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THE EFFECT OF TASK STRUCTURE AND TIME STRUCTURE ON KNOWLEDGE CREATION USING GROUP SUPPORT SYSTEMS

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Abstract

*Group support systems have been found useful for idea generation on the path to knowledge creation. However, the ability of groups to converge on the most worthy ideas to translate into knowledge has been generally neglected in the research literature. This empirical research assesses and validates the effects of task and time structure on the ability of computer mediated groups using a group support system (GSS) to perform an idea convergence task. Convergence was examined through literature review of past research and theory, with a focus on information processing theory. Using a 2*2 factorial study, a set of 5 person groups were asked to converge upon the most worthy ideas for further consideration. Task structure and time structure were varied and a kappa measure of convergence and subjective measures were developed to substantiate convergence. Results indicate that task structure has an influence on convergence, and time structure influences satisfaction with convergence. It was also found that cognitive load correlates with the group convergence using the knowledge that was generated. Recommendations are made for the improvement of convergence activities towards knowledge creation support and management using a GSS.*

Keywords: Knowledge creation, convergence, Group Support System, mental load

1 INTRODUCTION

Alavi and Leidner (2001) recognize phases of creation, storage, transfer and application as aspects of knowledge management from a process perspective. Electronic Brainstorming (EBS) is a Group Support System (GSS) tool that has been productive in supporting the idea generation stage of meetings as a precursor to knowledge creation. A substantial amount of research has demonstrated that groups supported by EBS tools generate more ideas than traditional unsupported groups in the same amount of time (e.g., Nunamaker et al. 1997). In an EBS session, GSS groups have been found to generate 50 percent more ideas in 60 percent less time (Grise and Gallup 2000). Ideas are more akin to information (rather than data) in that they typically have meaning. They are often the precursor to knowledge in the absence of comparison, consequences, connections and conversation (Davenport and Prusak 1998). According to Nonaka (1994), information is a flow of messages, while knowledge is created and organized by the flow of information anchored on the commitment and beliefs of its holder. Thus, in the context of a GSS supported meeting, group processes are aspects of convergence and consensus that need to be effectively dealt with in order for groups to move toward knowledge creation worthy of subsequent storage, transfer and application as a desired outcome.

Knowledge creation is further complicated in that aspects of both tacit and explicit knowledge co-exist. Nonaka (1994) notes that "in order to raise the total quality of an individual's knowledge, the enhancement of tacit knowledge has to be submitted to a continual interplay with the evolution of relevant aspects of explicit knowledge." Such is the nature of convergence. Nonaka (1994) also notes that "efficient knowledge creation requires quick inquiry and preprocessing of existing knowledge and information." EBS is especially suited to this activity in that ideas are quickly exchanged amongst individuals in a team that help counteract the problem of human exhaustion noted as a team weakness in information and knowledge creation (Nonaka 1988). GSS may increase the quality of knowledge creation by creating a forum for constructing and sharing beliefs, for confirming consensual interpretation, and for allowing expression of new ideas (Alavi and Leidner 2001).

Unfortunately, GSSs often demonstrate weaknesses in effectively supporting convergence (Kwok, Ma and Vogel 2002). There has been a paucity of focused research into convergence in GSS, and little is known about the factors involved in this important activity. There could be many possible factors and relationships influencing convergent processes. Our research question in this study addresses structure, which is central to the issue of converging during an overloaded and complex task. More specifically, the research measures the effects on group idea convergence of variations in task structure and time structure. The purpose of this paper is to present these findings. Implications are discussed and conclusions are drawn relative to knowledge creation and management.

2 BACKGROUND

A group using a GSS can generate a large pool of ideas in a very short time, but it can be difficult to manage such a large set of ideas and comments, which is one reason the pool of ideas tends to get shelved and not moved forward towards knowledge creation. In fact, groups that are more successful or productive in the idea-generation phase of an electronic meeting may find themselves completely bogged down by an overwhelming volume of ideas and comments to organize (Gallup et al. 1988; DeSanctis and Poole 1991). Groups in an overload condition can tend to take unnecessary risks (Lamm and Trommsdorff 1973) by accepting impractical ideas, making interpretation errors, or ignoring important ideas. Progress may even slow to a stop from group members becoming frustrated or confused (Guildford 1984).

From a general systems theory perspective, information overload results from the inability of living systems to process an excessive amount of data or information (Miller 1978). However, McGrath and Hollingshead (1994) define information overload as having too many things to do at once, and stress that GSS research should pay more attention to active physical operations and temporal features. Thus information load, in the context of GSS, has four components: task domain, the number of ideas, idea diversity, and time. Task domain is the general problem definition or question being addressed. Thus, some domains may trigger higher information loads than others. Controversial topics may induce higher levels of stress than more neutral topics. The second component is the number of ideas. In idea organization, this refers to the number of ideas presented to the group or individual group members. Higher numbers of ideas may lead to a higher information load. The third component is idea diversity. Some sets of ideas may represent more dimensions than others (Huff 1990). Multiple dimensions or higher idea diversity may be associated with higher information loads (Zigurs and Buckland 1998; Kiger 1984; Landauer and Nachbar 1985).

Time also has a significant impact on information load. While time is considered an environmental constraint in many models, it is an inherent part of information load and thus is included here, rather than in the environmental variable section. Given a large number of ideas to handle, reducing the amount of time available may increase information load. Therefore, a pool of ideas must be assessed for the number of ideas, the intrinsic load of the subject, or the task complexity, and the time constraints of the convergence task. Thus, the Newell-Simon model of human information processing suggests that there is an optimal level for humans to process data, and this is directly related to short-term memory (Davis and Olson 1985). Within Simon's framework (Kirton 1989), information overload may result from the interaction of high information loads, high task complexity (Jessup et al. 1990), and the limitations of the human information processor.

In comparison with cognitive load, Time-Interaction-Performance (TIP) theory predicts the effects of time pressure on groups, and (similar to cognitive load) may be of importance to convergence in GSS

meetings (McGrath 1991). For example, a central concept of TIP theory is entrainment, which occurs when members of working groups become somewhat synchronized, or temporally coupled, to one another and to the rhythms of the task that they are performing (Smith and Hayne 1997). A group can find that there is a transition at the midpoint of their allotted time for a task; pacing patterns can differ between the first half and the second half of the groups' task span. Thus, cognitive load may have some parallels with TIP theory in the context of GSS convergence.

With increased task complexity, or information load, the human information processor requires a reduction in cognitive effort by changing to a more effective information-processing strategy (Newell and Simon 1974). People try to minimize the effects of information overload by employing conscious or even unconscious strategies or heuristics in order to reduce information load (Cook 1993; Jacko and Salvendy 1996). Thus, it is likely that aligning the convergence task with the human information processing capability will improve the management of knowledge within GSS supported idea organization activities.

3 RESEARCH APPROACH

The research model below is designed to examine the effects of task structure and time structure on idea convergence. This research study falls into Quadrant II of McGrath's (1994) research strategies in which idea generation and intellective tasks are studied. The model shows the convergence interaction processes as a consequence of the properties of the group's members, their patterned relationships, the task, and the context in which they are working. The convergence activity, taking place in a group may enhance or reduce convergence effectiveness. The group's overall effectiveness in convergence depends upon the balance of factors illustrated in Figure 1.

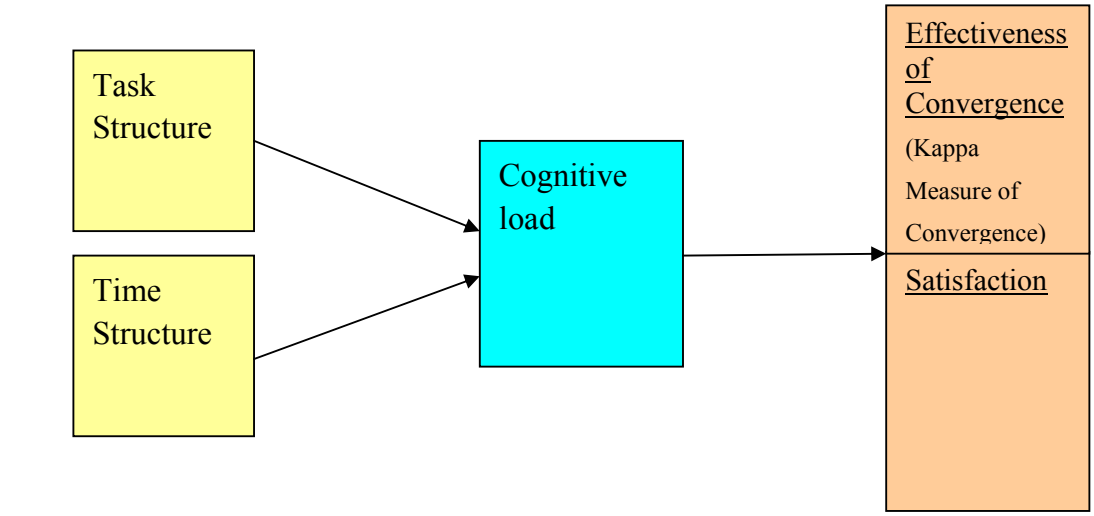

Figure 1 *Research Model: Convergence is defined as "moving from having many ideas to a focus on a few ideas that are worthy of further attention."*

3.1 Hypotheses

H1: Groups selecting ideas from a multiple criteria task formulation will converge better than groups working on a single criterion formulation.

It is proposed that by working on a subset of the main question, a subject will be able to spread their attention more evenly across the idea pool during the overall convergence process. This will reduce the chance of a question being overlooked, and questions more worthy for further consideration will be more to gain a high overall rating by the group.

H2: Groups working in multiple time periods will converge better than groups working in a single time period.

It is proposed that providing multiple time periods will introduce more primacy and recency into the task, and may also introduce "incubation" periods. This time structuring may have the same effect as the task structuring method. When individuals continue the task, they may focus on fresher aspect of the solution space, so that they redirect their efforts to a previously overlooked area. Studies of incubation have indicated that an incubation period of only a brief few minutes is sufficient to induce individuals to redirect their efforts and improve performance (Adamson and Taylor 1954).

H3: The effect of multiple time periods and multiple questions will be additive in terms of effecting convergence

It is hypothesized that the effects of task structure and time structure will be additive. Both of these variables will lead to an improved search and a reduced cognitive load, which should lead to better convergence performance. The wider exploration of the subject and focused attention on each part of the task will add effectiveness to the convergence effort, just as the reduced load due to increased primacy and recency through structuring the time periods will add to the effectiveness of convergence.

H4: Groups selecting ideas from a multiple criteria formulation will be more satisfied than groups working on a single criterion formulation.

Individuals in groups using multiple criteria will perceive that they have a useful method by which to converge, and a set of tasks that they can use to structure their own search for ideas. Multiple criteria may better direct participant's attention and reduce uncertainty as to how to converge, or how to select ideas more worthy of further consideration. Participants may also be more satisfied because they will perceive that they are under a low cognitive load during the proceedings.

H5: Groups working in multiple time periods will be more satisfied than groups working in a single time period.

To some extent, the perception of time available may be more important than the actual time available (Locke and Latham 1990). Considerable research has shown that the amount of time allocated to the initial time period can establish the pace of work used in subsequent time periods, even if those time periods are of different lengths (Kelly and Karau 1993). This effect, called "entrainment," shows that a short initial work period can induce the group to work more quickly in subsequent time periods when more time is available and that a long initial time period induces slower work even when faced with time pressure in later periods. Thus, assigning a set of short periods for convergence with breaks in between may better set the pace and mental set for convergence activities and this may lead to a more positive mental set and better satisfaction level.

H6: The effect of multiple time periods and multiple questions will be additive in terms of affecting satisfaction with convergence.

Multiple time periods and multiple criteria will better direct attention and structure convergence. This could reduce uncertainty by providing both time and task structure, and it is proposed that as subjects are quite capable of detecting the amount of mental load associated with a task, the subjects will appreciate the ability to rate ideas under reduced load. Participants will appreciate being able to assess which ideas are most suitable with a wider choice of questions to stimulate their thinking while reducing load. The ability to access more ideas in their mind will also increase the likelihood of the

activity being interesting. The reduced load from breaks during convergence will also increase levels of satisfaction. Therefore, increasing task and time structure will have an additive effect on the satisfaction levels associated with GSS convergence.

3.2 Operationalization

The pilot test involved an investigation into producing a representative pool of ideas and comments for convergence, how well the system performed for convergence, the level of consistency of the data produced, and an exploration into how best to conduct the main study.

The procedure for generating the original pool of ideas was conducted using 3 consecutive sets of 5 person groups using a GSS (GroupSystems) to brainstorm ideas. About 300 ideas and comments were initially generated. The ideas were sifted and the comments selected out to reduce redundancy, and some of the comments and ideas were improved for clarity and brevity in order to improve the flow of the experiment. Thus the pool was reduced to 100 ideas and comments; a manageable size for the experimental convergence task. The ideas chosen were used later for the measure of convergence.

Altogether 240 subjects undertook the convergence task. Twelve groups of 5 subjects were randomly assigned to each cell of the 4 treatments. Twelve groups of 5 were chosen for each of the 4 treatment cells as it has been found that below a certain number of groups per treatment, there is a significantly higher chance of an inconclusive result due to low statistical power (Fjermestad 1998).

The task set for the subjects was to converge on the most appropriate ideas to suit a particular goal, using the pool of ideas presented to them. The problem set for the subjects was to converge upon the ideas most worthy of further consideration, from a large pool of ideas that were generated to solve the problem of lack of space for social interaction at the university, and subsequently sorted to reduce redundancy of ideas. More specifically, the subjects were instructed to assess a large collection of ideas (100 ideas) generated by students and rated by an expert panel, and then select the best ideas from the original pool that they considered to be the most worthy of further consideration.

As the ideas were voted upon using a rating tool, the final rating list could be statistically compared for level of fit with a list rated by experts. Experts were chosen from the Campus Planning Department, the student Liaison department, and the health and safety departments in order to rate the ideas they thought most worthy of further consideration. The ideas were then taken together and ranked in order to find the overall expert ranking of ideas. The ratings were ranked, and the "expert rater's" ranking was used to determine the degree of agreement between the experimental groups and the expert ranking. The Kappa coefficient shows the level of agreement and takes into account the agreement occurring by chance (Cohen 1960). Thus, results could be grouped from zero to one, zero being no

agreement, 0.01–0.20 Slight agreement; 0.21– 0.40 Fair agreement; 0.41–0.60 Moderate agreement; 0.61–0.80 Substantial agreement; 0.81–0.99 Almost perfect agreement.

The treatments involve 4 different combinations. The 2*2 factorial experiment involves varying the criteria for convergence (1 question only, or 3 sub-questions), and varying the time structure (breaks every 5 minutes, or no breaks at all). Group 1 used a single criterion, and structured time convergence technique involving the use of just a single instruction for convergence (no sub-question sheet), and breaks were provided every 5 minutes until completion. Group 2 used a multicriteria and structured time convergence technique providing a sheet of 3 sub-questions to help the subjects in the group rate the ideas. There were 2 minute breaks provided every 5 minutes until completion. Group 3 used a multicriteria and unstructured time convergence process. This subjects were provided with a sheet of 3 sub-questions to help the subjects in the group rate the ideas. There were no breaks provided. Group 4 used a single criterion and unstructured time convergence process involving the use of just a single instruction for convergence (no sub-question sheet), and there were no breaks provided.

4 RESULTS

In this study, MANOVA tests were used to measure the main and interaction effect of time structure and question criteria on convergence and satisfaction with convergence. Results for each group process gain and process loss are illustrated in the summary tables. A discussion of the experimental results for each hypothesis and the implications of these results are presented below. The effect of multiple criteria seems to interact with the effect of time structure, increasing the overall effect on the kappa measure of convergence for that combination. The interaction on the MANOVA result is F=(4.417), P=(0.04) (Table (1)). Thus, the interaction between the breaks treatment and the multiple criteria treatment shows a significantly and additively higher score on the objective Kappa convergence measure.

Source	Dependent Variable	F	Sig.	Observed Power(a)
Interaction effect	Satisfaction	2.87	0.10	0.381
	Kappa	4.42	0.04	0.538

Table 1 Interaction effect between break/no break treatments and multi-mono question treatment

Table 2 shows the means of the results of each treatment. As shown, kappa is highest for multicriterion and breaks, and lowest for monocriterion and breaks. Satisfaction is highest for monocriterion and breaks and lowest for monocriterion and no breaks. Mental load results are highest in monocriterion and no breaks, and lowest in multicriterion with breaks.

	Mean Scores / (S.D).			
	Group 1 Monocriterion and breaks	Group 2 Multicriterion and breaks	Group 3 Multicriteria on and no breaks	Group 4 Monocriterion and no breaks
Kappa Results	0.31(0.07) Fair agreement	0.48(0.09) Moderate agreement	0.39 (0.12) Fair agreement	0.35(0.13) Fair agreement
Satisfaction Results	7.80(0.40)	7.47(0.59)	7.26(0.52)	7.12(0.40)
Mental Load Results	5.75(0.53)	5.48(0.36)	5.92(0.54)	6.03(0.56)

Table 2 The average of results of each treatment group

	Treatment	Hypotheses	MANOVA	Chi squared
Effect on convergence	Multi question	(H1)	Supported	Supported
	Time structure	(H2)	Not supported	Not supported
	Interaction effect	(H3)	Supported	NA
Effect on satisfaction	Multi question	(H4)	Not supported	Not supported
	Time structure	(H5)	Supported	Supported
	Interaction	(H6)	Weak support	NA

Table 3 A summary of the main results of the experimental study

Table 3 shows a summary of the main results of the study in terms of support for each hypothesis. In addition to the information tabulated, there is also strong evidence for the covariance of reduction in mental load with the increased Kappa measure of convergence ($F=17.159$ $p=0.000$). There was no support for the covariance of mental load with satisfaction, however ($F=0.254$, $p=0.617$). Therefore, lower mental load is associated as a correlation with higher convergence performance according to the Kappa measure of convergence, though higher satisfaction is not strongly associated as a correlation with mental load.

5 DISCUSSION

Results of the experiment indicated that both time structure, and question criteria do seem to have a direct effect on perceptual and empirical measures of convergence in this study and there is some interaction effect between time structure and question criteria. Findings additionally indicated that multiple time structure and multiple question criteria seem to act in an additive interactive fashion most strongly in the case of the empirical Kappa measure of convergence. There was also a weak interaction effect between multiple time periods and multiple questions additive in terms of affecting

satisfaction with convergence. This was tentatively explained with reference to the possibility of a reduced uncertainty associated with having 3 guidelines with which to help converge. Research into idea generation by Valacich et al (1994) shows that there can be a tradeoff between performance and satisfaction with performance in group support systems in idea generation specifically. A similar tradeoff is indicated in this study of convergent activities. Thus, as group work does rely somewhat upon sustained activity, satisfaction is an important consideration and breaks can be considered, even though there may be an impact upon performance.

Subjects in the multi question convergence sessions achieved a higher quality of convergence than those in the single criterion convergence sessions according to the kappa measure of convergence. This followed the hypothesis that the complexity of the material relevant in a sub-question will be less than that of an overriding question and the 3 sub questions could possibly make a better job of specifying the task of convergence to individuals. In this way they may be better able to think about the problem within, or closer to the optimal level of working memory. Cognitive load shows a correlation with convergence quality, and this also supports the first hypothesis in that a reduction in cognitive load is expected to increase mental processing capacity. Time structure had a positive effect on satisfaction with convergence. It is proposed that this may be due to the perception of time available and its effect on the perceptions towards the result. Time structure had no significant effect on convergence. This has also been found with idea generation tasks (Dennis et al. 1999), in that time structure had no significant effect on idea generation. It may also be that the primacy and recency effects of taking breaks may not be sufficient to significantly increase the memory of the overall range of ideas.

Therefore, as with studies looking into idea generation using a GSS, structuring the group process in this way is likely to have an effect on the process in the field. As the effects are interactive, care and planning should be taken in order to produce the desired effect. As cognitive load co-varied with the ability to converge according to the test, and this confirms previous conjectures and theories, cognitive load research is relevant in managing and organizing knowledge on group technology such as GSS. This is especially important regarding well organized screen design, and organizational schemas such as advanced organizers and outlines (Allen 1983), and this research indicates that managing the group process and the technology within mental load capacity will increase the likelihood of knowledge being more usefully organized within the final product of a convergence activity.

6 CONCLUSION

This study contributes to the field of GSS in that it has shown that development of an objective measure of convergence is possible, and can be developed further. Theoretically, the study has shown that HCI and information processing theories can be applicable to the study of convergence processes on the way towards knowledge creation. Practical contributions are the indication that multiple

question formats may well improve convergence activities and mental search, and that mental load is a correlated with convergence outcomes. These can be easily manipulated using a variety of tools, processes and adjustments, such as with specific ranking and voting features that are important for pragmatic GSS implementation (Stahl 2006).

The study is limited to generalization only within the student population. However any difference in ability should have been handled using random assignment of subjects. As multiple criteria seem to improve convergence, it seems it would be beneficial to measure other methods for improving mental search, and clarifying the goals of the convergence task. Theory and measurement of convergence requires further similar studies in the research stream in order to confirm and clarify this study.

It is hoped this research will be a preliminary direction guide, in addition to other research on GSS, for helping practitioners improve convergence on GSS as an aspect of knowledge creation. It is also suggested that further research be conducted in order to confirm the results of this research with the possible use of other variables. In this way, research into convergence activities in GSS will continue to remove uncertainties and clear the way for improved practice in the field.

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