously. If over 20 subjects, the processing speed of the server dropped and the number of presented idea seeds was lower. This occurs because of the combination of a temporary infinite loop to find a unique random number and parallel input from a participant for more than 20 instances. In addition, the use of databases to record random numbers generated and parallel comments submitted, which require instantiations to the databases, is another factor to slow down the process. This resulted in the development of a second-generation simulator to handle as many subjects as possible in an effort to reduce a number of experimental sessions.

3.2 Phase II : The Second-Generation Simulator and Strengths

In order to handle as many subjects as possible without slowing down the server's processing power, we created a time-delay mechanism, which mimics the exact sequence of the way idea seeds are presented in the first-generation simulator. To create such a mechanism, we first ran the first-generation simulator and recorded time stamps for idea seeds when they were presented. We then calculated the time gaps between presented idea seeds. This time gap information is fed into the time-delay mechanism. We also used text files to record all submissions (both idea seeds and comments from participants) rather then relying on databases. <Figure 2> shows the entire time-delay mechanism visually.

When this logic is activated, it first reads the RefreshDelay file, which has "0" value in it. When the mechanism detects the "0" value, it swaps the "0" value in the RefreshDelay file to "1" and is instructed to wait 10 seconds for participants to warm up. This reflects Gallupe et al. (1994) who reported participants in computer-based groups spend approximate 9.5 seconds to produce a contribution. After 10 seconds, the mechanism swaps the RefreshDelay file value "1" to value "2", reads the first idea seed and presents, and waits for X seconds. After X seconds, the mechanism swaps the RefreshDelay file value "2" to value "3", reads the second idea seed and presents, and waits for X seconds. This



〈Figure 3〉 Simulating a Time-delay Mechanism

mechanism continues until it reaches the last idea seed and presents. The second generation is as precise as the first generation, but it is superior to the first generation in terms of its capacity to handle as many subjects as possible. However, it relies on the first generation to draw the exact time sequence of idea seeds presentation.

3.3 Phase III : Additional Experiment

Prior studies [72, 102, 103] consistently suggest five as the most ideal group size in dealing with intellectual tasks, including idea generation. Accordingly, the group simulator with group size five was tested in a fifteen-minute session and yielded a satisfactory result. To further validate the use of the group simulator, we employed Grisé and Gallupe's [40] information-load model, which suggests 40 ideas to be sufficient in a ten-minute period. This anchors 20 ideas as low load and 80 ideas as high load.

To create three idea streams, an independent coder reviewed a master idea list (containing 457 ideas) that was created from a large public university in the United States and selected 80 unique ideas (M = 4.69, SD = .93). The overall inter-rater reliability of the ratings was .92. From 80 selected ideas, 20 and 40 ideas were randomly selected to serve as low load and high load, and 80 ideas were also randomized to serve as extreme high load. These idea streams were then fed into the group simulator to mimic a real, interacting group idea-generation session.

A total of 76 participants were invited for additional simulation runs. To verify whether or not the simulator accurately reproduced the sequence and interactions of "real" group idea-generation sessions, each participant was asked a post-session question "How many people do you think you were working with on this task?" On average, participants reported working with 3.27 group members (SD = 1.10) in the 20 stimuli condition, with 4.38 group members (SD = 1.66) in the 40 stimuli condition, and with 8.45 group members (SD = 2.81) in the 80 stimuli condition. Thus, it appears that we have strong evidence to deploy the group simulator in an experimental setting.

4. Case Studies

4.1 Study 1 [116]

This study examined the effects of individual cognitive ability and idea stimulation on idea-generation performance. In interacting groups, as compared to nominal groups where individuals work independently, group members must devote considerable social and cognitive effort to support three simultaneous functions [70]. Throughout an idea generation session, individuals must manage their social relationships with others (i.e., member-support function), maintain behavioural performance norms (i.e., group well-being function), and associate close (or familiar) and, in particular, distant (or unfamiliar) patterns to create quality ideas (i.e., production function). Thus, those in interacting groups tend to perform less effectively due to various psychosocial inhibitors. According to the notion of social comparison and matching, people tend to compare and match their performance to the group's baseline level. Since the goal of idea generation is to produce as many quality ideas as possible, overall performance is more likely to depend on the competencies of high performing group members [22, 43]. However, with random group composition, high performers tend to engage in negative productivity matching if they are in a group with lower performers [116]. Thus, Roy et al. [97, see also 95] suggests eliminating poor performers as a possible approach to maintain higher levels of motivation and in turn to enhance the performance of interacting groups.

To better understand how stimulation from the ideas of others (that are actually drawn from a database of present ideas) will influence an individual's idea-generation performance, we examined the performance of individuals with high and low cognitive ability who received high- or low-quality stimulation. The findings were that while the performance of individuals with high cognitive ability were consistently high when given high-quality stimuli, the performance of individuals with low cognitive ability did not improve significantly when given high quality stimuli. When given low-quality stimuli, the performance of high cognitive individuals was similar to that of low cognitive individuals. Cognitive ability and stimuli interacted such that high cognitive individuals and high-quality stimuli led to the highest performance in terms of the quantity and quality score of high-quality ideas. The findings suggest that group composition can not only significantly influence the overall ideational performance of a group but also that of individual group members (in particular, high performers).

4.2 Study 2 [100]

This study examined the effect of electronic junk on computer-mediated idea generation performance. One factor potentially limiting the effectiveness of computer-mediated group idea generation is the influence of comments that are of inferior quality and are not task relevant (i.e., electronic junk-[51] -e.g., I am hungry; I am gonna go and have a drink). These frivolous comments often have a negative contagion effect on task performance. Many of these comments can spur reactions by other group members, moving the group off its primary task. Hiltz and Turoff [51] suggest that the lack of social controls in the interaction process can lead to junk comments, which are considered "a human problem more than…a computer problem, the side effect of an on-line social system, rather than of any particular computer system" [p. 685].

Unlike face-to-face groups, where the spoken words are transient and quickly disappear as soon as they are verbalized, all contributions including junk comments in computer-based groups are preserved in group memory and are constantly displayed on the computer screen throughout the idea generation session. With the current practice of randomly displaying all contributions on the computer screen [20], junk comments that occur sporadically can be (probabilistically) placed next (or close) to thought-stimulating ideas. Hilmer and Dennis [50] suggest that individuals need to exert extra effort to discern and process stimulating ideas for cognitive stimulation if information is presented in a large, unorganized pool of information (as in computer-based groups). Junk comments may significantly interrupt or distract individuals' flow of cognition [106] on the primary task, that is, to generate as many quality ideas as possible.

Additionally, in computer-based groups, individuals are likely to confront a high volume of contributions produced at a high rate, experiencing information overload [74, 40]. Junk comments are one such contributor to information overload [16, 51].

This study posited that such frivolous comments draw more attention faster than task-relevant information does and are more likely to induce the same or similar type of comments, undermining the performance norm. The results showed that individuals who were exposed to frivolous comment stimuli produced more frivolous comments than did individuals who were not exposed to such stimuli. However, individuals in the moderate junk-comment condition performed better than individuals in the 0% and 45% junk comments conditions. Unlike our prediction of the negative effect of frivolous comments on performance, it appears that an extra dose of random noise can be beneficial rather than hinder the performance under the conditions of normal distribution of high, low, and medium performers and constant high-quality idea stimulation.

5. Implications for research

5.1 Introversion-Extraversion

Although studies commonly agree that personality differences stem from interaction between heredity (e.g., genes, ethnicity, and gender) and environment (e.g., culture, family, and life experiences), introversion-extraversion among the big five personality traits is believed to be a highly genetically determined component. This is the result of biological difference of the reticular activating system (RAS) that regulates the level of cortical arousal in the brain [104]. Eysenck [32] argues that introverts are more cortically aroused (i.e., more awake) than are extraverts chronically, resulting in a lower sensory threshold. Thus, it has been speculated that high arousal leads to a reduced range of cue utilization with narrowed attentional selectivity [26]. Additionally, in the condition of dual-task interference where parallel processing is required (e.g., group idea generation-individuals have to handle two or more alternative ideas at the same time [67]), studies indicate that introverts responded slower than did extraverts (e.g., [92]). In the Test of Attentional and Interpersonal Style, "introverts reported a tendency to make mistakes and become confused as a result of thinking about too much at once, whereas extraverts perceived themselves as being able to integrate many stimuli, to use information or ideas from several different areas effectively and to process a great deal of information" [32, p. 128; see also 14, 76]. Thus, the characteristics of introversion-extraversion individual differences have high relevance for computer-based ideational performance.

- Proposition 1 : Introverts tend to have a lower sensory threshold due to a higher level of cortical arousal. As the degree of stimuli increases, introverts will experience information overload faster than extraverts will experience, and cue utilization range will be decreased. As results, the performance of introverts will be negatively correlated with an increasing degree of stimuli.

- Proposition 2 : Extraverts tend to have a higher sensory threshold due to a lower level of cortical arousal. As a result, extraverts are less susceptible to information overload. As the degree of stimuli increases, extraverts will be more stimulated. However, according to the Yerkes-Dodson Law, performance tends to increase as arousal increases up to an optimal point, and further increases in arousal beyond this point tend to decrease performance. Thus, the performance of extraverts will be positively correlated with the degree of stimuli up to a certain stimuli level.

Howarth [53] reported that under distraction, extraverts performed better than introverts did. Case study 2 can be extended and applied to the introversion-extraversion context. Junk comments that occur sporadically can be (probabilistically) placed next (or close) to thought-stimulating ideas. Since individuals need to exert extra effort to discern and process stimulating ideas for cognitive stimulation if information is presented in a large unorganized pool of information, junk comments may significantly interrupt or distract individuals' flow of cognition [106]-refers to the intrapsychic processes that enable the acquisition, storage, transformation, and the use of knowledge [7, 107]-on the primary task (i.e., to generate as many quality ideas as possible). Additionally, given that individuals in a computer-mediated environment tend to experience information overload [40, 74], junk comments are one such contributor to information overload [16, 51].

- Proposition 3 : The performance of introverts will be affected by distraction caused by task-irrelevant comments. As the degree of junk comments increases, the performance gap between introverts and extraverts will be widened.

5.2 Introversion-Extraversion and short-term memory

Kasof [57, see also 4] posits that "creative ability is related to chronically wide breadth of attention" [p. 304] and reports that breadth of attention (the number and range of environmental stimuli attended to at any one time) was found to correlate positively with creativity and quality. Similarly, other studies (e.g., [22, 25, 71]) suggest that less creative individuals seem to exhibit more narrowly focused attention than do more creative individuals. Humans differ in their attentional levels (e.g., [28, 56, 96]). Such attentional differences can be partially traced to personality dimensions of introversion-extraversion and can be measured by working (or short-term) memory capacity. Prior studies (e.g., [60, 121]) have documented that under high cortical arousal, people tend to recall poorly; they recall conversely under low arousal. Eysenck proposed that extraversion has a higher arousal threshold in the RAS, leading to lower cortical arousal. Other prior studies (e.g., [53, 54, 66], see also [81]) that extended the relationship between arousal level and recall performance consistently suggest superior working-memory capacity of extraverts over introverts.

Working memory can be further extended to reading ability. Reading involves cognitive processing to comprehend written words and sentences by selection and assimilation stimuli. In this process, memory to store, search, retrieve, and reproduce information plays a central role [52]. Unlike the speech signal that reaches our ears sequentially, the written signal (i.e., visual) is processed simultaneously in large chunks-that is, several words at a time-with each eye fixation (saccade). Matlin [67] suggests that our saccadic eye movements regulate our visual attention during reading and that people have trouble searching quickly for visual stimuli. The good reader makes larger jumps and is also less likely to make regressions by making good use of a large working memory. Prior studies (e.g., [27, 34, 93, 99]) found that extraverts are superior to introverts in reading. Riding and McQuaid [94] suggest that extraverts learn better from text and introverts learn better from pictorial presentation. In short-term settings, such as group idea generation, these findings may play an important role. Specifically, in the context of electronic brainstorming, participants are constantly exposed to others' ideas in a text format on the computer screen and have to read to obtain cognitive stimulation. Thus, there may be a significant performance difference between extraversion and introversion. Eysenck [31] proposes that the recall interval threshold between short-term and long-term is about five minutes.

- Proposition 4 : Extraversion leads to superior working-memory capacity and reading ability. Extraverts will perform better before recall interval occurs and introverts will perform better after recall interval occurs.

5.3 Introversion-Extraversion and gender differences

In the context of group idea generation, prior studies (e.g., [49, 59, 116]) consistently report no gender difference. However, when it comes to reading, Riding and McQuaid [94] suggest that extraverts are verbalizers while introverts are imagers. They report that there were more boys than girls in the poor reader group and more girls than boys among the good readers. Riding and McQuaid's [94] study suggest that personality-based gender may have an effect on ideation performance. According to established gender roles across cultures, girls/women are talkers and boys/men are doers [41]; this notion can be extended in a way that introverted men are slower readers than are introverted women. Therefore, we posit the following :

- Proposition 5 : Introverted women will perform better than introverted men will perform as the degree of idea stimuli increases.

- Proposition 6 : There will be no performance differences between extraverted men and women regardless of the degree of stimuli.

5.4 Group simulator and beyond

The group simulator separates individuals from their groups and allows examination of how individual differences interact. The capability of the group simulator can be further extended by combining it with Functional Magnetic Resonance Imaging (fMRI) technology.

Recently, neuroscientists have begun to apply MRI, which tracks the biochemical processes of the human brain, to understand how the human brain operates under specific treatments (e.g., [9, 79, 112, 120]). However, the major limitations of fMRI are that (1) subjects inside the MRI device are not allowed to move (speak or type) because of the machine's sensitivity to movement when scanning brain activity, and (2) pre-developed questions (typically multiple choices) are used to test brain activity in response to particular stimuli as a result of movement inhibition. This significantly limits measurement of a full-range brain operation on open-ended creativity tasks such as idea generation. For example, idea generation promotes divergent thinking due to its tight link to creativity, and open-ended questions (e.g., how can we improve university's parking problem; what features should the new university library have) are typically used. Unlike multiple-choice questions, open-ended questions involve more cognitive activities. For instance, generating high-quality ideas requires a great deal of cognitive effort to assimilate others' ideas and to associate familiar and unfamiliar meanings. Thus, it is interesting to see how the cerebral cortex combines neurons in different areas and operates to come up with quality ideas. Also, it would be interesting to compare brain activity differences when generating high-quality ideas and low-quality ideas. Additionally, it will be interesting to compare and contrast brain activities of introversion/extraversion when generating high-or low-quality ideas. As mentioned, subjects inside an MRI device cannot speak or type (but can see a projected computer monitor) : consequently, a new technology on the horizon, i.e., brain-wave (or brain-reading) computing (BWC) can be incorporated to overcome the limitations of fMRI. BWC is an ultimate extension of speech-recognition technology in a way that it recognizes sentences in thought with brainwave frequencies rather than in speech frequencies (e.g., [10, 75, 110]). The combination of group simulator, MRI, and BWC will ultimately push the boundary of technologies and the level of individual differences study to the next level, opening up new research opportunities.

6. Conclusion

There are many group characteristics, such as group size, proximity, cohesiveness, composition, and so on, that can influence group interaction and performance. Most of these factors have been examined in prior group and social psychological studies. However, "individual differences" have been one of the least studied variables since Huber's [55] harsh criticism toward cognitive-style research. Because the nature of the idea-generation task is tightly linked to creativity [69], there is no doubt that individual characteristics, such as cognitive ability, cognitive styles, and personality traits, play a critical role in the creative process and in turn influence the outcomes. In this study, we introduced the concept of a group simulator as one approach to investigate individual differences along with six interesting propositions (but not limited to six) that could be examined with the group simulator.

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〈Appendix A〉

A coding scheme to create a downward curvilinear relationship

```
< %
DSNless = "DRIVER = {Microsoft Access Driver (*.mdb)}; "
DSNless = DSNless and "DBQ = " and server.mappath("IdeaPool.mdb")

RANDOMIZE
Pick_Num = Int((50 - 1 + 1)*RND + 1)    ' Generate a random number between 1 and 50
Set Conn = Server.CreateObject("ADODB.Connection")
Conn.Open DSNless
sql = "SELECT * FROM RecRanNum WHERE riid = '" and Pick_Num and "';"
set Rs = Conn.execute(sql)
recordcount = 0
str = ""
' This loop checks if a random number generated is already on the list of used numbers
Do Until Rs.EOF
        recordcount = recordcount + 1
        str = str and Rs("RandomID")
        rs.movenext
Loop

If (recordcount < 1) Then
// Select an idea and display
Else
     ' This temporary infinite loop is to produce a unused number
     Do Until 1<>1
        RANDOMIZE
        Pick_Number = Int((50 - 1 + 1)*RND + 1)
        Set Conn = Server.CreateObject("ADODB.Connection")
        Conn.Open DSNless
        sql = "SELECT*FROM RecRanNum WHERE RandomID = '" and Pick_Num and "';"
        Set Rs = Conn.execute(sql)
        recordcount = 0
        str = ""

        Do Until Rs.EOF
                  recordcount = recordcount + 1
                  str = str and Rs("RandomID")
                  Rs.MoveNext
        Loop

        Rs.Close
        Conn.Close

        If (recordcount < 1) Then
                  Exit Do
        End If
     Loop

              // Select an idea and display
End If
% >
```

〈Appendix B〉

A coding scheme for a time-delay mechanism

```
< %
Dim num
Set FileObject = Server.CreateObject("Scripting.FileSystemObject")
TestFile = Server.MapPath ("RefreshDelay.txt")
Set InStream = FileObject.OpenTextFile(TestFile, 1, False, False)
DelayNum = CInt(Instream.ReadLine)

Select Case DelayNum
        Case "0"
           Call Refresh_Change(1)
                          Delay = XX seconds
        Case "1"
           Call Refresh_Change(2)
           Call Read_Idea(1)
                          Delay = XX seconds
        Case "2"
           Call Refresh_Change(3)
           Call Read_Idea(2)
                          Delay = XX seconds

:
:
:

        Case "49"
           Call Refresh_Change(50)
           Call Read_Idea(49)
                          Delay = XX seconds
        Case "50"
           Call Refresh_Change(0)
           Call Read_Idea(50)
                          Delay = 900 seconds      ' This is to stop refreshing
End Select

Sub Refresh_Change(RC)

     // Change the number for the next idea

End Sub

Sub Read_Idea(RI)

     // Select and display the current idea

End Sub
% >
```