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Computer-mediated group communication and ideation performance

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Abstract

Computer-based group idea generation is used in a variety of organizational settings to generate ideas that are helpful in attaining a goal. In such situations, the characteristics of the interaction may impact on the group processes, and accordingly on group performance. This paper reports on a study investigating the impacts of synchronicity, parallelism and identification on ideation performance. The results show that both parallelism and synchronicity are important for ideation performance, but that the levels of these affordances have no impacts when it comes to generation of low quality ideas. However, as the quality criteria are sharpened, the importance of the affordances increases. The results thus show that high degrees of parallelism and synchronicity are important for generation of high-quality ideas in computer-mediated group work. The results also point to the importance of adopting rigorous measures when investigating group ideation performance. Implications for research and practice are discussed.

Keywords: ideation, computer-mediated communication, electronic brainstorming, virtual groups, idea quality

1 INTRODUCTION

New organizational forms and work arrangements are evolving as the increase in use of information and communication technologies (ICT) renders possible real-time data sharing and comprehensive interaction across geographical and organizational boundaries. In order to create successful new products and services in competitive and global markets, new product development groups whose members interact by use of ICT (i.e. virtual groups), are increasingly being assembled both within and between organizations (Jung, Schneider, & Valacich, 2010). Such groups consist of members who are formally assigned and work towards achieving a specific goal, and thus differ from networks and communities of practice.

Producing creative solutions to problems is an important task for virtual groups in the workplace (DeRosa, Smith, & Hantula, 2007). That is, the quality of the ideas the virtual group produces is fundamental (Girotra, Terwiesch, & Ulrich, 2010), and the objective of this study is to investigate the effects of communication characteristics on ideation performance of virtual groups. This field of research has received substantial attention the last decades, but research within this domain has been conducted based on a widely accepted belief that there is a positive relationship between the quantity and the quality of ideas that are put forth in group work. Recent research has been questioning this view (Briggs & Reinig, 2010), and has actually shown that high idea quantity may be detrimental to the generation of high quality ideas that are worth pursuing in later innovation phases.

On this basis, this study analyses the impacts of communication media affordances on several performance indicators, and by this makes a more rigorous investigation of the relationship between communication characteristics and ideation performance. The paper is organized as follows. First, the theoretical basis for the research is presented, including development of hypotheses. The methodological approach is thereafter described, and the results of hypotheses tests are presented. Finally, the paper concludes with a discussion of results, limitations of the study, and suggestions for further research.

2 THEORY AND HYPOTHESES

All innovations originate from ideas (Boeddrich, 2004). The very early stages of the innovation process, often referred to as the fuzzy front end of innovation (Smith & Reinertsen, 1991), are therefore important in order to generate ideas that can be developed into practicable project proposals and subsequently result in successful innovations (de Brentani & Reid, 2012; Boeddrich, 2004). In this respect, the concept of *ideation* refers to the process of generating or conceiving of new ideas, and the main objective is generally to generate ideas of high quality (i.e. ideas which are helpful in attaining a goal) (Reinig, Briggs, & Nunamaker, 2007). Ideation is typically carried out in brainstorming groups, as it is widely believed that groups are superior to unaided individuals (DeRosa et al., 2007). This is based on the proposal of Osborn (1957) that groups would produce more and better ideas than individuals working alone. However, these assertions have been subject for extensive investigation, and have been disconfirmed in numerous studies (DeRosa et al., 2007; N. L. Kerr & Tindale, 2004). In light of these findings, considerable attention has been devoted to studying electronic brainstorming groups as the communication form is believed to reduce some of social psychological factors that are said to underlie the weaknesses of traditional (face-to-face) brainstorming (Mullen, Johnson, & Salas, 1991; Munkes & Diehl, 2003). In fact, the superiority of electronic brainstorming over face-to-face brainstorming has been clearly demonstrated (D. S. Kerr & Murthy, 2009; Valacich, Dennis, & Connolly, 1994; Valacich, Paranka, George, & Numamaker, 1993).

Ideation is to a large extent a social process, and Leonard and Sensiper (1998) assert that quality of group collaboration is more important than individual factors in idea generation. The social context may thus enhance or inhibit creative activity. Accordingly, in group-based problem solving situations, it is common to speak of process gains and process losses as results of elements like group characteristics, task characteristics, context characteristics, reward structure, etc. (McGrath, 1984). An individual's contribution (e.g. idea, comment, criticism, etc.) in group work is shaped by this context of enhancing and stifling forces (Valacich, Dennis, & Numamaker, 1992). In other words, certain aspects of the situation improve outcomes, while others impair outcomes, and the results of problem solving activities are thus contingent upon the balance of the process gains and losses (Connolly, Jessup, & Valacich, 1990). There are many different sources of gains and losses that can be attributed to situational factors of group interaction. Nunamaker, Dennis, Valacich, Vogel and George (1991) list several process gains and process losses that, depending upon the situation, vary in strength (or may not exist at all).

The processes of *production blocking*, *free riding* and *evaluation apprehension* are identified as significant causes for productivity loss in brainstorming groups (Diehl & Stroebe, 1987, 1991; Paulus & Yang, 2000). Production blocking implies that group members are prevented from contributing ideas as they occur (e.g. because only one group member may speak at a time). Evaluation apprehension refers to withholding of ideas and comments due to fear of negative evaluations from other group members, and free riding occurs when group

members rely on others to accomplish the tasks (as they expect that the ideas will be analysed at a group level). This is related to social loafing, referring to the tendency of individuals to exert less effort when working with others (Wagner, 1995). Communication technologies that are able to reduce such inhibiting group processes may thus facilitate ideation. In this respect, Avital and Te'eni (2009) use the concept of generativity when discussing the importance of computer systems to "enhance our creativity, reveal opportunities, and open new vistas of uncharted frontiers" (p. 345). In particular, they argue that generative fit, denoting the extent to which an information system can complement, bolster and enhance the users in seeing new configurations and possibilities for the task they face, is essential for system design and usage. Usefulness of communication media thus depends on the tasks that are to be solved (Dennis, Wixom, & Vandenberg, 2001).

According to Leonardi (2011), technologies have material properties that afford different possibilities for action. Burgoon et al. (1999) also argue that communication technologies can be understood in terms of their abilities to enable specific affordances of the communication process. In group-based ideation, affordances of communication media that are influential for the strength of production blocking, evaluation apprehension and free riding may therefore be central performance determinants. Generative fit may thus depend on the abilities of the communication media to reduce these process losses, and in this respect we argue that the affordances of synchronicity, parallelism and identification are central.

Synchronicity refers to whether the interaction is same-time or not (Burgoon et al., 1999), and may be important for ideation performance in group work. While there are many different methodologies about how to most effectively engage in idea generating activities, one element they have in common is that the free flow of initial ideas must occur without the interruptions of criticisms or evaluations. In this respect, the level of synchronicity may be important as it is influential for the response characteristics of the interaction. That is, group members' expectancies regarding timing of feedback may depend on the level of synchronicity of the interaction. It is for example likely that the group members expect immediate responses on the ideas that are presented when the interaction occurs in real time, and may therefore influence the level of production blocking. Further, it can be argued that high synchronicity does not render possible a critical examination of neither the ideas that the sender is to put forth (rehearsability), nor the ideas or messages that an individual has received from other participants (reprocessability) before composing a response. High synchronous interaction may by this reduce evaluation apprehension, and thereby facilitate the proposal of numerous and innovative ideas. We therefore propose that:

Hypothesis 1: Participants involved in interaction with high synchronicity produce a higher number of new ideas, and b) ideas with higher quality than participants involved in interaction with low synchronicity.

Parallelism refers to the number of simultaneous conversations that can effectively take place in a group work situation (Dennis, Fuller, & Valacich, 2008; Dennis & Valacich, 1999). Interaction with high parallelism thus implies that the group members can be engaged in multiple dialogues at the same time, and therefore do not have to take turns in utterance of contributions. This characteristic of interaction may be of particular importance when it comes to the level of production blocking, which may occur when group members cannot express their ideas when someone else is talking (Diehl & Stroebe, 1991; Paulus & Yang, 2000; Shepherd, Briggs, Reinig, Yen, & Nunamaker, 1995). In these situations, a group member may forget an idea while waiting for a turn to speak, or may devote attention to remembering an idea and may therefore be too distracted to generate new ideas (Diehl & Stroebe, 1987; Nunamaker, Dennis, Valacich, & Vogel, 1991; Nunamaker, Dennis, Valacich, Vogel, et al., 1991). In line with this, Nijstad, Stroebe and Lodewijkx (2003) found that delays between production and articulation of ideas are an important factor for production blocking. Dennis et al. (1997) also found that groups involved in multiple dialogues generated more ideas, more high-quality ideas, and more novel ideas than groups using single dialogues. We therefore expect that:

Hypothesis 2: Participants involved in interaction with high parallelism produce a higher number of new ideas, and ideas with higher quality than participants involved in interaction with low parallelism.

Identification refers to the degree to which the originator of contributions to group work can be identified. This affordance is by this equivalent to the understanding of content anonymity, which Valacich et al. (1992) define as "the extent to which group members can identify the source of a particular contribution to the group" (p. 224). Several authors have identified anonymity as an important aspect of group decision support systems as it may encourage full participation of group members that otherwise would have been socially inhibited from expressing ideas (Kraemer & King, 1988; Nunamaker, Applegate, & Konsynski, 1988). In other words, group members engaged in problem solving sessions where the contributions are linked to the contributor, may be unwilling to express their ideas because they are afraid of negative evaluation (Paulus & Yang, 2000). Maintaining anonymity can thus reduce evaluation apprehension and might promote the generation and sharing of more non-redundant ideas and more controversial ideas (Cooper, Gallupe, Pollard, & Cadsby, 1998; DeRosa

et al., 2007). In contrast, there is also a possibility that low identification will lead to a reduction of the group members' awareness of responsibility. However, Suleiman and Watson (2008) found that identifiability of group members had no observable effect on social loafing. Jessup, Connolly and Galegher (1990) also studied the influence of anonymity on group processes in a CMC setting, and found that anonymous interaction resulted in more comments, more critical probing, and more clarifications and adding to ideas that were put forth. Similarly, both Cooper et al. (1998) and Connolly et al. (1990) found that anonymous groups generated more different problem solutions than identified groups. We therefore expect that:

Hypothesis 3: Participants involved in interaction with low identification produce a) a higher number of new ideas, and b) ideas with higher quality than participants involved in interaction with high identification.

3 METHOD

3.1 Experimental design and treatments

To compare the ideation performance of group members communicating by use of media with different levels of synchronicity, parallelism and identification, we designed an experiment that allowed us to manipulate the communication affordances and measure the quantity and quality of ideas generated during a problem solving session. The research design including collaborative tools and manipulations is shown in Table 1. Text-based communication tools were chosen because of the need to create variance in synchronicity, parallelism, and identification while holding the levels of other communication affordances constant across conditions.

Table 1: Experimental design

Condition	**Collaborative tool**	**Affordances**		
		Synchronicity	***Parallelism***	***Identification***
1	Discussion forum	*Low*	*High*	*High*
		Time-lag of minimum 3 minutes between posting and reading of messages	Multiple dialogues possible	Link between contributor and contribution
2	Shared note-pad/ text editor	*High*	*Low*	*Low*
		Real-time interaction	Sequential contributions - similar to face-to-face interaction	No link between contributor and contribution
3	Discussion forum	*High*	*High*	*Low*
		Real-time interaction	Multiple dialogues possible	No link between contributor and contribution

12 experimental sessions with a total of 27 problem-solving groups and 95 participants were conducted. The subjects were randomly distributed into problem-solving groups that belonged to one of the three conditions. Condition 1 consisted of 8 groups (and a total of 32 participants), condition 2 consisted of 10 groups (32 participants), and condition 3 consisted of 9 groups (31 participants). There were between 3 and 5 participants in each problem-solving group.

Manipulation of synchronicity was ensured by instructing groups in condition 1 to work offline, except for brief online periods every three minutes when the contributions (ideas, comments, etc.) were transmitted. Problem-solving groups in condition 2 and 3 were working online. Regarding parallelism, high parallelism (groups in conditions 1 and 3) was implemented as discussion forums that allowed for simultaneous postings. Participants in condition 2 on the other hand were communicated by typing messages in a shared text editor, and simultaneous typing would thus be regarded as mutual interruption. In order to ensure high perceived identification (groups in condition 1), the names of the contributors were displayed together with their postings. This was not the case for the problem-solving groups in conditions 2 and 3, thus ensuring low identification.

3.2 Task and subjects

The theme of the group work was streaming of music and peer-to-peer sharing of audio files on the Internet. More specifically, the group members were given the task to discuss the problem of non-commercial (private) distribution of music on the Internet, and come up with ideas and solutions for products and services that were suitable and beneficial for both the music industry (various actors) and the consumers. A business-

related challenge caused by increasing use of information and communication technologies was thus chosen instead of a typical creativity research task (e.g. the "additional thumbs problem" - see e.g. Dugosh & Paulus, 2005) in order to increase the practical value of the experiment. The groups were given 30 minutes to discuss the problem, and the total experimental session (including introduction and debriefing) lasted for approximately 45-50 minutes. The interaction among the group members was based on Groove (collaboration software), and the subjects were given an introduction to the software in plenum prior to the problem solving session. In addition, letters explaining the task to be solved and the specific use of collaboration tools in Groove (according to the manipulations) were handed out.

As a consequence of the characteristics of the experimental setting, the participants had to be relatively experienced in using electronic communication media (collaboration software in particular). They further needed some prior knowledge of the problem that was to be discussed (peer-to-peer file sharing), and use of business school students therefore seemed appropriate. Subjects (56% male and 44% female) for the experiment were on this basis recruited from several graduate and undergraduate courses within the fields of information science, organizational behaviour, and strategy and management at a business school. Participation in the experiment was voluntary, and had no bearing on performance on the courses. A small compensation was provided for participation.

3.3 Measures

According to Lowry, Romano, Jenkins, & Guthrie (2009), participants' perceptions of media affordances are central when investigation effects of communication characteristics on group work. On this basis, the experimental setup, including configuration of collaborative tools and work process instructions, was designed to create variance in perceptions of synchronicity, parallelism, and identification. These perceptions were measured by use of a questionnaire applying a five-point Likert scale distributed after the problem solving sessions. The following items were applied (resulting in satisfactory discriminant and convergence validity of the constructs):

Synchronicity: 1) I could provide immediate feedback on the other group members' contributions; 2) I could get immediate feedback on my contributions; 3) My response time to contributions from other participants could be very low (*negative indicator*); 4) The response time of the other group participants to my contributions could be very low (*negative indicator*). Parallelism: 1) Thoughts and ideas that popped up could be presented without interrupting other group participants; 2) Ideas and thoughts that popped up could be framed immediately without risking everyone speaking at once; 3) It happened that I delayed proposing thoughts and ideas that popped up because I didn't want to interrupt other group participants (*negative indicator*). Identification: 1) The other participants in the group knew which contributions were mine; 2) It was easy to know who had presented an idea/comment; 3) It was easy to relate a specific contribution to the person who proposed it; 4) The contributors were generally unknown (*negative indicator*), 5) The collaborative tool made it possible for me to present my contributions without the other participants knowing that they were mine (*negative indicator*).

Based on the perceptions of affordances, the participants were distributed in groups of high and low levels of synchronicity, parallelism and identification, which again were applied in the hypotheses testing. T-tests to assure that the differences in perceived values of the independent variables between groups were appropriate for further analyses were also conducted. The results of these tests showed that the difference in score on synchronicity between the high/low synchronicity-groups was significant (high=4.43 vs. low=2.80, giving: t=-12.94, d.f=64, p<0.00), while the differences in scores on parallelism and identification were not significant (high=3.81 vs. low=3.65, giving: t=-0.72, d.f.=89, p=0.48, n.s., and high=3.12 vs. 2.98, giving: t=-0.60, d.f.=89, p=0.57, n.s., respectively). For the high/low parallelism-groups, the difference in scores on parallelism was significant (high= 4.49 vs. low=2.82, giving: t=-12.18, d.f.=57, p<0.00), and the differences in scores on synchronicity and identification were not significant (high=3.76 vs. low=3.60, giving: t=-0.82, d.f.=69, p=0.41, n.s., and high=3.10 vs. low=3.00, giving: t=0.43, d.f.=89, p=0.66, n.s., respectively). Finally, the difference in scores on identification for the anonymous/identified-groups was significant (high=4.09 vs. 2.09, giving: t=-18.15, d.f.=88, p<0.00), but the differences in scores on synchronicity and parallelism between these groups were not significant (high=3.62 vs. low=3.77, giving: t=0.71, d.f.=89, p=0.48, n.s., and high=3.73 vs. low=3.74, giving: t=0.01, d.f.=89, p=0.99, n.s., respectively).

Regarding ideation performance, there is a widely held conjecture that all else being equal, more ideas give rise to more good ideas (Reinig & Briggs, 2008). However, in testing the hypothesis that an increase in the quantity of brainstorming ideas (i.e. the total number of ideas, including bad ones) might directly stimulate the production of more good ideas, Briggs, Reinig, Shepherd, Yen and Nunamaker (1997) found that idea quantity was far stronger correlated with bad ideas than with good ideas. Accordingly, a quality focus may be more useful in ideation research (Briggs & Reinig, 2010), and multiple measures/indicators of ideation performance were on this basis applied in the study. That is, the measures of "idea count", "good idea count", "sum of quality" (i.e. sum of the quality scores of the individual ideas) and "average quality" as discussed by Reinig et al. (2007) were applied.

In order to obtain these measures of ideation performance, content analyses of the transcripts from the group discussions were conducted by three independent people. Ideas (i.e. solutions for the problem that was discussed in the groups) were identified, and also rated on a quality scale from 1 to 5 (i.e. the degree to which the idea was a novel and practical solution to the problem at hand). The coders did not discuss the content of the transcripts, and did not see the others idea-selections and ratings. Accordingly, they were not to discuss the ideas and agree on whether a contribution represented an idea or making quality assessments. The measures therefore represent the arithmetic means of the three coders.

4 ANALYSES AND RESULTS

Table 2 below presents an overview of the various performance indicators, more specifically the average number of ideas, the sum of quality, and average quality of the ideas put forth by individuals in the three affordances groups. The idea count columns show both the average number of idea contributions in total, and the average number of ideas within the quality categories (level 1 being ideas rated as poor quality, while level 5 is ideas rated as best quality).

Table 2: Descriptive statistics - ideation performance

Affordance	Group	Idea count (mean)						Sum of quality	Average quality
		Total	*Level 1*	*Level 2*	*Level 3*	*Level 4*	*Level 5*		
Synchronicity	High	9.3	1.2	1.5	2.2	2	2.6	31.5	3.3
	Low	7.7	0.9	1.7	2.1	1.7	1.7	25.5	3
Parallelism	High	10	1.1	1.7	2.3	2.1	2.8	33.6	3.3
	Low	7.1	1	1.5	2	1.5	1.5	23.5	3
Identification	High	8.1	0.9	1.5	1.9	1.9	2.1	27.4	3.1
	Low	9.1	1.2	1.7	2.5	1.8	2.3	30.3	3.2

As can be seen from Table 2, the high and low groups of both synchronicity and parallelism appear to differ on the ideation quality indicators. That is, the high-conditions obtain higher scores on both total idea count, sum of quality, and average quality of ideas. In contrast, the low identification condition seems to obtain higher scores on the indicators, but these differences are not as evident as for the synchronicity and parallelism conditions. In order to test the hypothesized differences between high and low levels of synchronicity, parallelism, and identification on number and quality of proposed ideas, analyses of variance were undertaken. Table 3 below shows the results of tests of differences in the average total (i.e. all innovativeness levels) number of ideas put forth by participants in the high and low groups of the three conditions.

Table 3: Dependent variable - number of new ideas

Independent variable	Group means		F	p
	High	Low		
Synchronicity	9.3	7.7	2.3	.135
Parallelism	10.0	7.1	7.6	.007
Identification	8.1	9.1	0.6	.455

Table 3 above shows that there are no differences in number of ideas proposed by participants in the synchronicity and identification conditions (high versus low). This does not lend support of H1a and H3a. However, we also see that participants involved in interaction with high parallelism produce a higher number of ideas during the problem solving session than participants in the low parallelism group. Accordingly, H2a is supported.

These results indicate that only parallelism is influential for the ideation performance of problem solving groups. However, following the argument in Briggs and Reinig (2010) and Reinig and Briggs (2008) that the number of ideas generated in an ideation session not necessarily is positive for ideation quality, other indicators should be included in the tests of hypotheses. According to Reinig et al. (2007), the sum of quality has a bias similar to the total idea-count measure as the score on this indicator can be increased by the presence of numerous poor-quality ideas. We therefore proceed with analyses of average quality (of all ideas) and good-idea-count.

Table 4 below shows the results of tests of differences in the average quality of ideas put forth by participants in the high and low groups of the three conditions.

Table 4: Dependent variable - average quality

Independent variable	Group means		F	p
	High	Low		
Synchronicity	3.3	3.0	4.1	.046
Parallelism	3.3	3.0	4.5	.037
Identification	3.1	3.2	0.2	.694

As can be seen from Table 4, there is no difference between participants in the high and low identification conditions, and H3b must therefore be rejected. For the corresponding groups in the parallelism and synchronicity conditions on the contrary, we find that the participants in groups with high levels of these affordances produce ideas with a higher degree of innovativeness compared to the low groups. This lends support for H1b and H2b.

In order to further investigate the impact of the synchronicity, parallelism and identification on ideation performance, 5 variables of idea count with various degrees of innovativeness were constructed: 1) "Idea quality 1" (innovativeness rating 1, i.e. poor quality ideas); "Idea quality 2" (innovativeness ratings 2 through 5); "Idea quality 3" (innovativeness ratings 3 through 5); "Idea quality 4" (innovativeness ratings 4 through 5); and "Idea quality 5" (innovativeness rating 5, i.e. high quality ideas). Thus, the variables represent an increase in the quality of ideas put forth in group work. Analyses of variance were conducted in order to test whether there were differences between high and low levels of media affordances on the various performance variables. Table 5 below shows the results of the tests.

Table 5: Effects of independent variables on ideation performance

Independent variable	Dependent variable	Group means		F	p
		High	Low		
Synchronicity	Idea quality 1	1.2	0.92	1.1	.301
	Idea quality 2	8.3	7.1	1.5	.226
	Idea quality 3	6.7	5.4	2.2	.143
	Idea quality 4	4.6	3.4	3.2	.077
	Idea quality 5	2.6	1.7	5.0	.028
Parallelism	Idea quality 1	1.1	0.98	0.7	.416
	Idea quality 2	8.8	6.6	5.3	.024
	Idea quality 3	7.2	4.9	6.6	.012
	Idea quality 4	5.0	3.1	8.0	.006
	Idea quality 5	2.8	1.5	11.7	.001
Identification	Idea quality 1	0.9	1.2	0.75	0.387
	Idea quality 2	7.3	8.2	0.55	0.462
	Idea quality 3	5.8	6.4	0.43	0.515
	Idea quality 4	4.0	4.2	0.11	0.747
	Idea quality 5	2.1	2.3	0.14	0.710

From the first five rows in Table 5 we see that the differences between the groups of high and low synchronicity are not significant for the first four dependent variables. For "Idea quality 5" however, the high synchronicity group has generated a significantly higher number of ideas than the low synchronicity group. It should also be noted that the differences between the groups increase as the quality standards get higher (though it is only the highest quality measure that turns out significant).

Regarding parallelism, Table 5 shows that the differences between the groups are significant for all variables, except "Idea quality 1". For "Idea quality 2" and "Idea quality 3", the differences between the groups are significant at the 5% level, while the differences between the groups are significant at the 1% level for the last two dependent variables. As for the effects of synchronicity, the differences between the groups (high versus low parallelism) increase with increasing quality standards. Regarding identification, no differences between the groups are found.

In summarizing the tests of hypotheses, we found that the number of ideas put forth in group work were dependent on level of parallelism (high parallelism resulted in a higher number of ideas compared to low parallelism), but not on different levels of synchronicity and identification. H2a was thus supported, while H1a and H3a were rejected. Regarding quality of ideas put forth, both parallelism and synchronicity were important. The tests revealed that high levels of these affordances resulted in higher quality of the ideas, and H1b and H2b

were thus supported. The level of identification had no significant effect on idea quality, and H3b was therefore rejected.

5 DISCUSSION

The study revealed some interesting relationships. First, the results showed that the level of parallelism is important for ideation performance. In general, interaction characterized by high parallelism appears to be more suited for generation of both numerous and high quality ideas. This is thus consistent with finding of Dennis et al. (1997). The fact that high degree of parallelism is positive for the total amount of ideas proposed is not surprising. Naturally, as the participants have to take turn speaking (low parallelism), the number of ideas that can be put forth is reduced. What is interesting is the difference in the quality aspect of the ideas. For ideas rated as having a poor quality (level 1), there were no difference in the number of ideas put forth. The same type of relationship is also found when it comes to the impacts of synchronicity. That is, the differences in ideation performance between the high and low conditions of both parallelism and synchronicity increase as the idea evaluation criteria are sharpened (i.e. increasing idea quality). This is particularly obvious for high synchronous interaction, as we find significant effects on ideation performance only for ideas with the highest quality. This means that the levels of these affordances are important for generation of high quality ideas.

With reference to the underlying rationale of the hypotheses, the results may indicate that production blocking caused by low parallelism and low synchronicity is a major detrimental factor for ideation performance. That is, production blocking is most apparent in interaction with low parallelism, causing the groups in this condition to perform significantly poorer on ideation work. Further, as discussed in the theoretical section, the effect of synchronicity can be attributed to both production blocking and evaluation apprehension. Whether the effects of this affordance on ideation quality were caused by either or both of these group processes is a question that remains to be answered, hence the combination of evaluation apprehension and production blocking is important to investigate in future research.

The results also indicate that production blocking is more evident for generation of high quality ideas. This can be explained by a plausible relationship between cognitive efforts and quality standards in idea generation. That is, the manifestation of deteriorative cognitive processes of group members due to production blocking becomes more evident with increasing ideation quality standards. Related to this, we should also notice that the results provides support for the assertion of Briggs and Reinig (2010) that the number of ideas proposed in idea generation tasks is an insufficient measure regarding the ideation performance of virtual groups.

The results showed that the level of identification had no influence on ideation performance in this study. This may indicate that identifiability of group members does not affect evaluation apprehension in a way that reduces the number and quality of ideas proposed in group work. Another explanation can be that the reduction of evaluation apprehension is overruled by an increase of free riding. In this case, the contributions of individual members are less apparent in an anonymous environment, and the production focus is thus moved from the individual to the group. As group members may expect that their ideas to be evaluated at the group level only, they may be inclined to free ride on the efforts of others (Diehl & Stroebe, 1987). However, whether the lack of a relationship between identification and ideation performance is caused by free riding problems remains an unanswered question. The relationship between evaluation apprehension and free riding issues in group interaction with various degrees of identifiability of group members should therefore be addressed in future research.

6 CONCLUSIONS

The overall objective of this research was to investigate how characteristics of computer-mediated communication influence ideation performance in virtual groups. An experiment was on this basis conducted that investigated the effects of different levels of synchronicity, parallelism, and identification on the number and quality of ideas put forth in group work. Regarding the former performance measure (idea quantity), the results of the study showed that high parallelism resulted in a larger number of ideas put forth compared to low parallelism, while there were no significant effects of synchronicity and identification. Regarding idea quality, identification of participants had no effects. In contrary, both parallelism and synchronicity were significant variables as high levels of these affordances resulted in higher quality of the ideas that were generated. The study further showed that the importance of these affordances for group ideation increases with increasing quality criteria. That is, the differences between high and low levels of synchronicity and parallelism increase as the quality standards get higher. This finding is the most important contribution of this study, and implies that computer-mediated group work aiming at generating high-quality ideas should consider the levels of parallelism and synchronicity in group interaction. In other words, these communication affordances seem to be important for the fuzzy front end of innovation.

Some limitations of the study should also be addressed. The first issue that should be commented is the lack of measurement of the important mediating variables of group processes (i.e. evaluation apprehension,

production blocking and free riding). This means that the explanatory logic underlying the interpretation of the results is on a hypothetical level. Future research should therefore measure important group processes in order to make a more rigorous analysis of the relationship between communication affordances, group processes, and ideation performance. The potential importance of group size when it comes to group processes (evaluation apprehension, production blocking, and free riding) in computer-supported group work, and subsequently on ideation performance, should also be mentioned. As an example of group size effects, Valacich et al. (1992) compared ideation performance between groups of 3 and 9 participants, and found *that* larger groups generated significantly more ideas (and higher-quality ideas as rated by judges) than did smaller groups. Mullen et al. (1991) also showed that process losses increase with group size. An important issue for future research is thus whether (and in case to what extent) the effects of various affordances on process losses dependent on group size, which again impact on ideation performance. Finally, the use of students as participants in the study may have affected the results. As pointed out by Pissarra and Jesuino (2005), use of students as subjects and running the experiments in a scholarly context, may contribute to the elimination of fears and to freeing the participants from evaluation apprehension. The degree to which the findings can be regarded as valid for other people (and in other settings) should be addressed in later studies.

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