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An interaction between cognitive ability and personality on the performance of computer-based group idea generation*

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〈Content〉

Ⅰ. Introduction

With the support of the mobile computing platform, the waves of the fourth industrial revolution (4IR) rapidly impact all industries through automation (e.g., Amazon Go) and informatization (e.g., SAP Digital Boardroom). As results, it is even predicted that about 50% of our jobs might be disappeared by the effect of so-called computer (or artificial) intelligence, which is a linchpin of 4IR. In such an environment, futurists urge our attention to the role of higher cognitive skills, such as creativity, problem solving, and decision making, which belong to human’s unique area, to open up new windows of future job-related opportunity. Among those cognitive skills, creativity that exploits intellectual capital and generates novel and useful ideas seems to be the foundation for all other higher-level cognitive skills (Jung, 2015). For this reason, over the past half century, researchers across

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disciplines have given a significant consideration to the idea generation task, which is tightly linked to creativity (Valacich et al., 2006), and have accordingly developed numerous techniques to enhance the productivity of idea generation (Jung et al., 2012).

One of the major issues through a long development history is to identify the most efficient and effective method for creative idea generation. Computer-based idea generation (CIG), which attempts to combine “positive elements of verbal (members share ideas and build on them) and nominal (members generate ideas with minimal production blocking and evaluation apprehension)” (Dennis and Valacich, 1993, p. 532), is one such technique. CIG utilizes computer screen as a group interface (see Appendix B with no visual aid) and offers a number of unique experimental advantages over other methods. For example, Jung and colleagues (Jung et al., 2010; Jung, 2014, 2017, and 2018) developed several different versions of real-time goal/ performance graph (see Appendix A) that summarizes the cumulative contributions of each subject and incorporated it into an existing CIG system. Such capability of customization allows us to explore various creativity-related cognitive and social factors that have been uncharted before.

Ⅱ. Theoretical Framework

Among various psychosocial factors unexamined (see Pinsonneault et al., 1999 for a detailed list), three factors (i.e., negative social comparison, attention blocking to stimuli, and cognitive interference via information overload) are considered most critical in hindering the effective improvement of computer-based idea generation (Jung et al., 2010, 2012). Thus, we review below recent relevant studies that have attempted to mitigate the negative effect of those three factors on performance.

2.1 Literature Review on Computer-Supported Idea Generation

The followings are Jung and colleagues’ several exemplary studies using performance graph in an effort to reduce productivity losses due to negative social comparison (comparison and adjustment of individual productivity to a baseline level): (1) Jung et al. (2010) combined performance feedback and goal setting to induce upward social comparison (i.e., the matching of one’s own performance to that of better performing group members); (2) Jung (2014) revised a quantity-based performance feedback to a quantity-quality-based performance feedback and presented in the form of a process performance feedback, encouraging two-dimensional social comparison for both quantity and quality; (3) Jung (2017) integrated process performance feedback with goal setting to enhance productivity by inducing sustained competitiveness; and (4) Jung (2018) modified prior operating performance graph to be more playful (see Appendix B). The key contribution of Jung and colleagues' work is that the design of the human-computer interface (HCI) can be an important factor in increasing productivity because all studies (Jung et al., 2010; Jung, 2014, 2017, and 2018) consistently demonstrated performance enhancement with the visual aids (see Appendix B).

Related to attention blocking to stimuli and cognitive interference via information overload which go hand-in-hand, prior studies (Jung et al., 2012; Paulus et al., 2001) have pointed out a much less meaningful influence of cognitive stimulation (i.e., the value of seeing all ideas on the computer screen (see Appendix B)), which is considered the major benefit in interacting groups, on performance. Recent study (Girotra et al., 2010) also finds that "building on others' ideas is counterproductive ... such buildup neither create more ideas, nor are the ideas that build on previous ideas better" (p. 591). Since the beginning of idea generation, the assumption that the larger the pool of ideas, the more the likelihood of novel and useful ideas has been advocated. However, a literature review (e.g., Paulus et al., 2001) indicates that CIG has less than expected influence of cognitive stimulation on inducing a large enough pool of ideas. To answer why individuals are not optimally taking advantage of the structural features of CIG, such as anonymity, group memory, and parallel input, for better cognitive stimulation, previous research provides evidence that individual differences could play a significant role (e.g., Jung et al., 2012; Jung, 2015). To be specific, given the evidence that CIG tends to foster the breadth of information sharing (Jung et al., 2012), studies (Hilmer and Dennis, 2001; Valacich et al, 2006) suggest that group members often do not focus on others' ideas they see, which is a necessary ans sufficient condition to obtain cognitive stimulation. This means that with a typical group interface, which displays others' ideas randome-like in a text format, the magnitude of attention to stimuli may differ, depending on the innate characteristics of individuals. However, with a traditional CIG, it has no feature to separate individuals from their groups to examine how individual differences interact in a collective setting and, in turn, induce positive or negative influences on performance.

Another contribution of Jung and colleagues' work lies in their CIG's capability to create a simulated artificial group (see the "group simulater" section in this paper). Like the underlying conventional assumption "there is no such thing as a bad idea," most of the CIG related studies have used randomization to compose groups. Although such practice reduces sampling error, it induces a variety of psychosocial factors (including the ones mentioned above) that hinder the performance of computer-based groups (Jung, 2009). With such capability of creating a simulated systematic artificial group, Jung et al. (2012) carried on two controlled experiments to test whether or not individual differences (i.e., extraversion/introversion) could play a meaningful role in group-based idea generation. Concurring with Yellen et al. (1995), The results showed that individual differences in extraversion/introversion play a significant role in affecting the level of member participation and in turn productivity in computer-mediated meetings. Thus, this study focuses on the remaining issues of attention blocking to stimuli and cognitive interference via information overload and attempts to find a better way to alleviate the effect of such process losses on performance.

2.2 Theoretical Background

In the perspective of human-computer interaction, WYSIWYG (what you see is what you get) is a widely adopted notion of information processing. We mentioned above that the interface of CIG displays others' ideas randome-like in a text format and those ideas quickly build up on the computer screen as an ideation session progresses. In such an environment, most individuals perceive overload (Jung et al., 2012) and exert additional time and effort to find stimulating ideas for cognitive stimulation. However, the findings from Jung et al. (2012; see also Yellen et al., 1995) evidence that individuals with a certain characteristics (i.e., extraversion) are better suited for the CIG environment because they consistently performed better in varied conditions. Similarly, given that a random experimental design has been used to compose groups in much of the CIG related studies, it (probabilistically) equally includes high cognitive and low cognitive individuals. Roy et al. (1996) suggest an elimination of lower performers who tend to generate more frivolous ideas, hiding in the crowd (Valacich et al., 2006). Thus, to find a linkage between individual difference and cognitive ability and in turn to find a better fit between CIG (with a computer screen as a group interface) and individual difference, we delve into the personality traits related to cognitive processing below.

Personality - refers to a relatively stable set of physical and mental characteristics that distinguishes an individual – is an important determinant of how and why an individual thinks, feels, and behaves as he/she does. 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) (Jung, 2015). For example, extraversion/introversion personality difference is believed to be a (relatively) highly genetically determined component as the result of biological difference of the RAS (Jung, 2015).

Since the goal of idea generation is to come up with as many quality ideas as possible, creative group idea generation depends largely on the relative strengths of an individual's cognitive ability. In order to meet the objective of idea generation, a deep learning process, which involves transformation of acquired information to creative knowledge, is critical. Hackman and Morris (1975) support this view in that for tasks that use member knowledge and skill and do not require complex social processes (e.g., such as group idea generation), member competencies (i.e., cognitive ability) are the greatest predictor of group effectiveness. Zhang (2003) found that individuals who reported a deep approach to learning tended to employ thinking styles that are more creativity-generating and more complex. Studies (Furnham, 1992; Zhang, 2003) further point out that the deep approach to learning is closely related to the personality characteristics such as (1) intellectually curious, (2) extraverted, and (3) conscientiousness.

Regarding the intellectual curiosity, high performers, whose personality characteristics include high intrinsic motivation, high stimulation seeking, and high independence, tend to meet such criterion to motivate them. For example, the findings from Valacich et al.'s (2006) study indicates that the performance of high cognitive individuals enhanced when given high-quality stimuli, whereas the performance of low cognitive individuals was consistently meager regardless of stimuli quality. This supports our view that a removal of low performers who tend to generate low quality ideas better serves the goal of idea generation that is to come up with as many quality ideas as possible (Valacich et al., 2006). Related to the extraversion domain, the neurological-biological approach of individual differences suggests that extraversion whose cortical arousal is less sensitive and whose breadth of attention is chronically wide (Jung, 2015) is expected to be more tolerant than introversion in computer-mediated idea generation. Recent studies (Jung et al., 2012; Jung, 2015; Yellen et al., 1995) consistently support this view.

For the conscientiousness trait, Komarraju et al. (2011) extent the big five personality traits model to cognition in terms of cognitive learning styles and suggest that "[c]onscientiousness was positively and significantly associated with all ⋯ learning styles, and also showed the strongest association of any of our predictors with GPA [(i.e., cognitive ability for performance)]" (p. 476). As Lievens et al. (2009) suggest that a combination of Big Five traits such as extraversion and conscientiousness has also been found to predict GPA (i.e., performance), especially when students apply previously accumulated knowledge to real life settings (e.g., such as group idea generation where participants are asked to produce ideas on an issue based on their personal knowledge and experience), we are encouraged to further explore the potential effects of personality (i.e., big five personality traits) on the performance of computer-based group idea generation. As mentioned earlier that (1) attention blocking to stimuli and cognitive interference via information overload hinder cognitive stimulation in the computer-based idea generation and (2) this occurs due to the use of computer screen as the group interface, identifying suitable personality characteristics, which could be more tolerable against attention blocking to stimuli and cognitive interference via information overload, may hold a key for the purpose of this study.

Unlike in nominal groups, where participants jot down ideas on a given paper, working separately, all comments in computer-based groups are recorded in group memory and are continuously displayed on the computer screen throughout the idea generation session. With the conventional practice of a random-like display (first come, first served) of all commets on the computer screen[1), the diversity of information accumulates fast a high volume at a higher rate. In this way, computer-based idea generation can facilitate and expand the breadth of information sharing (Jung, 2015), which underpins divergent thinking – a major key to understand creative productivity. However, the current practice of showing rapidly accumulating all comments on the computer screen induces information overload (Jung et al., 2012). Hilmer and Dennis (2001) further diagnose that when information is presented random-like in a text format, individuals perceive difficult to process and integrate information. In such an environment, studies (e.g., Jung et al., 2012; Jung, 2015) suggest that group members often do not attend to information they receive, which is a prerequisite to cognitive stimulation and divergent thinking in turn. To be specific, individuals tend to narrow their attention (Hilmer and Dennis, 2001; Jung et al., 2012) by filtering and/or ignoring stimuli (i.e., not exerting sufficient cognitive effort to process it).

Proposition: Although computer-based idea generation (CIG) showed superior performance over face-to-face idea generation, the performance of CIG when compared to that of paper-and-pencil-based nominal have not yielded substantial differences regardless of

1) This practice stems from the conventional assumptions such as (1) the larger the pool of ideas, the more the likelihood of stimulating ideas; (2) there is no such thing as a bad idea.

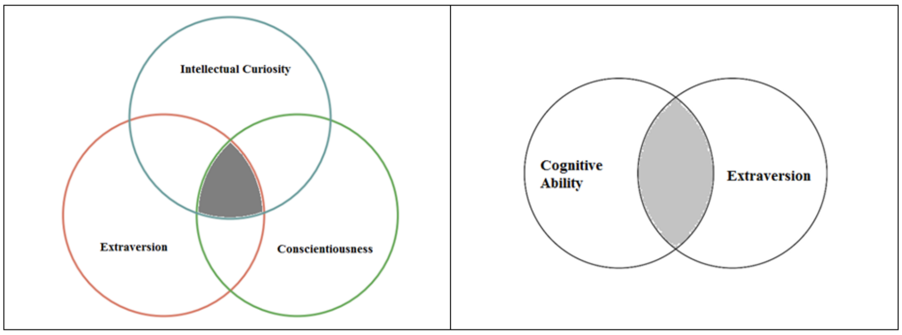
group sizes and other factors. The combination of intellectually curiosity, extraversion, and conscientiousness, taken together, may provide a possible theoretical explanation and a plausible practical solution to the issue of why individuals are not optimally taking advantage of the computer-based idea generation environment for better stimulation to create a large pool of ideas.

Ⅲ. Methods

The nature of this study is experimental. The methodical descriptions of sections 3.3 through 3.6 follow exactly the same as that of prior studies. In this way, this study (1) maintains integrity in analyzing data and interpreting the outcomes and (2) allows follow-up studies replicate the methods used in this study for their purposes. If each study's experimental method is different, the outcomes will not be compared and contrasted.

3.1 Participants

In order to identify target subjects with the personality characteristics of intellectual curiosity, extraversion, and conscientiousness, we used the following three constructs based measures: GPA, Francis et al.'s (1992) six-item Extraversion-Introversion measure, and DeYoung et al.'s (2007) conscientiousness measure. A total of 342 business students visited a secure web site and asked to complete Francis et al.'s and DeYoung et al.'s measures along with self-reporting their cumulative GPA (on a 4.0 scale). With three constructs based measures, we were able to identify enough subjects with intellectual curiosity and extraversion. But, we were unable to locate enough subjects when combined with the conscientiousness factor even with the shorter version of the measure[2]. As a result, we paid



<Figure 1> Target Subjects (Three Constructs Based vs. Two Constructs Based)

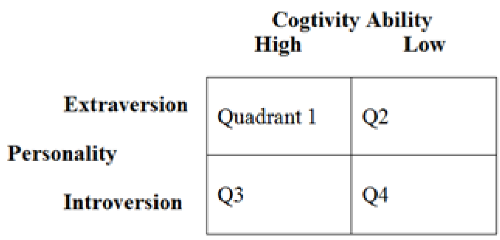
2) In fact, we employed Costa and McCrae's NEO-PI-R scale to test conscientiousness (efficient/organized vs. easy-going/careless) in a preliminary test. Even with the 342 volunteers, it was impossible to locate target subjects.

attention to the GPA construct to find a proxy alternative(s) because GPA could represent both intellectual curiosity and conscientiousness. As mentioned earlier, high performers reflect the characteristic of intellectual curiosity. Thus, high performers can be identified with GPA. Similarly, Komarraju et al. (2011) point out that "[c]onscientiousness … showed the strongest association of any of our predictors with GPA" (p. 476). Thus, it appears that GPA, which is synonymous to cognitive ability, has a broad characteristic that could encompass both intellectual curiosity and conscientiousness. This leads to the two constructs based measures as a proxy alternative to identify target subjects.

Among 425 subjects, we first identified 98 potential participants (60 extraverts and 38 introverts[3])) by creating as large difference in personality as possible. We then looked into the GPA list they self-reported to create the largest difference in cognitive ability, the 16 individuals (7 extraverts and 9 introverts) with the highest GPA, with a GPA ranging from 3.4 to 4.0, as well as the 11 individuals (6 extraverts and 5 introverts) with the lowest GPA, ranging from 2.0 to 2.5.

3.2 Research Design and Hypotheses

This yields a two-by-two between-subjects factorial design, crossing cognitive ability (high and low) and personality (extroversion and introversion) (see figure 2). We then randomly selected five subjects per each treatment to make the sample size equal.



<Figure 2> 2X2 Between-Subjects Design

Although (small) groups are a complex psychosocial phenomenon (Arrow et al., 2000), CIG is a less interdependent task, and lacks social control such as conformity due to the nature of the task that promotes divergent thinking (Jung et al., 2010). As Valacich et al.' (1994b) finding that physical proximity reduces the performance of computer-mediated groups further evidences more cognitive aspect of group idea generation than social, the performance of group idea generation appears mainly a cognitive phenomenon (Valacich et al., 2006). Valacich and Dennis (1994a) propose a succinct mathematical expression to measure group ideation performance.

Group performance = function (expected

3) Participants who scored 6 as extraverts and participants who score 0, 1 or 2 as introverts were recruited. This method is consistent with other prior studies (e.g., Jung et al., 2012; Jung, 2015).

individual performance + process gain - process loss)

Amabile (1998) suggests that creativity is a function of cognitive ability and motivation. Even though motivational influence of group members on each other is generally known as social, the impact of others on the productivity of CIG is due to cognition because individuals perform the task independently, and are cognitively motivated to increase or decrease performance by comparing their performance. Blumberg and Pringle (1982), which expands Vroom's expectancy theory of motivation model, posit that individual performance is a function of the interaction of ability, motivation, and opportunity to perform. Opportunity refers to “the particular configuration of the field of forces surrounding a person and his or her task that enables or constraints that person's task performance and that are beyond the person's direct control” (p. 565). By the same token, Hackman and Morris (1975; Michener and DeLamater, 1999) propose three general factors that influence group productivity: (1) the knowledge and skill of members, (2) motivation and effort brought by members, and (3) the task performance strategies (this can also be viewed as opportunity to perform) used by members. Thus, group performance can be expanded as:

Group performance = function (individual ability X motivation X opportunity to perform + process gain - process loss)

The opportunity to perform in CIG is stable over time because of the built-in parallel function, and process gains or losses stem mainly from motivation. Whereas, an individual’s ability and motivation seem unstable over time and vary from individual to individual and from situation to situation. According to the notion of absorptive (or cognitive) capacity, individuals, however, differ in their cognitive capabilities to assimilate existing knowledge and levels of accumulated prior knowledge that facilitates the creation of new knowledge (Cohen and Levinthal, 1990). Valacich et al.’s (2006) study suggests that the effectiveness of an individual’s cognitive effort is influenced by individual differences including cognitive ability, and evidences that individuals with high cognitive ability are high stimulation seekers. They hypothesized that high need-for-cognition individuals would be more intrinsically motivated to engage in effortful cognitive endeavors, and found that low need-for-cognition subjects generated fewer ideas than high need-for-cognition subjects.

With the conventional practice of a random-like display (first come, first served) of all commets on the computer screen, which the diversity of information quickly accumulates at a higher rate, we mentiond earlier that extraversion whose cortical arousal is less sensitive and the breadth of attention is chronically wide is more tolerant than introversion in computer-mediated idea generation. This suggests the following:

<H1> *High cognitive individuals will perform better than low cognitive individuals in terms of quantity of and quality score of ideas.*

<H2> *Extraverted individuals will perform better than introverted individuals in terms of quantity of and quality score of ideas.*

<H3> *Cognitive ability and Personality will interact such that individuals in Q1 will outperform (quantity of and quality score of ideas) all other treatments.*

3.3 Group Simulator

A simulator was designed to accurately control the presentation of ideas in order to control error variance that inevitably occurs in interacting groups (Jung, 2009). Also, the use of a simulator dramatically reduces the number of subjects needed for hypothesis testing and simultaneously increases the statistical power by controlling error variance by applying a uniform manipulation (Hilmer and Dennis, 2001). The simulator closely mimicked the sequence of a real, interacting group idea generation session; many ideas in the early stage and fewer responses toward the later stages, running out of ideas in the end. This pattern of idea presentation was controlled via programming within the simulator. Pilot testing confirmed that the simulator accurately reproduced the sequence and interactions of a real, interacting group idea generation session. Within the experimental sessions that simulate group size five, a post session question asked each participant “How many people do you think you were working with on this task?” On average, participants reported working with 4.76 group members (SD = 1.03). Thus, it appears that participants believed that they were working in a real, interacting group.

3.4 Idea-Stimulation Manipulation

For the idea-stimulation manipulation, participants were exposed to a stream of high-quality ideas from simulated group members because lower quality ideas significantly induced communication noise (see Valacich et al., 2006). To create an idea stream, 80 high-quality[4] ideas (M = 4.69, SD = .93) were first randomly selected from a master idea list of ideas. Next, these ideas were placed into the group simulator. Then, the simulator randomly selected 40 ideas to mimic

4) Since a 7-point scale was utilized to evaluate idea quality, ideas with an average rating of 4 or higher were considered high quality.

a real, interacting group idea generation session because 40 ideas to be sufficient to induce information overload in a ten-minute period according to the Grisé and Gallupe's (2000) information overload model.

3.5 Task and Procedure

Participants were asked to generate ideas on how to improve the university's parking problem. This task was chosen for its high relevance to the subjects – since it stimulates participants to draw on their personal knowledge and experience – and because it has been used in many prior studies (e.g., Garfield et al., 2001).

On reporting to the experimental site, participants were assigned to a workstation within a computer classroom. Participants were told that they would work with other team members who were located randomly throughout the room using a groupware system that would allow them to generate and exchange ideas. All participants were invited and allowed to become familiar with the operation of the simulator prior to the main task by first working on a practice task. Each participant' contributions and idea seeds from the database were anonymous. The experimenter then read aloud the experimental instructions to generate as many high quality ideas as possible while the participants followed in their own copies. Participants were also told that their results would be used to improve the university's parking problem. Pilot studies found that five-person groups produced approximately 50 idea submissions during a session. Therefore, to reflect a group size of five members (i.e., four simulated members plus the participant), the simulator randomly picked and displayed 40 preset ideas from the database. The simulator was programmed to terminate automatically after 10 minutes, after which the participants completed a brief questionnaire, were debriefed, and released.

3.6 Dependent Variables

In prior studies, performance has been the most generally measured by both quantity and quality of ideas generated. Thus, the dependent variables were quantity of ideas and quality score of ideas. To identify the number (quantity) of ideas generated, one coder first analyzed all comments captured by the group simulator. A methodology similar to previous studies was used to avoid duplicate comments (Valacich et al., 2006): If the participants' ideas were unique and presented before the stimulus ideas, they were counted. If ideas are the same or very similar to the stimulus ideas and they were presented after the stimulus, they were not counted. Consistent with prior studies, a second coder then independently analyzed a random subset of transcripts to confirm the initial coder's categorization. To measure the quality score, the unique ideas generated by participants were compared to a master list compiled during earlier studies. In those studies, idea quality had been rated by three senior parking experts on a 7-point Likert type scale anchored by 1 (A Very Poor Solution and 7 (A Very Good Solution) (see Appendix C for example). Any ridiculous ideas assessed by the experts were discarded. Overall, the reliability of the quality ratings of the ideas on the master list was high ($\alpha = .92$). The master list (containing 457 ideas) proved to be very inclusive, as all ideas generated during the experimental sessions could be matched to the master list. Thus, the idea quality score was calculated by summing the quality scores of the ideas after removing any redundant or frivolous ideas.

Ⅳ. Results

Table 1 presents a summary of the means, standard deviations, and results for the dependent variables. An alpha level of .05 was used for statistical tests. The dependent variables (quantity of and quality score of ideas) were not highly correlated ($r = .426$, $p > .05$), a two-way ANOVA was used for each outcome. Hypothesis 1, that high cognitive individuals will perform better than low cognitive individuals, was partially supported. Two-way ANOVAs found that a significant effect of cognitive ability on quality score of ideas ($F(1, 16) = 26.356$, $p < .05$, $\eta2 = .622$) but not on quantity of ideas ($F(1, 16) = 3.568$, $p > .05$, $\eta2 = .182$). Hypothesis 2, that extraverted individuals will perform better than introverted individuals, was supported. Two-way ANOVAs found a significant effect of personality for both quantity of ideas ($F(1, 16) = 22.827$, $p < .05$, $\eta2 = .588$) and quality score of ideas ($F(1, 16) = 4.695$, $p < .05$, $\eta2 = .227$). Hypothesis 3, that cognitive ability and personality will interact such that individuals in Q1 will outperform (quantity of and quality score of ideas) all other treatments, was not supported. Two-way ANOVAs found no significant interaction effect between cognitive ability ($F(1, 16) = 1.494$, $p > .05$, $\eta2 = .085$) and personality ($F(1, 16) = 3.291$, $p < .05$, $\eta2 = .171$). However, given the effect sizes of both cognitive ability ($\eta2 = .085$) and personality ($\eta2 = .171$) large enough, it appears that not significant interaction effect is due to small sample size.

Regarding the effect of cognitive ability, the outcomes showed that it had an effect on quality, not quantity. A close examination of the data showed that this is due to extraverted low cognitive individuals who generated as many ideas (but low in quality) as extraverted high cognitive individuals. Given that (1) extraverts tend to generate more ideas than introverts as figure 1 demonstrates and (2) low

<Table 1> Means and Standard Deviations for Individual Performance

	Quantity of ideas		Quality score of ideas	
	Extraversion	Introversion	Extraversion	Introversion
Cognitive Ability				
High	(E-HC)	(I-HC)	(E-HC)	(I-HC)
	12.20	9.00	37.33	27.59
Low	2.77	1.22	6.38	5.98
	(E-LC)	(I-LC)	(E-LC)	(I-LC)
	11.60	6.20	17.66	16.66
	2.19	1.48	5.59	7.24

cognitive individuals tend to focus on quantity even when exposed to high-quality stimuli (Valacich et al., 2006), extraversion and low cognitive ability, combined together, appear to generate a larger quantity of ideas than introverted high cognitive individuals and to generate as many ideas as extraverted high cognitive individuals. We ran t-tests to compare two sub-groups: one between extraverted high cognitive individuals and extraverted low cognitive individuals and the other between introverted high cognitive individuals and extraverted low cognitive individuals. Through the data analysis, it confirms that extraverted low cognitive individuals generated as many ideas as extraverted high cognitive individuals ($t(8) = .378$, $p > 0.05$) and introverted high cognitive individuals ($t(8) = 2.316$, $p = 0.05$). However, the quality of ideas generated by extraverted low cognitive individuals was much lower than both introverted high cognitive individuals ($t(8) = 3.793$, $p < .05$) and extraverted high cognitive individuals ($t(8) = 5.180$, $p < .05$).

Regarding the effect of personality, the outcomes showed that it had an effect on both quantity and quality. Although extraverted low cognitive individuals' average performance on quality was lower than that of introverted high cognitive individuals, their effort to improve their images by enhancing their performance induced upward (or positive) social comparison when exposed to high-quality stimuli. This, combined with the performance of extraverted high cognitive individuals, yielded the effect of personality on quality. As for the effect of personality on quantity (as pointed out above that extraverted low cognitive individuals generated as many ideas as extraverted high cognitive individuals ($t(8) = .378$, $p > 0.05$) and introverted high cognitive individuals ($t(8) = 2.316$, $p = 0.05$)), the finding is consistent with prior studies in that extraverts generated more ideas than introverts (Jung et al., 2012). Regarding no interaction effect between cognitive ability and personality, our null finding warrants additional research. As pointed out, it might be due to small sample size, given the effect sizes of both cognitive ability ($\eta 2$ = .085) and personality ($\eta 2$ = .171) large enough. However, sub-group analyses using t-tests (1) between extraverted high cognitive individuals and introverted high cognitive individuals (Quantity: $t(8) = 2.359$, $p < .05$; Quality: $t(8) = 3.293$, $p < .05$) and (2) between extraverted high cognitive individuals and extraverted low cognitive individuals (Quantity[5]): $t(8) = .379$, $p > .05$; Quality: $t(8) = 5.180$, $p < .05$) yielded that extraverted high cognitive individuals indeed performed the best on both quantity and quality.

Ⅴ. Discussion

This study extended extraversion- introversion individual differences with cognitive ability, arguring that cognitive ability and personality would interact such that individuals in Q1 would have the highest performance. The outcomes in this study support our theoretical arguments in that individual differences such as cognitive ability and personality matter. To be specific, since the goal of idea generation is to produce as many quality ideas as possible, all three factors (cognitive ability, personality, and their interaction) showed an effect on quality. Furthermore, regarding a general view of idea generation in that it is mainly a cognitive phenomenon and creative, novel ideas are products of a cognitive process where quality depend on the relative strengths of an individual's cognitive ability (Valacich et al., 2006), our consistent finding of the extraversion-introversion individual differences on the performance of CIG adds additional insight on our research question of "what impedes the development of large enough cognitive stimulation and why it occurs," in particular, in the CIG environment. Such cognitive stimulation discrepancy could be reduced by utilizing and leveraging not only cognitive ability but also personality characteristics. In other words, exposing individual to the stimuli, regardless of their levels of cognitive capacity, is insufficient to fully activate production rules. The effectiveness of an individual's cognitive effort can be moderated and mediated by individual differences such as personality. Finally, our series of studies including this study theoretically and practically address the concern made by Pinsonneault et al. (1999).

Although the definite performance measure in prior studies was based on the quantity of and quality score of ideas, we conducted an

5) Although the quantity of ideas extraverted low cognitive individuals generated was not statistically different when compared to that of extraverted high cognitive individuals, the average quality score of ideas was as poor as introverted low cognitive individuals. Given that the goal of idea generation is to come up with as many quality ideas as possible, extraverted low cognitive individuals' contribution in this regard is meager.

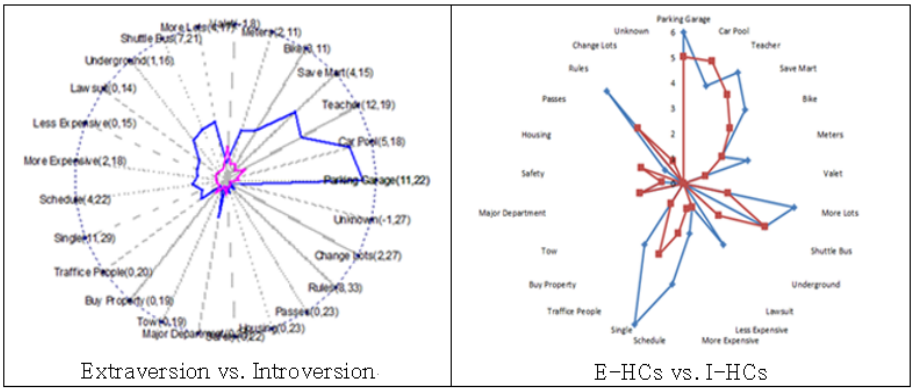
additional analysis using the number of unique ideas and diverse ideas (Jung et al., 2012). Since performance has two sub-constructs, efficiency (unique ideas) and effectiveness (diverse ideas) (Jung et al., 2012), this analysis yielded a different view of the outcomes. The number of unique ideas is the same as the quantity of ideas and analyzed above in detail. Regarding the number of diverse ideas, table 2 shows no statistic differences among E-HCs, E-LCs, and I-HCs (I-LCs are ruled out because they performed the lowest level). Ruling out E-LCs, whose contributions were weak in terms of quality although they generated enough number of ideas, figure 4 shows a holistic view of divergent thinking ability for E-HCs and I-HCs. Using the same categorization method used in Jung's 2015 study, we categorized all identified ideas and compared the performances on multiple dimensions. The radar chart clearly shows that E-HCs' polygon encompasses that of I-HCs and the size of polygon is larger. The interpretation of this graph is straightforward; (1) cognitive ability and personality interacts because the size gap between E-HCs and I-HCs is significantly reduced when compared to the size gap between extraversion and introversion only (see figure 3) and (2) cognitive ability and personality combined appear to facilitate divergent thinking because the reduced size gap implies that I-HCs in particular leveraged on the degree of idea rarity, which is a major key to understand creative productivity in the problem-solving process. Since the outcome shows that E-HCs tend to yield a larger pool of ideas, another interpretation is that group composition with E-HCs compared with I-HCs may create a logically larger group, which is important to increase the performance of group-based idea generation (e.g., Valacich et al., 2006).

Ⅵ. Contribution and Practical Impalication

This study's main contribution lies in

<Table 2> Means and Standard Deviations for Idea Rarity

	Cognitive Ability	
	High	Low
Number of diverse ideas		
Extraversion	(E-HC)	(E-LC)
M	5.80	5.62
SD	1.51	2.13
Introversion	(I-HC)	(I-LC)
M	5.55	3.87
SD	1.84	2.03



<Figure 3> Categorical Performance Comparison on Multiple Dimensions

investigating the potentials of individual differences in the context of CIG by developing a new feature (i.e., a group simulator). Simulation (e.g., Monte Carlo) has been a common practice in all disciplines in situations where an outcome does not meet the assumptions. Thus, as the results of the study empirically demonstrated that an integration of CIG and individual differences yields an increased performance, this research supports the notion that a group simulator can be used to explore various factors that may influence cognitive stimulation, motivation, and performance within interacting groups. In addition, a research stream in CIG has literally been stopped after Pinsonneault et al. (1999) posed various cognitive and social issues related to the performance of CIG. Since then, no major theoretical development or practical improvement has been observed. As our study attempts to answer psycho-social concerns raised by Pinsonneault et al. by modifying the user interface of CIG (see Appendix A, B), our approach may rekindle the CIG related research by bridging the research gaps.

One practical implication is the redesign of the group interface when displaying the comments. Since the beginning of CIG, the user interface, which displayed all comments first-come first-serve based, has not been changed with the assumption that a random-like display facilitates divergent thinking. However, we argued that such a practice (1) induces cognitive loading to discern stimulating ideas and (2) interferes with a train of thought, hindering cognitive stimulation. Nijstad et al. (2003) suggested one solution to maintain stimulation and to prevent interference simultaneously, i.e., a clustering of semantically related ideas. The current CIG that supports categorization of ideas only after idea generation session ends needs to consolidate categorization of ideas into the idea generation process. In this way, similar ideas are clustered, reducing attention blacking and congitive inteference via information overload.

Ⅶ. Limitations

Like any research, the method used in this study is limited in some aspects. First, regarding the personality dimension of introversion-extraversion, we chose this dimension over others (confer such as the big five personality traits and Myers-Briggs Type Indicator) due to its high relevance in CIG. As mentioned in the introduction, the computer screen used to display the comments of all member has both advantages and disadvantages. Based on our observation over years, a high volume of ideas that quickly build up as an idea generation session progresses most likely offsets the advantages of the use of computer screen. In this vein, the selective use of a particular personality trait may provide a plausible solution to mitigate the side effect of computer screen and could guide future research in the area of CIG. Second, regarding a rather small sample size used in this study, we mentioned in the participants section the difficulty of locating target subjects although 425 subjects volunteered. Given that a large sample size is normally prefered in quantitative research, an additional study with a larger sample size is warranted to better understand the outcomes. Third, regarding the use of GPA as a proxy for cognitive ability, GMA (general mental ability) has been considered an acceptable measure of individual cognitive ability. Although the GMA test involves high cost and a considerable time, an additional study with GMA is warranted to better understand the outcomes.

Ⅷ. Conclusion

Paulus et al. (2001) cast the question “creative groups should generate many ideas from a wide variety of domains or categories, generate a high number of unique ideas, and provide opportunities for elaboration of each other’s ideas” (p. 330). However, Hackman and Morris (1975, p. 81) point out that “the chances of members using one another to learn genuinely innovative patterns of behavior – or to seek out and internalize knowledge that initially is foreign to them – are very slim.” Cognitive stimulation and cognitive interference are both sides of the same coin that occur in the idea generation process (Jung, 2010). They both occur by reading the contributions of others displayed on the computer screen. It was assumed that if the synergy of process gains is greater, cognitive stimulation occurs and if the contagion of process losses is greater, cognitive interference occurs. Given that many previous studies have pointed out a much less meaningful influence of cognitive stimulation in computer-based groups (e.g., Garfield et al., 2001; Paulus et al., 2001), our consistent findings including this study suggest that the CIG environment may require different types of individual differences to maximize cognitive stimulation under the current practice of the group interface, which randomly presents all comments in a large text format. Although this practice is to increase the diversity of information and in turn to facilitate divergent thinking, cognitive ability and personality combined appear to better attend to information they receive, expanding not only the breadth but also the depth of information sharing.

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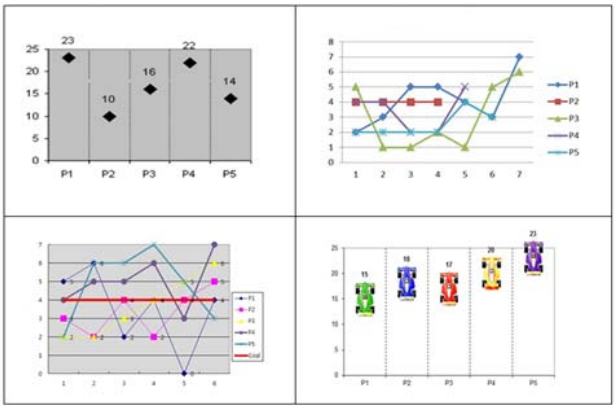
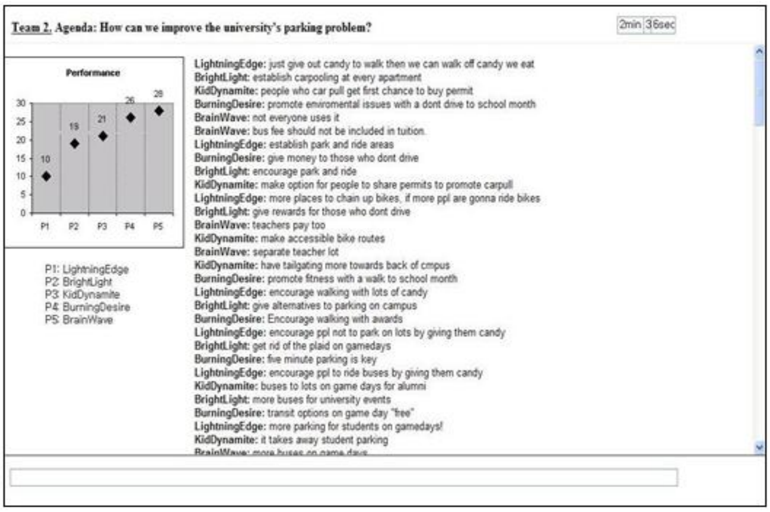
Appendix A: Examples of Performance Graph

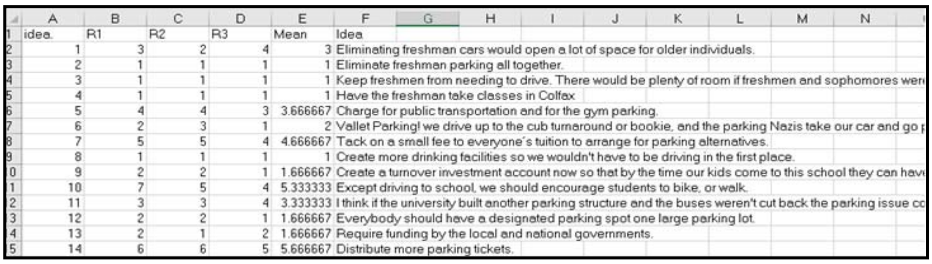
(Clockwise from Top Left: Jung et al., 2010; Jung, 2014; Jung, 2018; Jung, 2017)



Appendix B: A Computer-Based Ideation Environment with Performance Feedback



Appendix C: An Excerpt of the Master Idea List



	A	B	C	D	E	F
1	idea.	R1	R2	R3	Mean	Idea
2	1	3	2	4	3	Eliminating freshman cars would open a lot of space for older individuals.
3	2	1	1	1	1	Eliminate freshman parking all together.
4	3	1	1	1	1	Keep freshmen from needing to drive. There would be plenty of room if freshmen and sophomores wer
5	4	1	1	1	1	Have the freshman take classes in Colfax
6	5	4	4	3	3.666667	Charge for public transportation and for the gym parking.
7	6	2	3	1	2	Vallet Parking! we drive up to the cub turnaround or bookie, and the parking Nazis take our car and go
8	7	5	5	4	4.666667	Tack on a small fee to everyone´s tuition to arrange for parking alternatives.
9	8	1	1	1	1	Create more drinking facilities so we wouldn't have to be driving in the first place.
10	9	2	2	1	1.666667	Create a turnover investment account now so that by the time our kids come to this school they can hav
11	10	7	5	4	5.333333	Except driving to school, we should encourage students to bike, or walk.
12	11	3	3	4	3.333333	I think if the university built another parking structure and the buses weren't cut back the parking issue co
13	12	2	2	1	1.666667	Everybody should have a designated parking spot one large parking lot.
14	13	2	1	2	1.666667	Require funding by the local and national governments.
15	14	6	6	5	5.666667	Distribute more parking tickets.

<Abstract>

An interaction between cognitive ability and personality on the performance of computer-based group idea generation

Jung, Joung-Ho

Purpose

Among various psychosocial factors, negative social comparison, attention blocking to stimuli, and cognitive interference via information overload are considered most critical in hindering the effective performance improvement of computer-based idea generation. Given that the effect of negative social comparison along with a plausible solution based on the notion of performance feedback and goal setting has been successfully addressed, this study focused on the remaining issues of “attention blocking to stimuli and cognitive interference via information overload” and attempted to find a way to alleviate the effect of such process losses on performance.

Design/methodology/approach

A 2 × 4 between-subjects design was used, crossing cognitive ability (high and low) and personality (extroversion and introversion). Five subjects per each treatment were randomly selected to make the sample size equal. The group simulator was used to measure individual-level performance. The dependent variables were the quantity of and quality score of ideas. The manner by which these performance measures were operationalized was consistent with prior studies. An additional analysis using the number of diverse ideas was also conducted.

Findings

Three arguments were made in this study: (1) high cognitive individuals would perform better than low cognitive individuals, (2) extraverted individuals would perform better than introverted individuals, and (3) cognitive ability and personality would interact such that individuals in Q1 would have the highest performance. Cognitive ability had an effect on quality not quantity. Personality had an effect on both quantity and quality. An interaction between cognitive ability and personality was not found due to small sample size despite the use of the group simulator.

Keyword: Idea Generation, Individual differences, Performance, Creativity

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