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The Effect of Graphical Formats on Computer-Based Idea Generation Performance*

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〈목 차〉

Ⅰ. Introduction

Information Graphics (Infographics) present quantifiable data and information in various graphical formats quickly and clearly. Tufte (2001) asserts that "'high information displays are not only an appropriate and proper complement to human capabilities, but such designs are frequently optimal" (p. 168). Since human brains are adjusted to catch images faster than texts or numbers (Jung, 2014), infographics have a substantial potential to improve cognition - the mental process of acquiring and understanding knowledge and producing relevant solutions in a creative way – and, in turn, to enhance the efficiency of decision-making (see figure 1). An adoption and exploitation of such a technique seems a must in today's fast-paced business environment (Jung et al., 2013; Kim et al., 2016). Despite the widespread use of infographics in business in the form of

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"information dashboard," which provides at-a-glance views of key performance indicators, Groupware – a collaborative software system recognized as a key driver of organizational performance – has neglected the adoption and use of information graphics, in particular, in the idea generation process. In addition, given that an overall performance of groupware-based idea generation (a.k.a. electronic brainstorming) is no better or worse than that of the (paper-and-pencil-based) Nominal Group Technique regardless of a variety of factors (Paulus and Brown, 2003; Pinsonneault et al., 1999), the net benefit of quite pervasive use of groupware-based idea generation in real-world organizations is questionable because Groupware requires high cost of setting up and maintenance. Unless there is a way to solve the illusion of electronic brainstorming productivity, Jung (2010) concludes that the status of electronic brainstorming has come to a fork in the road to be (or not to be) a part of management technique. In an effort to solve this conundrum, Pinsonneault et al. (1999) specifically suggest to look into "social loafing and negative social comparison … how or why EBS should influence the extent of negative social comparison exercised by the participants" (p. 112) among various process loss factors. In interacting groups, all the evidence suggests social impairment (i.e., negative (or downward) social comparison, which adjusts overall performance to the least performing members) to be more dominant. In electronic interaction, due to the combined effects of random group composition and anonymity in conjunction with unregulated (i.e., unrewarded and unpunished) individual performance behavior (Jung, 2013), performance tends to

<Figure 1> Monitoring Key Revenue Metrics (www.sap.com)

regress toward the mean.

To be specific, (1) randomization, which conventionally used to control any threats to internal validity, has been employed to compose groups in the experimental setting. This method (statistically) equally includes low performers and high performers in each group; (2) individuals' performances are not controlled (i.e., unrewarded and unpunished) with the support of anonymity or pseudonymity. This makes individuals difficult to assess their own performances (e.g., how many ideas they produced and how their ideas are going to be evaluated); (3) with the support of the group interface, which captures and shows all contributions (i.e., comments) on the computer screen, group members engage in social comparison and matching of their performances to that of others based on their own performance perceptions. In the comparison process, low performers tend to engage in positive social comparisons if they are in a group with higher performers, whereas high performers tend to engage in negative social comparisons if they are in a group with lower performers. In sum, it appears that the absence of a clear performance guideline such as performance feedback induces social loafing and negative social comparison, leading to the reduction of overall performance.

Thus, there is a need for infographics to better guide performance behavior and assessment in the context of groupware-based idea generation. Accordingly, Jung and colleagues (Jung et al., 2010; see also Jung, 2014) adopted the notion of information graphics in the form of performance feedback in the idea generation process (see Appendix A and B) in an effort to solve the performance singularity. The results clearly and consistently show that the provision of performance graph has beneficial effects on performance enhancement. Since the performance graph constitutes a shared interactional space for task goals to be accomplished, it reveals individuals' accumulated contributions in a comparative perspective. Thus, it appears that performance information arouses group members the sense of social presence and spurs them to be competitive, inducing upward social comparison. With the effect of performance graph proved to be beneficial, an interesting observation is that groups with the bar chart type treatment performed better than groups with the dot chart type treatment (see table 1). Independent t-tests showed significant

<Table 1> Performance Comparison among Different Graph Treatments (Jung et al., 2010)

	Bar Graph	Dot Graph	No Graph
Total Ideas			
Idea Quantity	69.61	43.30	25.85
Idea Quality	160.08	127.67	67.80

statistical differences ($p < .05$) on both quantity and quality of ideas.

Ⅱ. Experiment 1

2.1 Theoretical Framework

According to the anchoring framework that matches data extraction tasks with graphical representations (Tan and Benbasat, 1990), it suggests bar and dot charts to be more suitable over a line chart when two dimensional x- and y- values need to be anchored high (e.g., Appendix A and B). Simkin and Hastie (1987) suggest that a bar chart fits well for a comparison judgment task such as performance feedback for idea generation. Similarly, Zacks and Tversky (1997) suggest adults' preference to use bars for conveying discrete information because of the naturalness of bar graphs for categorical comparison. On the other hand, some researchers (e.g., Cleveland and McGill, 1984) suggest a dot chart over a bar chart when applying visual judgmental processing of statistical graphics. Cleveland and McGill (1984) argue that all values can be compared clearly by making positional judgments along a common scale in a dot chart, whereas all values are converted to length or area in a bar chart, which causes misinterpretation rates to be 40 ~ 250% higher than a dot chart for positional judgments. Nonetheless, the purpose of the first experiment is to find performance consistency between the findings in Jung et al.'s study (2010) and the outcomes from this experiment.

2.2 Research Design

A total of 60 upper-level business students served as subjects. Group size was five. They were randomly assigned to the treatments (a bar graph or a dot graph). The participants were asked to generate ideas on "How can we improve the university's parking problem?" Following prior studies (e.g., Connolly et al., 1990; Garfield et al., 2001), this task was proven for its high relevance to the subjects because it stimulates participants to draw on their personal knowledge and experience. Regarding a real-time visual aid for subjects' performances, we employed the same systems used in Jung et al.'s study (2010). Regardless of chart types (a bar or a dot), it displayed accumulated contributions for all group members and was redrawn every ten seconds.

2.3 Procedure

Subjects were told that (1) Groupware would allow them to produce and exchange ideas; (2) their submissions could be identified by the assigned pseudo names, but they would not be able to know who the other subjects are; (3) a set of built-in procedures would count the number of ideas; (4) they could observe their performances in real time. Then, the experimenter guided subjects to follow Osborn's (1957) brainstorming rules (i.e., "to generate as many ideas as possible, to withhold criticism, to include wild ideas, and to build on the ideas of others" (Jung et al., 2010, p. 732)). The system stopped after 15 minutes.

2.4 Dependent Variables

The dependent variables were quantity and quality of ideas after removing redundant ideas. The manner by which these performance measures were operationalized is consistent with many prior studies (e.g., Connolly et al., 1990; Diehl and Stroebe, 1987). Ideas were compared to a master idea list compiled during prior studies over the years. The quality of the ideas on the master idea list has been rated by three senior parking experts. The master idea list proved to be very inclusive, as no additional ideas were generated during the experimental sessions. Regarding the quality score, the sum of the quality rating has been found to be the most reliable measure of idea quality (Diehl and Stroebe, 1987). Thus, the idea quality score was calculated by summing the quality scores of all ideas.

2.5 Results

Table 2 presents a summary of the means and standard deviations. Because the dependent variables (quantity and quality score of ideas) were highly correlated ($r = 0.826$, $p < .001$), a one-way MANOVA was utilized. The results showed that groups in the bar chart treatment performed better than groups in the dot chart treatment for both quantity ($F(1, 10) = 7.614$, $p < .05$) and quality ($F(1, 10) = 12.201$, $p < .05$).

<Table 2> Means and Standard Deviations for Idea Generation Performance

	Graph Type	
	Bar	Dot
Idea Quantity		
M	60.83	42.50
SD	14.79	6.77
Idea Quality		
M	132.94	103.98
SD	17.27	10.70

Ⅲ. Experiment 2

3.1 Theoretical Framework

Just like our interesting (and unexpected) finding in Jung et al.'s study (2010), the same pattern of performance was observed. Despite that the dot chart is less clustered and does not require a zero baseline as does the bar chart (Robbins, 2006), these consistent findings draw a suggestion that individuals with the bar chart treatment would perform better than individuals with the dot chart treatment. This comes to a research question: is there a way to make a dot chart more effective in terms of increasing productivity? Webster and Martocchio (1992) suggest that computer “playfulness” is positively related to involvement and satisfaction. In other words, mixing task and play can improve performance. According to Moon and Kim (2001), “playfulness” has a motivational characteristic of individuals. Since performance information can strengthen the critical motivational linkages between effort-performance and performance-reward (Jung et al., 2010), playfulness if combined with performance information has a potential to further strengthen the motivational linkages by moderating or mediating. In addition, playfulness has a situational characteristic where the role of context affects individuals’ subjective experiences and involvements in the relatively short run. Venkatesh (2000) suggests that “higher levels of ⋯ playfulness lower perceptions of effort – i.e., for the same level of actual effort/time invested, perceptions of effort/time will be lower in the case of a more “playful” user when compared to a less “playful” user” (p. 349). In sum, if a playful atmosphere for idea generation is provided, there could be a high possibility of performance enhancement. In order to create a playful environment, we chose car racing because all sorts of racing simulation games can be easily found on the Internet and on the smartphone applications. They are already popular to all ages and bring enjoyment. Since the meaning of enjoyment is closely linked to playfulness, a car racing environment establishes a necessary and sufficient condition for “playfulness.” Thus, the followings are hypothesized:

H1: Groups in the revised-dot graph treatment at least will perform better than groups in the dot graph treatment.

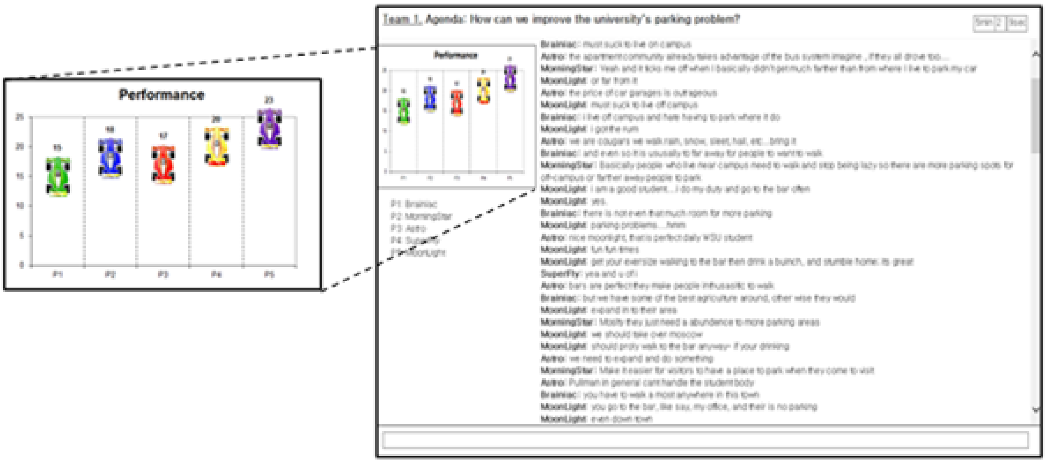
H2: Individuals in the revised-dot graph treatment will express the higher “perceived playfulness” than individuals in other treatments.

3.2 Research Design

A total of 30 undergrad business students participated in the experimental sessions. The task, procedure, and dependent variables were exactly like those used in experiment 1. Regarding the operationalization of “playfulness” in conjunction with performance graph, we modified the performance feedback program used in experiment 1 to convert dots to car images in the performance graph (see figure 2). The task, procedure, and dependent variables were the same as in Experiment 1.

3.3 Results

Additional data collected from the



<Figure 2> A Revised-Dot Performance Graph with Car Images

revised-dot performance graph treatment was combined with the data from Experiment 1 for performance comparison. Because the dependent variables (quantity and quality score of ideas) were highly correlated ($r = 0.801$, $p < .001$), a one-way MANOVA was utilized. Hypothesis 1, that groups in the revised-dot graph treatment at least will perform better than groups in the dot graph treatment, was supported. The results showed that there were performance differences for both quantity ($F(2, 15) = 6.281$, $p < .05$) and quality ($F(2, 15) = 14.239$, $p < .05$). Post-hoc Tukey's tests found that the two groups being compared were significantly different from one another at the $p < .05$ level. In the results, groups with a bar (and a revised dot) and groups with a dot were statistically significantly different from one another. Hypothesis 2, that individuals in the revised-dot graph treatment will express the higher "perceived playfulness" than individuals in other treatments, was also supported. Based on Venkatesh and Davis's (1996) four-item Perceived Playfulness measure (e.g., delightful/not delightful, exciting/dull, thrilling/not thrilling, fun/not fun; response scale: 7-point Likert), a one-way ANOVA showed that there was statistical difference in perceived playfulness ($F(2, 87) = 18.832$, $p < .05$). Post-hoc Tukey tests found that the revised-dot graph treatment expressed the highest playfulness among three treatments (see Appendix C).

Ⅳ. Discussion

4.1 Research Summaries

The overview of this study is on finding a plausible solution for the issue posed by Pinsonneault et al. (1999, p. 112): “Past research is less clear on how EBS may reduce productivity losses due to social loafing and negative social comparison.” We argued that the absence of a clear performance guideline in the idea generation process induces such losses and, in turn, results in the reduction of overall performance. The main reason for overlooking external interventions to mitigate or eliminate “social loafing and negative social comparison” in prior studies is that most idea generation related researchers followed the conventional assumption “there is no such thing as a bad idea” due to the idea generation task’s tight link to creativity. However, given that an overall performance of computer-based brainstorming is no better than that of the (paper-and-pencil-based) Nominal Group Technique, Jung and colleagues (Jung et al., 2010; see also Jung, 2014) employed performance feedback as an external intervention and consistently demonstrated performance enhancement, answering Pinsonneault et al.’s (1999) claim.

With this study background, we had noticed a superior performance of a bar chart over a dot chart in our prior study (Jung et al., 2010). Therefore, we conducted a second experiment by duplicating the same experimental methods to test performance consistency. Our results confirmed a consistent superior performance of a bar chart. This implies that a bar chart is a better choice when stimulating performance with a visual aid in groupware-based idea generation. Although (1) researchers have different views on the cognitive match between the type of graphs and the effectiveness of a comparison task (e.g., Simkin and Hastie, 1987 vs. Cleveland and McGill, 1984) and (2) a bar chart was criticized in a way that errors of length-area judgments are 40 ~ 250% greater than those of positional judgments along a common scale, perhaps such illusion turned out to be facilitating upward performance comparison (i.e., the matching of one’s own performance to that of better performing group members) better. This brings out a research opportunity to theoretically understand why a bar chart shows better cognitive fit than a dot chart in the context of computer-based idea generation environment.

Regarding Experiment 2, retaining the same dot-based performance graph, we attempted to design the idea generation environment more playful by converting dots to racing cars in the

<Table 3> Performance Comparison among Three Studies

	Jung et al., 2010		Experiment 1		Experiment 2
	Bar	Dot	Bar	Dot	Revised Dot
Idea Quantity	69.61	43.30	60.83	42.50	61.67 (SD: 8.45)
Idea Quality	160.08	127.67	132.94	103.98	149.39 (SD:15.99)

performance graph. The outcome showed the order of performance in terms of quantity and quality score of ideas as follows: Bar >= Revised Dot > Dot (see Table 3). Ruling out the dot treatment, which consistently showed the lowest performance, the revised-dot treatment performed the same as (or lower than) the bar treatment. Thus, an additional research is warranted to find a consistent outcome.

As described the trait of "playfulness," it appears that there was an interaction between the motivational characteristic and the situational characteristic of playfulness because individuals in the revised-dot graph treatment performed better than individuals in the dot graph treatment. However, Venkatesh and Davis's (1996) four-item Perceived Playfulness measure showed that individuals in the revised-dot treatment yielded the highest playfulness. Despite the highest score for "perceived playfulness," the revised-dot treatment did not show the highest performance. Such incongruence between playfulness and performance brings another avenue for research. Follow-up studies may look into the Yerkes-Dodson law (Yerkes and Dodson, 1908), which describes an empirical relationship between arousal and performance. According to this theory, performance increases with stimulation (playfulness in this case) up to a certain threshold point and decreases with further increase in arousal. Given that the revised-dot treatment did not yield the highest performance, individuals in the revised-dot treatment might still be under-aroused. Thus, finding a better way to reinforce "playfulness" seems an interesting research.

4.2 Implications for research and practice

The essence of information graphics is how to construct and interpret graphics effectively so that it reveals the shape of the data in a comparative perspective. Accordingly, graph comprehension as reading and interpreting graphs has been widely studied. However, little is known other aspects of graph comprehension such as graph construction and graph choice (Friel et al., 2001). Regarding graph construction (or invention), we only take graphs in Microsoft Excel for granted, not considering possibilities of customized graphs. For example, a radar chart allows the comparison of different entities along multiple dimensions. Dimensions are the attributes used for the comparison. Microsoft Excel's built-in radar chart uses a single "value axis" to represent all the different attributes, which makes attribute points with smaller values clump together. However, it is common for the different attributes are measured using different scales. TM Radar Chart (www.tushar-mehta.com) creates a radar chart that plots each attribute axis on its own scale. In addition, it has an option to normalize all the attributes resulting in a uniform radar chart. Jung (2015) utilized the TM Radar Chart to compare performance on multiple dimensions, clearly showing that extraverts' polygon encompasses that of introverts and the size of polygon is distinctively larger.

Regarding graph choice, DeSanctis (1984) suggests that graphical characteristics such as the type of graphs (e.g., bar chart, pie chart, trend line) and its features (e.g., color, complexity, realism, labeling) should fit with characteristics of the user and the decision-making context when the effectiveness of graphics is studied. However, under the general assumption of cognitive fit that matches specific skills to problem representation and task, much of information systems studies paid attention to simply comparing "spatial" and "symbolic" tasks that characterize the differences between graphs and tables (e.g., Dennis and Carte, 1998; Speier, 2006), away from a need for more focused research on graphics as decision aids. As a result, little is known about matching data extraction tasks with graphical representations, except Tan and Benbasat's (1990) anchoring framework. Thus, we urge future studies to "identify specific contexts in which certain kinds of graphics may be most useful to decision makers … [because] no one graphic format will prove universally superior. Each format has its own domain of application" (DeSanctis, 1984, p. 481).

"To the user, the system is the interface" (Gray et al., 1993, p. 192). This is the most critical component of Groupware between the system and its users. For the user, the interface is the only part of the system that is meaningful, and the rest is invisible. Moreover, decision processes are strongly contingent upon the graphical presentation format. "The graphical format alone accounted for 40 percent of the variance in the acquisition direction and 17 percent of the variance in the evaluation direction" (Jarvenpaa, 1989, p. 298). Jung (Jung et al., 2010; Jung, 2014) conducted a series of studies with various graphical formats (e.g., quantity-based, quantity-quality-based, process-based) in an effort to reduce performance measure deficiency. Different graphical formats yielded different results as Jarvenpaa (1989) pointed out above. One possible explanation is that there might be a threshold in reading and interpreting the performance graph on the computer screen. For example, the quantity-quality-based process performance feedback, which is intended to reveal performance histories by accumulating past task behavior, seems to require more cognitive effort to keep track of their own performances when compared to that of the quantity-based performance feedback, which is rather simple to follow and contrast. "A graphical presentation format is a part of a task environment, and changes in a presentation format can lead to changes in the decision strategies used. Specifically, the way the graphical information is arranged on a display affects the order in which decision makers acquire information" (Jarvenpaa, 1989, p. 298). Thus, given that the inclusion of the performance feedback graph in computer-based idea generation consistently leads to better performance, an in-depth examination of the level of graph readability is needed.

Ⅴ. Conclusion

Information systems researchers rarely study idea generation with Groupware after the debate for the productivity paradox. However, our work with infographics demonstrates consistent performance enhancement when compared to the performance of the traditional idea generation practice, opening up new windows of research and practice opportunities. As the digital boardroom, which presents a live picture of an organization's performance, shows an ultimate example of using infographics in business, there should be more effort to better understand the role of external interventions (in particular infographics) in the idea generation process and to specify the conditions where graphics can be most effectively employed.

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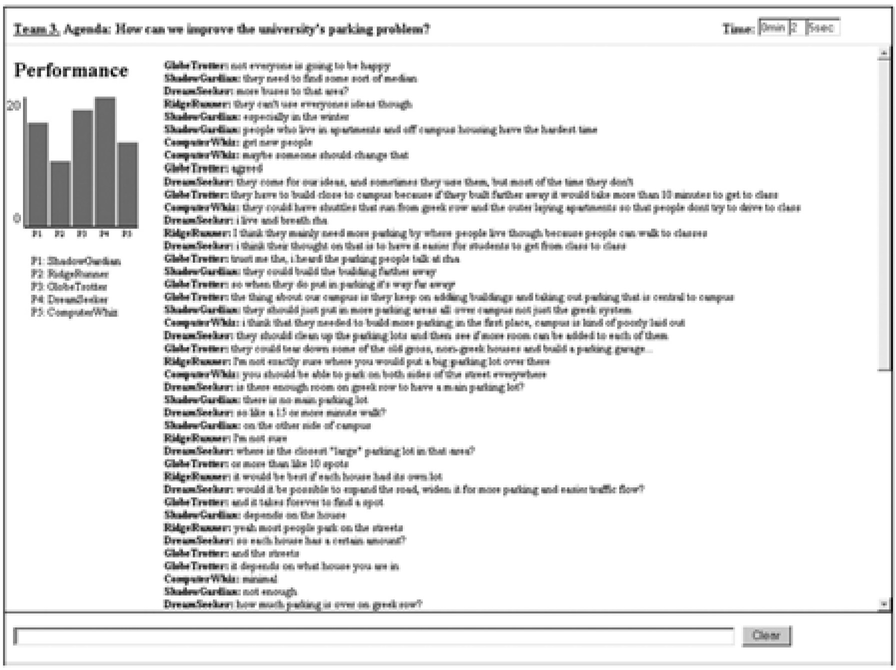
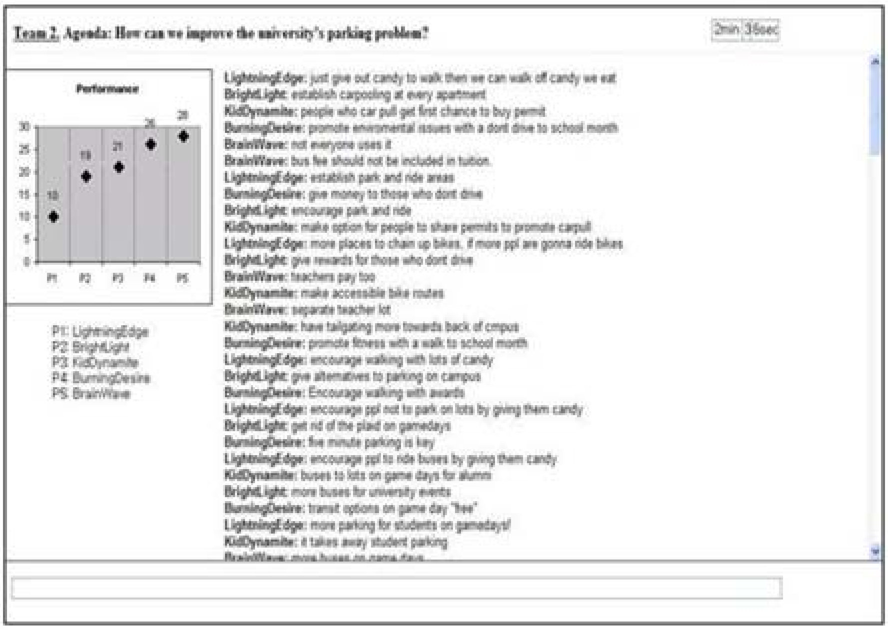
Appendix A: A Bar Chart Based Performance Feedback



Appendix B: A Dot Chart Based Performance Feedback



Appendix C: Multiple Comparisons for Perceived Playfulness

Tukey HSD

(I) Treat	(J) Treat	평균차(I-J)	표준오차	유의확률	95% 신뢰구간	
					하한값	상한값
1.00	2.00	.5583*	.17454	.005	.1422	.9745
	3.00	1.0708*	.17454	.000	.6547	1.4870
2.00	1.00	-.5583*	.17454	.005	-.9745	-.1422
	3.00	.5125*	.17454	.012	.0963	.9287
3.00	1.00	-1.0708*	.17454	.000	-1.4870	-.6547
	2.00	-.5125*	.17454	.012	-.9287	-.0963

Treat 1: The Revised-Dot; Treat 2: The Bar; Treat 3: The Dot

Appendix D: Descriptive Statistics for Perceived Playfulness

Treat	평균	표준편차	N
1.00	6.1167	.50742	30
2.00	5.5583	.55197	30
3.00	5.0458	.89928	30
합계	5.5736	.80004	90

Treat 1: The Revised-Dot; Treat 2: The Bar; Treat 3: The Dot

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<Abstract>

The Effect of Graphical Formats on Computer-Based Idea Generation Performance

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Purpose

Since human brains catch images faster than texts or numbers, infographics has been widely used in business in the form of "information dashboard" to enhance the efficiency of decision-making. Groupware, however, has neglected the adoption and use of infographics, in particular, in the idea generation process. Given that an overall performance of groupware-based idea generation is no better than that of the (paper-and-pencil-based) Nominal Group Technique, Jung et al. (2010) adopted the notion of infographics in the form of performance feedback to solve the productivity paradox. With the consistent results, which demonstrate beneficial effects of infographics on performance enhancement, an interesting observation that groups with the bar chart treatment performed better than groups with the dot chart treatment was made. The main purpose of this study was to find if there were a performance consistency between the outcomes from the previous study and the outcomes from the current study.

Design/methodology/approach

In experiment 1, we employed the same system used in the previous study (i.e., Jung et al., 2010). As individuals' contributions accumulated, the mechanism visually displayed individuals' performances two-dimensionally in the form of a bar chart or a dot chart. Then, we compared the performance outcomes from this study to the outcomes from previous study (i.e., Jung et al., 2010). In experiment 2, we modified the performance graph to test the effect of "playfulness" on performance by converting dots to car images. Then, we compared the performance outcome from experiment 2 to the outcomes from experiment 1.

Findings

Just like our interesting (and unexpected) finding in Jung et al.'s study (2010), the outcome confirmed a consistent superior performance of a bar chart. This implies that a bar chart is a better choice when stimulating performance with a visual aid in the context of groupware-based idea generation. Although a bar chart was criticized in a way that errors of length-area judgments are 40 ~ 250% greater than those of positional judgments along a common scale, such illusion turned out to be facilitating upward performance comparison better. Regarding Experiment 2, the outcome showed that the revised-dot graph is as good as the bar graph in terms of quantity and quality score of ideas. We attribute the performance enhancement of the resized-dot to the interaction between the motivational characteristic and the situational characteristic of playfulness because individuals in the revised-dot graph treatment performed better than individuals in the dot graph treatment. Given the order of performance (Bar >= Revised Dot > Dot) that the revised-dot treatment performed the same as (or lower than) the bar treatment, an additional research is warranted to reach to a consistent outcome.

Keyword: Idea Generation, Performance Feedback, Bar Graph, Dot Graph

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