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Conditions for innovation behaviour of virtual team members: a 'high-road' for internationally dispersed virtual teams

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Abstract

The central research question of this paper is "What are the conditions for innovative behaviour of virtual team members?". This is an important issue for companies given the impact of ICT on work. Virtual teams are assumed to be part of normal business life. This paper presents a preliminary model on three possibly relevant characteristics of virtual teams, and technological and organisational factors that moderate the relationship with innovation behaviour. Based on a survey among virtual team members (N=83 from 16 organisations with virtual teams) we present the results of a multilevel analysis. Main findings are that members spending more time in a virtual team score higher on innovative work behaviour. In virtual teams innovation behaviour can be stimulated by using reciprocal IT tools (like document sharing), coordination by trust (not by output) and high job demands. Counter-intuitive is the result, that high task dependencies in virtual teams in highly complex surroundings are negatively associated with innovation.

Keywords: virtual teams, innovation behaviour, co-ordination by trust and output, job demands

1. Introduction

How do virtual teams contribute to innovation? That is an important issue for companies given the impact of ICT in our world of work. The implications for teamwork are strong. Virtual teams differ from traditional teams at least on two characteristics: geographical dispersion and technology-mediated communication. Both benefits and pitfalls of virtual teams have been reported. Lipnack & Stamps (1997) observe important advantages of virtual teams, such as increased productivity, better knowledge sharing and cost savings by using less office space. Gassmann & Von Zedtwitz (2003), Jarvenpaa & Leidner (1999), Precup et al. (2006) and Shapiro et al. (2002) emphasise the risks of virtual teams, such as inefficiencies, poor collaboration, distrust, increased stress, work-life imbalance and technological problems. Several review studies on the effects of virtual teams report both positive and negative consequences for performance and satisfaction (see e.g. Martins, Gilson & Maynard, 2004; Powell, Piccoli & Ives, 2004; Hertel, Geister & Konradt, 2005). Therefore, the challenge for contemporary research is not only to study the effects, but rather to identify the *conditions* for successful virtual teamwork, both on organisation, group and individual level.

The central research question of this paper is "What are the conditions for innovative behaviour of virtual team members?". Based on a literature search on the conditions for virtual team innovativeness we present a model on characteristics of virtual work and moderating variables to innovative behaviour of virtual team members. The moderating variables that influence the relationship between virtual teams and innovation are technology related (such as use of ICT, type of collaboration tools) and organisation related (such as job demands, coordination mechanism and task dependencies).

We present the data of a new cross-sectional survey among virtual team members of sixteen Dutch companies that have globally dispersed virtual teams. The data were collected in 2006. The respondents work in virtual teams (operationalised as working at least 1/4 of their time in (project) teams with geographically dispersed members in different countries).

The paper is organised as following. Section 2 describes the theoretical framework. Section 3 is the method description. Section 4 presents the results of the multilevel regression analyses including interaction effects. Section 5 is the discussion of the results; here, both theoretical and practical implications will be provided.

2. Theoretical framework: virtual teams and innovation behaviour

Virtual teams are assumed to become mainstream in modern organisations: especially the multinationals that are operating globally are using this type of work organisation. By using virtual teams, they pull together all relevant knowledge's from different parts of the company. Estimates of the Gartner Group of some years ago were that in 2005 more than 60% of the professionals would work in virtual teams (Kanawattanachai & Yoo, 2002). To date, we do not know of any empirical study on this subject, so this is difficult to

judge, nevertheless, we may safely assume that particularly global operating companies are using virtual teams to cooperate across place, time and organisation boundaries.

The literature on virtual teams is growing; most of it is management-oriented literature, such as Lipnack & Stamps (1997). During the last decade a lot of academic literature has been published. They report studies on the effects of using virtual teams on human cooperation, team processes and organisational issues. Yet, many authors complain about the current state-of-the-art of the academic literature: most issues are unclear with diverse outcomes (Bell & Kozlowski, 2002; Griffith & Neale, 2001). Most of the literature is still conceptual, not empirical. If there is empirical literature, most studies are based on descriptive case-studies or quasi-experimental settings with (MBA)students as respondents. We may add that the empirical articles mostly report on specific issues; therefore the literature may be characterized as fragmented. To date, some good reviews are available of the existing academic literature on virtual teams (Beyerlein, Johnson & Beyerlein, 1999; Cooper & Rousseau, 1999; Gibson & Cohen, 2003; Martins et al., 2004; Powell, Piccoli & Ives, 2004; Hertel, Geister & Konradt, 2005).

Defining virtual teams

Among the more recent literature, some consensus exists on a minimum number of characteristics of virtual teams. The former definitions focused mainly on the virtual aspect of virtual teams. A widely used definition is from Lipnack & Stamps (1997, p.7): 'a virtual team works across space, time, and organizational boundaries with links strengthened by webs of communication technologies'. Two aspects are characteristic for the virtual setting: (a) distributed working, in other words co-operation between geographical dispersed locations, and (b) technology-mediated communication, since face-to-face communication is not possible. However, the team aspect also is vital. Therefore, the classic elements of teamwork are also important in virtual teams, such as task interdependence and shared goals. The more recent definitions of virtual teams take both sides into account: both the virtual and the team aspect. For instance, Martins et al. (2004) and Hertel et al. (2005) by and large have common elements in their definitions. Furthermore, it is striking that the recent definitions emphasise the degree of virtuality. Many empirical studies show that it is very difficult to assess the boundary between the 'real traditional team' and the virtual team. The more recent definitions acknowledge this issue and incorporate the degree of virtuality, such as Kirkman et al. (2004). The degree of virtuality is one of the constituent characteristics of teams, like the degree of diversity, autonomy or cohesion.

We may summarise these elements in the following definition:
'a virtual team is a group of people who cooperate to attain a common goal; the cooperation is supported by ICT to enable them to a certain degree to communicate and coordinate across time, place and/or organisational boundaries'.

A research model for the conditions for innovative virtual teams

The main research question of this paper is focusing on the relationship between virtual teams and innovation. Specifically we wonder what conditions shape innovation behaviour of virtual team members. The inputs-processes-outcomes (I-P-O) model is the

dominant framework used in the study of teams, both traditional and virtual teams (see e.g. Nunamaker et al, 1991). Team inputs are team size, knowledge, skills and abilities (KSAs), member characteristics and so on. Processes represent the dynamic interactions within the team, such as planning processes, communication and interpersonal processes that are characterised by a certain amount of trust, group identity and cohesion. Team outcomes are measured on organizational, group and individual level, such as performance, satisfaction and innovation. We followed a similar framework, albeit presented as an Input-Outcome model. However, the team processes are understood as moderating the input-outcome relationship.

We may conclude that the research into the effects and conditions of virtual teams is only at the beginning. So far, little unequivocal outcomes have been reported on the effects of virtual teams, both on the organisational and individual level. It is impossible to take into account all relevant input and moderating variables that have an impact on the relationship between virtual teams and outcomes. In addition, the phenomenon of virtual teams itself is a moving target: studies of the early 1990s measured the impact of a different generation of groupware and ICT compared to the more recent studies, ten to fifteen years later. The study we report here is not pretending to have all answers on the main research question regarding the conditions for innovative virtual teams. Nevertheless, some relevant insights are provided.

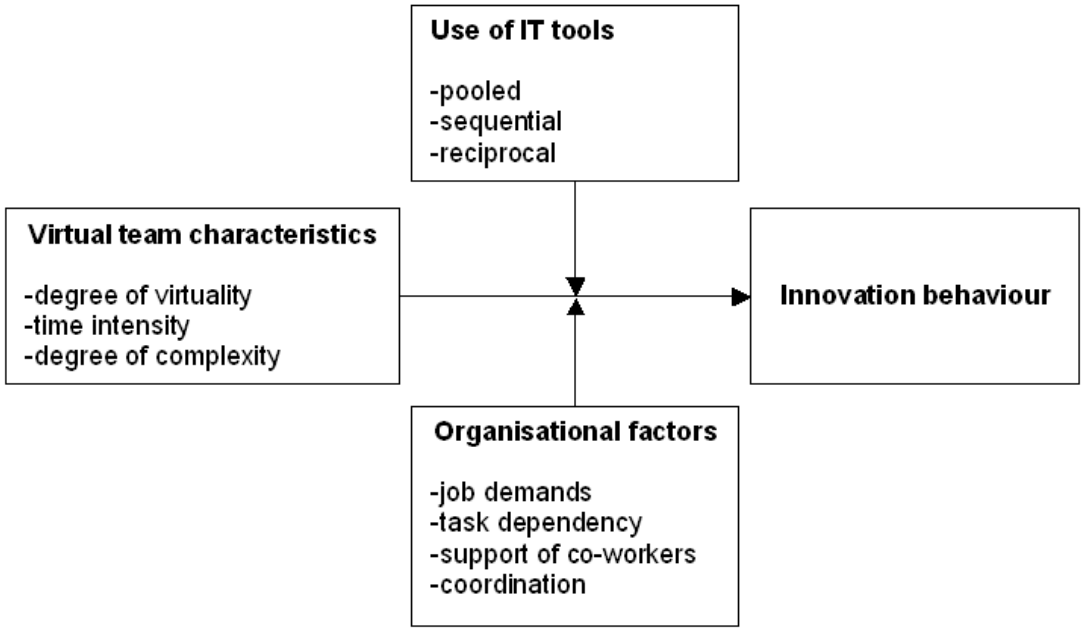
The research model presents a subset of relevant variables (Figure 1). Let us summarise our line of reasoning. We think it is important to distinguish between different characteristics of virtual teams. We make distinctions in the degree of virtuality (put in another way: the amount of face-to-face contacts), the time team members spend on their virtual activities, and the complexity and diversity of the team members. We may assume that virtual teams do have a high cultural and functional diversity. Team members with different nationalities and disciplines have to cooperate to accomplish their tasks. Several authors have raised the diversity issue as a potential source of misunderstandings and conflicts (see e.g. Susman et al., 2003; Fleming, 2004; Basset-Jones, 2005). Conflicts may harm the potential for innovation (Fleming, 2004; Basset-Jones, 2005). Therefore it seems to be an important condition for innovative virtual teams to deal with diversity and conflicts. One of the most important issues to deal with these potential conflicts is openness. Several researchers have shown that when task conflicts come up, those teams that can express their uncertainties and worries openly will be more innovative (Lovelace et al., 2001). Furthermore, greater trust among team members and among team leader and team members leads towards less conflict and more cooperation within the team (Williams, 2001). Additionally, the link between openness and information sharing is quite close. Open disclosure of information helps to overcome the inherent shortcomings of virtual teams: no face-to-face communication, feedback delays and lack of prior experience between team members.

Two broad sets of conditions are proposed in our model: technological and organizational conditions. Regarding technology, virtual teams do make use of technology by nature, they have to rely on ICT to communicate and work together. We make use of Thompson's (1967) three types of interdependence (pooled, sequential and reciprocal) to

classify IT tools supporting the virtual teams. We assume that every virtual team member uses the standard ICT like e-mail and mobile phone. In addition they use other types of IT tools that may differ in the degree of interdependence needed for using it. Pooled IT tools are the ones that may be used rather independent from each other, although the outcomes are important for the whole team (examples of this type of IT tools are file transfer protocol for exchanging files and shared project planning tools). Sequential IT tools are the ones that prescribe the sequence of activities, such as workflow software. Reciprocal IT tools are rather advanced tools for on-line collaboration such as online document sharing.

Regarding organizational conditions at least four issues are important. Job demands are the first one. Among others, Janssen (2000) showed the relationship between job demands and innovation behaviour. According to Karasek & Theorell (1990) task autonomy is an important factor in reducing the stress risks. If employees do have the possibilities to solve problems, the stress risks could be low. Kirkman et al. (2004) show that perceived autonomy is important: team empowerment – as perceived by the team members – is positive for the innovative capacity of virtual teams. The possibility of co-worker support is also important. This also may enhance a positive climate in the team and therefore the innovation capacity of the team members. The third organisational factor is the task interdependency. Teamworking is best when there is a certain degree of task and outcome interdependence (Wageman, 1995). When there is high task interdependence, one needs the other team members in order to be able to carry out the individual task. When there is high outcome interdependence one needs the other team members to achieve the own individual goals. The two forms of interdependencies together represent the strongest incentive for teamworking. While task interdependence increases the need for co-operation, outcome interdependence fosters the willingness to co-operate. Because then there is an individual gain in co-operation. For reasons of complexity and size of the model, we chose only to take the concept of the task interdependence. Finally, the last organisational factor is the coordination or control structure. We make a distinction between coordination by trust and coordination by output. High levels of trust lead towards high levels of cooperation and less levels of conflict between team members (Williams, 2001). We agree with other authors that trust is one of the fundamental factors that drive the success and failure of virtual teams (Lurey & Raisanghani, 2001; Kirkman et al. 2002). Daassi et al. (2006) showed that trust levels are associated with collective awareness levels; in addition they claim, in line with the studies of Van der Kleij (2007) that trust and collective awareness may increase over time making virtual teams more effective.

Figure 1: Research model



The research model (Figure 1) is used in the data collection and analysis of the data. The next section describes the method.

3. Research Method

3.1 Procedure and participants

The study was conducted among members in virtual teams with an international composition of team members. We used a two stage sampling procedure. Our gross sampling frame consisted of 2044 organizations. These were organisations with 100 or more employees in the IT, financial and other commercial services and organizations with 200 or more employees in the industrial sector. Because our aim was to test relationships between the concepts of interest, we used a fieldwork procedure in which we searched for cases fulfilling our criteria. A sample being representative for the Dutch workers' population was not our intention. As virtual teams with an international composition were not likely to be found in organizations in the public sector, agriculture and so forth, those sectors were excluded from our sampling frame.

To reach a sample with the size we aimed for (450 respondents) came out to be too ambitious due to practical reasons – i.e. costs, planning and response rate –, but probably also due to the size of the *population* of organizations with this kind of virtual teams. It might be questioned whether organizations applying this kind of teams are on the rise to such an extent as suggested by some consultants (like the Gartner group who estimated that in 2005 60% of professionals would have worked in virtual team settings).

The procedure followed in the fieldwork part of this study was phased as follows:

(1) An explanatory letter about the subject of this survey, addressed to HR.
(2) Telephonic screening aimed at a) examining whether the organization belonged to the group of organizations with internationally composed virtual teams, and b) contacting the - right - HR professional in the organization. We also used an incentive program in order to acquire a maximum response rate. HR professionals willing to co-operate in our research were given a voucher of 25 Euro for a 'charity' fund.
(3) When willing to co-operate in the survey, the HR professional received an automatic e-mail asking for the e-mail addresses of the virtual team members.
(4) A pre-announcement by the HR professional to the virtual team members. For this a text, which he could use, was provided to the HR professional.
(5) Online fieldwork amongst the team members, done by sending an e-mail with a link to the questionnaire. After two weeks, those who had not yet responded were reminded. Some non-respondents were reminded three items in total.

This procedure finally resulted in 156 respondents who opened the e-mail and clicked on the link to the questionnaire. Of those 156 respondents, 97 team members from 16 organisations in total met our criteria: working at least a quarter of the time in a virtual team with an international composition, not holding a supervisory position, and having filled out the questionnaire completely. Data from 14 respondents were removed, as they did not meet the inclusion criterion of having valid answers to all the variables of our research model. The final sample therefore comprised 83 participants working in 16 different organizations.

3.2 Description of the respondents

The questions assessing demographical information show that by large the respondents are male (78%). In general, the respondents are higher educated: 77% attained a higher vocational or academic degree, and another 20% higher general secondary/pre-university/intermediate vocational level. The respondents are approximately 35 years on average (range 20-50 years).

Most of the virtual team members (86%) in the sample work 30 to 40 contractual hours weekly. Working overtime is quite common (only 15% never does so, while 31% do work overtime 1-4 hours per week; 28% 5-8 hours per week, 19% 8 -16 hours/week and 7% more than that). Most of the virtual team members in the sample (98%) work during regular office hours (Monday to Friday in the daytime). Some work (also) during the evenings (12%), on Saturday (5%) or Sunday (5%), and/or during the night (2%). The sample consists of 35% of the respondents who work (almost) all of their time in (one or more) virtual teams, 19% does so approximately half of their working time, and 46% approximately a quarter of their time. The teams consist of 8.6 persons on average (SD=5.1).

The core business of the virtual team is characterized as 'software development, maintenance and support' by 28% of the respondents. By 24% it is characterized as

'creative/content-generating work (research & development, design, editorial work)', while in 18% of the cases the team's core business is 'data processing, typing and other forms of data input'. The others work in teams with another core activity. According to most respondents knowledge (48%) is the prime reason why the respondent has been selected to participate in the virtual team. Past performance was the prime reason in case of 16% of the respondents. 'Simply' the way the company is organized, leading to a virtual way of working co-operation, or as a result of "outsourcing of design", is perceived as the prime reason by 15% of the respondents. Other reasons applied for the rest of the respondents.

The 16 virtual teams studied consist of 8.6 persons on average (SD=5.1). Per team the team members are working dispersed across 3.1 different locations (SD=2.1) and on average the maximum difference in time zones is 4.9 hours on average (SD=3.8) between the locations where the team members are located. The respondents themselves mainly work in Europe (78%), 15% works in South- or East Asia, and 5% in North America. Co-workers also are mainly located in Europe, and/or in South- or East Asia and/or North America. Only few virtual team members or their co-workers are located in continents other than mentioned. The majority of the respondents (80%) work in a virtual team of which the members all belong to the same organization, while working across organizational boundaries applies to 20% of the respondents in the virtual teams studied. In the past 6 months, the entire virtual team met face-to-face only 2.4 times on average (SD=6.2).

3.3 Measurements

Table 1 presents the operationalisation of the characteristics of the virtual team setting, the organisational and technological conditions and the innovation behaviour while working. Here we explain only the three dimensions of virtuality. One dimension is 'time intensity of working in the virtual team', that is measured straightforward by one indicator on the amount of one's working time in a virtual team. The second dimension – 'degree of virtual (vs. physical) cooperation' – is operationalised on basis of the following indicators: 1) the number of times the entire virtual team did meet face-to-face; 2) whether a face-to-face kick-off meeting organized during the first two weeks of the start-up of the virtual team, and 3) the number of times the virtual team member uses face-to-face talks to communicate with other team members. The third dimension of the virtual team setting – the 'degree of complexity' – regards differences in time zones, cultures, number of locations and companies. The indicators used are: 1) the number of separate locations/buildings where the members of the virtual team work; 2) the number of organisations involved, and 3) the number of different continents involved in the virtual team.

Table 1. Measurements of the concepts under study

Concept	Sample item	Cronbach 's alpha	No. of items	Source
BACKGROND VARIABLES VIRTUAL TEAM				
History/experience in virtual team in years	How long ago did you join this virtual team? (number of years)			TNO (self designed)
Temporary (vs. permanent) virtual team	Is the virtual team you work in, a permanent or a temporary team? (0=permanent team; 1=temporary team)			TNO (self designed)
CHARACTERISTICS OF VIRTUAL TEAM SETTING				
Degree of virtual (vs. physical) cooperation	- In the past 6 months, how many times did the entire virtual team meet face-to-face? (min.=0; max.= 100) - During the first two weeks of the virtual team, was a face-to-face kick-off meeting organised?' (yes=0; no=100); - How often do you use face-to-face talks to communicate with other team members? (100=every day; 75=at least once a week; 50=a couple of times a month; 25=less often; 0=never)	.60	3	TNO (self designed)
Time intensity working in this virtual team: share of working time	How much of your working time do you spend in this virtual team? (25=approximately 1/4 of the time; 50=approximately 1/2 of the time; 100=(almost) all my working time)	-	1	TNO (self designed)
Degree of complexity of virtual team setting regarding difference in time zones, cultures, no. of locations and companies (range 0-100)	- In how many separate locations/buildings do the members of your virtual team work?' (max.=100); - Do all of the members of the virtual team belong to your company? (no=0; yes=100) - In which continent do you yourself work for the virtual team, most of the time? Combined with: In which continents do (some of) the other members of the virtual team work? (0=virtual team with members working only dispersed across locations in Europe; 50=across Europe ánd: Australia/New Zealand/Oceania or North- or South-America; 100=Europe and in: Africa or South- or East-Asia or the Middle East)	Index	3	TNO (self designed)
TECHNOLOGICAL AND ORGANISATIONAL CONDITIONS **Job demands**				
Quantitative job demands	My job requires working very fast (1=certainly not-5=most certainly)	.82	4	NOVA WEBA, translated and slightly modified (Dhondt & Houtman, 1992), (Kraan, Dhondt, Houtman, Nelemans, & Vroome, 2000)

Concept	Sample item	Cronbach's alpha	No. of items	Source
Use of Information technology (IT)				
Use of pooled/collective collaboration IT tools (ftp, shared tool for project planning)	How often do you use each of the following functionalities for data/information exchange with other team members: • file exchange through a network, for example using FTP (file transfer protocol); a shared tool for project planning (5=every day; 4=at least once a week; 3=a couple of times a month; 2=less often; 1=never)	Index (.44)	2	TNO (self designed)
Use of sequential/coordinated collaboration IT tool (1-never=5=every day) [tool: workflow software]	How often do you use each of the following functionalities for data/information exchange with other team members: • workflow software (5=every day; 4=at least once a week; 3=a couple of times a month; 2=less often; 1=never)	-	1	TNO (self designed)
Use of reciprocal/concerted IT tool (1-never=5=every day) [tool: document sharing]	How often do you use each of the following functionalities for data/information exchange with other team members: • document sharing (5=every day; 4=at least once a week; 3=a couple of times a month; 2=less often; 1=never)	-	1	TNO (self designed)
Task dependencies				
Intra team task dependencies	To complete my tasks, I am completely dependent on the way my colleagues execute their tasks (1=certainly not-5=most certainly)	.63	2	Campion, Medsker, & Higgs, 1993
Support of co-workers possible				
Support of co-workers possible	Colleagues in my virtual team are able to take over work if I cannot finish my tasks in time	-	1	NOVA WEBA, translated (Dhondt et al., 1992), (Kraan et al., 2000)
Control structure				
Coordination by output	In the past 12 months did you and your hierarchical supervisor make agreements about goals/targets to reach in your work?	.77	2	TNO Labour Relations survey 2005 (Kraan et al., 2006), modified and translated
Coordination by trust	My team leader trusts completely that I bring my tasks to a favourable result	.68	2	Trust Only Inventory (Gabarro & Atos, 1976), (Robinson, 1996), translated and modified.
OUTCOME				
Innovation behaviour	In my work I discover new solutions for bottlenecks in my work that remain unsolved	.77	3	Janssen, 2000, Janssen & Van Yperen, 2004, shortened, modified and translated

3.4 Statistical analyses

Descriptive analysis: characteristics of the virtual team setting and (production) organisational and technological conditions and innovation behaviour of the worker: Means and standard deviations of all model variables were computed, and correlations were computed to obtain insight especially in the associations between the innovation behaviour and the characteristics of the virtual team setting and the examined conditions (Table 2).

Testing of the relationships: multilevel analyses. Correlations offer basic insight in the associations among the innovation behaviour, characteristics of the virtual team setting and organisational and technological conditions. However, the structure of our data cannot be neglected and needs further examination. As explained in the previous section the sample consists of not just one respondent per company. As a result of our data collection design the data of the virtual team members (level 1) are not statistically independent as they are nested within companies (level 2). Statistical independency is the assumption of many regularly used statistical analysis techniques. Multi-level analysis (Hox, 2002) takes into account that the data at the lowest level are nested within a higher-order level, effectively resolving the statistical dependencies and the bias this may create.
A first measure indicating this dependency is the Intra-Class Coefficient (ICC or rho). In case of our dependent variable innovation behaviour of the worker, the ICC is 0.12 (computation based on Ukoumunne, Gulliford, Chinn, Sterne, & Burney (1999)). Thereby, the 'company effect' (level 2) in our study should be labelled as medium (0.10) to large (.15) according to a 'rule of thumb' by Hox (2002): cf. Zyzanski (2006). The maximum value for an ICC is 1, indicating that the variance in the dependent variable is totally accounted for by the variance at level 2. An ICC of 0 indicates that all variance is accounted for by the variance at the individual level 1 units. One can also study the design effect, in which the number of observations per group is an important factor. The design effect in our case is 1.51. It is sometimes stated that design effects smaller than 2.5 do not make it necessary to account for a multi-level structure. However, on basis of the mentioned rule of thumb (Hox, 2002) we decide to use multi-level analysis. We will specify several models and compare these models. The first model to be compared includes only an intercept and in the following models predictors (both on the person and on the day level) can be added consecutively. The improvement of one model above a previous one can be tested using a likelihood ratio statistic (following a χ^2-distribution with the number of additional predictors as df) (Hox, 2002).
We used the MLWiN 2.0 software package [Centre for Multilevel Modelling. MLwiN 2.0. Bristol: University of Bristol, 2005] and all variables were standardized based on their grand mean. As there was no reason to expect relationships between independent and dependent variables to differ between the companies in the study, we chose not to model random slopes, but only a random intercept. Another indicator for degree of dependency of the data is a test of the difference between the -2*Log Likelihood (-2*LL) of a first model with fixed intercepts and fixed slopes (not shown in Table 3) and our Null model with random intercept only: the -2*LL of the first model is 234.538, while the -2*LL of our Null model with random intercept is 231.234. The difference between these models (3.304) is not statistically significant (p=.069).

Table 2. Means, standard deviations (SD) and correlations (Pearson) of the variables under study (N=83).

	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11	12	13
1 History/working experience in virtual team [number of years]	2.61	3.84													
2 Temporary (vs. permanent) virtual team? [0=permanent; 1=temporary]	0.36	0.48	-.27*												
3 Degree of virtual (vs. physical) cooperation [scale 0-100]	77.79	24.40	.15	-.27*											
4 Time intensity working in this virtual team: share of working time [25=appr. 1/4 of the time; 50= appr. 1/2 of the time; 100=(almost) all my working time]	56.02	33.72	.20	-.14	-.17										
5 Degree of complexity of virtual team setting regarding difference in time zones, cultures, no. of locations and companies [Index 0-100]	32.16	26.89	.04	.32**	-.04	-.20									
6 Intra team task dependencies [1=certainly not-5=most certainly]	3.52	0.83	.05	.11	.01	-.02	.19								
7 Use of pooled/collective collaboration IT tools [tools: ftp, shared tool for project planning] [1-never=5=every day]	2.49	1.25	-.13	-.01	-.09	.24*	-.30**	.00							
8 Use of sequential/coordinated collaboration IT tool [tool: workflow software] [1-never=5=every day]	1.90	1.43	.00	.07	-.21	.25*	.04	-.06	.24*						
9 Use of reciprocal/concerted IT tool [tool: document sharing] [1-never=5=every day]	2.80	1.64	.03	-.07	-.26*	.19	.01	.03	.33**	.23*					
10 Control by output: targets to reach/possible to measure separate performance/organisation does this [1=certainly not-5=most certainly]	3.59	0.91	.10	.09	-.17	.04	.09	-.09	.11	.09	.20				
11 Support of co-workers possible [1=certainly not-5=most certainly]	3.24	1.21	-.04	-.05	-.01	.18	-.04	-.07	.15	.12	.06	.26*			
12 Coordination by trust [1=certainly not-5=most certainly]	3.98	0.75	.16	-.04	.00	.00	.06	-.20	-.10	.03	-.02	.42***	.46***		
13 Job demands [1=certainly not-5=most certainly]	3.72	0.74	.18	-.03	.12	-.05	.06	.09	.11	-.19	.07	.18	-.03	.01	
14 Innovation behaviour 1=certainly not-5=most certainly]	3.58	0.84	-.18	.16	-.25*	-.01	.07	-.06	-.10	-.08	.27*	-.04	.17	.11	.05

Note: * p<.05; ** p<.01; *** p<.001

However, because our sample size is rather small, statistical significance should not be the most important criterion. Therefore, we adhere to the first rule of thumb mentioned above, and go ahead with testing the relationships of interest using multi-level analysis. A series of analyses was conducted to study the relationships between on the one hand the characteristics of the virtual team setting and organisational and technological conditions and on the other hand the innovation behaviour of the virtual team member.
We started with a Null model, in which only a random intercept was specified. In Model 1, the characteristics of the virtual team setting and organisational and technological conditions were included to obtain insight in the relationships between these variables and innovation behaviour of the virtual team member. Model 2 additionally included the interaction terms: the 3 distinguished characteristics of the virtual team setting x the 8 conditions. These interactions are our main focus and indicate whether the strength of the relationship between the characteristics of the virtual team setting and innovation behaviour is modified by the organisational and technological conditions, and, especially, by which conditions. As can be seen in Table 3, every model mentioned is statistically significantly better in explaining innovation behaviour than the one previously tested. Or stated otherwise, the *interactions* of the characteristics of the virtual team and the organisational and technological conditions add explanatory ground in predicting the innovation behaviour of the virtual team member, as compared to a prediction simply based on the separate effects of the characteristics of the virtual team and the organisational conditions. In the next section we describe these results for the main and interaction effects more in depth.

Table 3. Multilevel estimates for Models relating innovation behaviour of the virtual team member to characteristics of the virtual team setting, and in interaction with the (work) organisational conditions.

Model:	-2*LL	diff -2*LL(df)	p	Level 1 intercept variance (SE)	Level 2 intercept variance (SE)
Null model	231.234				
Model 1	202.715	28.519(13)	.007	.863(.145)	.124(.111)
Model 2	149.422	53.293(24)	.001	.0612(.103)	.087(.078)

Note:
LL = log likelihood
diff = difference

Note:
Null model: Intercept only
Model 1: Intercept, main effects
Model 2: Intercept, main effects
+ interaction effects

Table 4. Innovation behaviour of the virtual team member (1=certainly not-5=most certainly)

	Beta	SE	Sign.
BACKGROUND VARIABLES VIRTUAL TEAM			
History/working experience in this virtual team	-.25	.128	n.s.
Temporary (vs. permanent) virtual team	.136	.089	n.s.
CHARACTERISTICS OF VIRTUAL TEAM SETTING			n.s.
Degree of virtual (vs. physical) cooperation	-.241	.124	n.s.
Time intensity working in this virtual team: share of working time	-.203	.09	p<.05
Degree of complexity of virtual team setting regarding difference in time zones, locations and companies	-.134	.095	n.s.
(ORGANISATIONAL AND TECHNOLOGICAL) CONDITIONS			
Intra team task dependencies	.004	.091	n.s.
Use of pooled/collective collaboration IT tools [tools: ftp, shared tool for project planning]	-.17	.104	n.s.
Use of sequential/coordinated collaboration IT tool [tool: workflow software]	-.101	.098	n.s.
Use of reciprocal/concerted IT tool [tool: document sharing]	.362	.112	p<.01
Coordination by output/targets to reach	-.422	.097	p<.001
Support of co-workers possible	.073	.100	n.s.
Coordination by trust	.411	.120	p<.01
Job demands	.106	.085	n.s.
CHARACTERISTICS OF VIRTUAL TEAM SETTING * (TECHNOLOGICAL, ORGANISATIONAL) CONDITIONS			
Degree of virtual (vs. physical) cooperation * Intra team task dependencies	-.291	.105	p<.01
Degree of virtual (vs. physical) cooperation * Use of pooled/collective collaboration IT tools	-.207	.133	n.s.
Degree of virtual (vs. physical) cooperation * Use of sequential/coordinated collaboration IT tool	-.105	.096	n.s.
Degree of virtual (vs. physical) cooperation * Use of reciprocal/concerted IT tool	.11	.141	n.s.
Degree of virtual (vs. physical) cooperation * Coordination by output/targets to reach	.114	.115	n.s.
Degree of virtual (vs. physical) cooperation * Support of co-workers possible	.06	.145	n.s.
Degree of virtual (vs. physical) cooperation * Coordination by trust	-.026	.159	n.s.
Degree of virtual (vs. physical) cooperation * Job demands	.289	.104	p<.01
Time intensity working in virtual team * Intra team task dependencies	-.145	.093	n.s.
Time intensity working in virtual team * Use of pooled/collective collaboration IT tools	-.035	.102	n.s.
Time intensity working in virtual team * Use of sequential/coordinated collaboration IT tool	.067	.097	n.s.
Time intensity working in virtual team * Use of reciprocal/concerted IT tool	-.141	.103	n.s.
Time intensity working in virtual team * Coordination by output/targets to reach	-.075	.090	n.s.
Time intensity working in virtual team * Support of co-workers possible	.255	.103	p<.05
Time intensity working in virtual team * Coordination by trust	.234	.121	n.s.
Time intensity working in virtual team * Job demands	.161	.115	n.s.
Degree of complexity virtual team setting * Intra team task dependencies	.151	.102	n.s.
Degree of complexity virtual team setting * Use of pooled/collective collaboration IT tools	.265	.104	p<.05
Degree of complexity virtual team setting * Use of sequential/coordinated collaboration IT tool	.174	.102	n.s.
Degree of complexity virtual team setting * Use of reciprocal/concerted IT tool	-.275	.095	p<.01
Degree of complexity virtual team setting * Coordination by output/targets to reach	-.379	.120	p<.01
Degree of complexity virtual team setting * Support of co-workers possible	.073	.115	n.s.
Degree of complexity virtual team setting * Coordination by trust	.575	.137	p<.001
Degree of complexity virtual team setting * Job demands	.421	.098	p<.001

Note: * p<.05; ** p<.01; *** p<.001

4. Results

Table 2 presents means, standard deviations (SD) and correlations of all variables under study. As can be seen from this table, only the degree of virtual (vs. physical) cooperation ($r=-.25$; $p<.05$) and use of a reciprocal/concerted IT tool (i.c. document sharing; $r=.27$; $p<.05$) are statistically significantly associated to innovation behaviour of the virtual team member. So, in this univariate analysis the organisational conditions are not statistically correlated to innovation behaviour of the virtual team member.

Results of the multilevel analyses: innovation behaviour of the worker
This section deals with the effects, as shown by the multi-level analysis (Table 4), of the characteristics and conditions of working in the virtual team on innovation behaviour by the worker. Besides several main effects the results also show several interaction effects. Although our sample is rather small, of the possible interaction effects of the three dimensions of virtuality on the one hand, and IT and organizational dimensions on the other, 8 out of 24 are statistically significant.

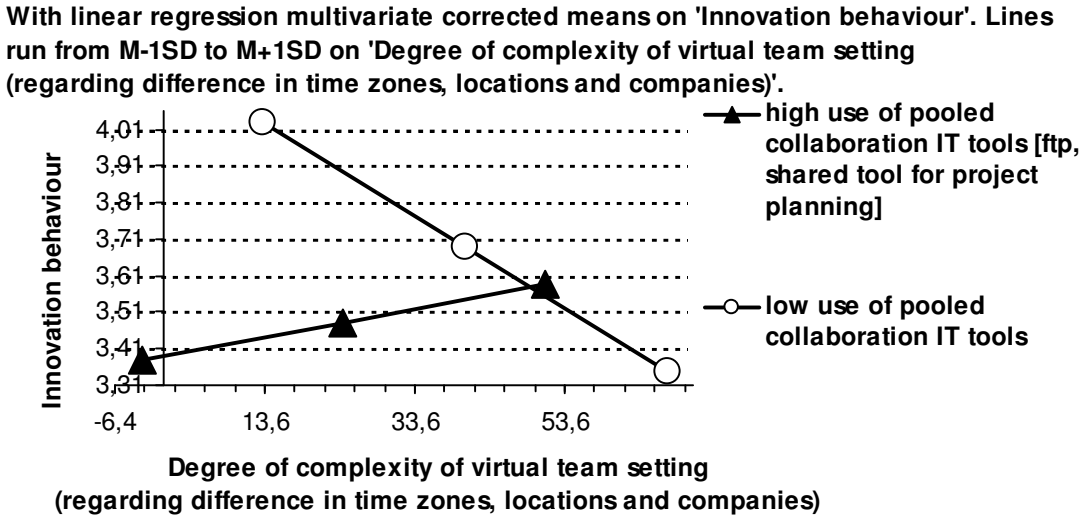
Regarding the three main characteristics of working in a virtual team, the results show that more time spent by the worker in a virtual team setting is associated with less innovation behaviour (beta=-.20; $p<.05$). The other two dimensions of virtuality (namely the degree of virtual instead of physical or face-to-face cooperation and the degree of complexity of the virtual team setting (regarding difference in time zones, locations and companies)) are not significantly associated with innovation behaviour of the worker. This result for the 'complexity' of the virtual team setting seems to be in contradiction with some literature (such as the information decision approach) stating that more diversity, which is partly measured by our indicator on complexity, is associated with more innovation behaviour.

Regarding the use of IT tools the analysis shows the relationship between the use of reciprocal/concerted IT tools – i.c. document sharing – and the worker's innovation behaviour (beta=.36; $p<.01$). Making more frequent use of reciprocal IT means more interaction and consequently more close and cohesive relationships within the group. That is positive for innovation behaviour. Use of pooled or sequential IT tools is not as such associated with innovation behaviour. Pooled IT tools are used for the planning of activities (the process), while reciprocal IT supports the content of activities. Therefore, we suggest that reciprocal IT is supporting innovation more than pooled IT.

However, the next two interaction effects provide a precision of this finding. The interaction effect shown in Figure 2 suggests that teams in highly complex virtual settings that make no or little use of pooled collaboration tools are showing less innovation behaviour. Apparently, investing little time in the process – supported by pooled collaboration tools like ftp, shared tools for project planning is bad for innovation. On the contrary, these highly complex virtual team settings need such kind of collaboration tools. However, this is not the case for low complex virtual team settings. The team members that make only low use of pooled IT show more innovation behaviour in low complex virtual settings. When teams are not so complex (in terms of number of time

zones, locations and companies involved), the need for pooled IT is not so high, probably because team members just are so homogeneous that they do not need advanced IT for project planning, agreement on activities etc.

Figure 2: Interaction effect "Degree of complexity virtual team setting * Use of pooled/collective collaboration IT tools" with innovation behaviour



Given our definition of virtual team complexity, in a context of high complexity the diversity is high. That means a lot of collaboration, adjusting and tuning to keep everyone in the team purposive. Nevertheless, the interaction effect illustrated by Figure 3 shows a different effect for the use of reciprocal/concerted IT tools (like document sharing). Within high-complex virtual teams the importance of using reciprocal IT tools decreases for the degree of innovation behaviour. Both reciprocal and pooled IT tools have a comparative effect on the degree of innovation behaviour in high complex virtual team settings.

About the organisational factors we present an interesting finding on task interdependence. As shown in Figure 4 the higher the task interdependence in highly virtual teams, the less innovative behaviour is found. That is counter-intuitive, because normally we assume that high task interdependency will benefit team performance (Wageman, 1995). Maybe an explanation is that high task interdependence leads to more interactions between team members. That requires a lot of the cognitive resources of the team members. To be innovative is then maybe too much of a good thing. As the cognitive network model suggests (Santanen et al, 2003), people cannot cope with too much interactions; the cognitive resources are in these complex settings needed for other matters.

Figure 3: Interaction effect "Degree of complexity virtual team setting * Use of reciprocal/concerted IT tool" with innovation behaviour

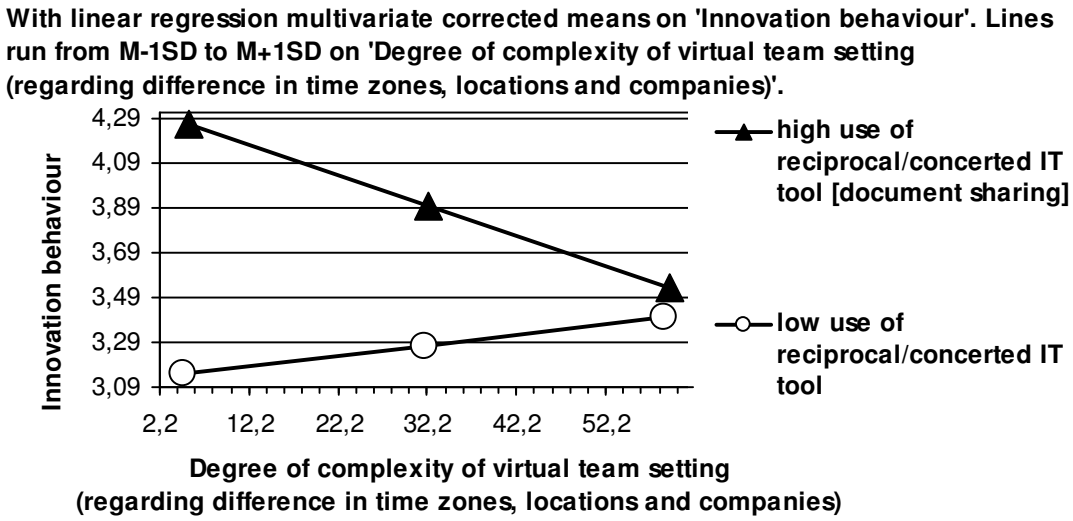
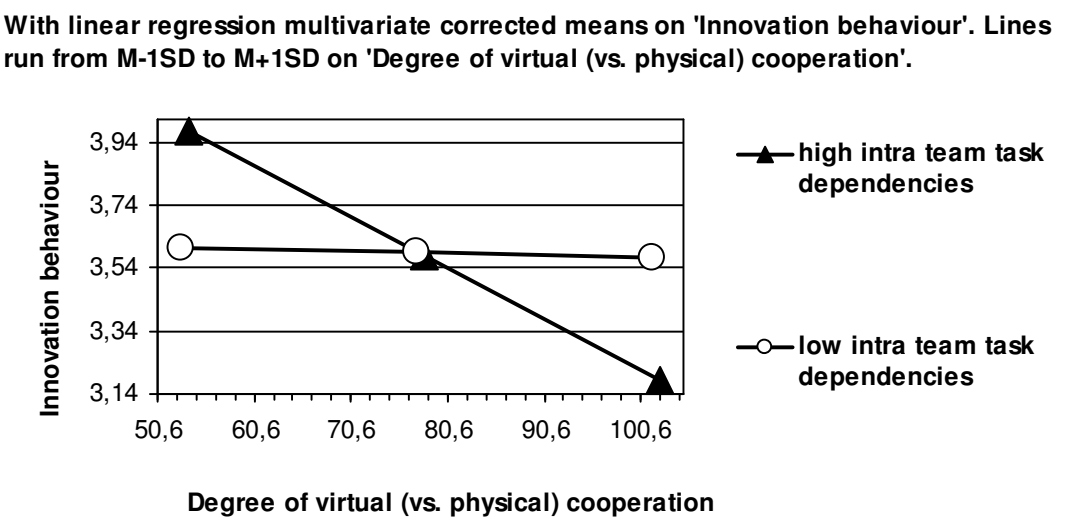


Figure 4: Interaction effect "Degree of virtual (vs. physical) cooperation * Intra team task dependencies" with innovation behaviour



The next issue in our research model regards the management of the virtual team members. The way the worker is managed matters for his/her innovation behaviour: in case of coordination by output/targets to reach, there is a negative association (beta=-.42; p<.001) with the innovation behaviour shown. Furthermore, our data suggest on the contrary, in the case of a high trust relationship, innovation behaviour by the worker is more common (beta= .41; p<.01).

On top of the negative main effect of coordination by output, Figure 5 also illustrates that less innovation behaviour is prevalent when coordination by output is applied more

strongly in virtual team settings with a high complexity. Again, the opposite is (strongly) the case regarding coordination based on trust (Figure 6): low trust relations in high-complex teams are associated with less innovation behaviour, whereas a high trust relationship is associated with more innovation behaviour.

Figure 5: Interaction effect "Degree of complexity virtual team setting * Coordination by output/targets to reach" with innovation behaviour

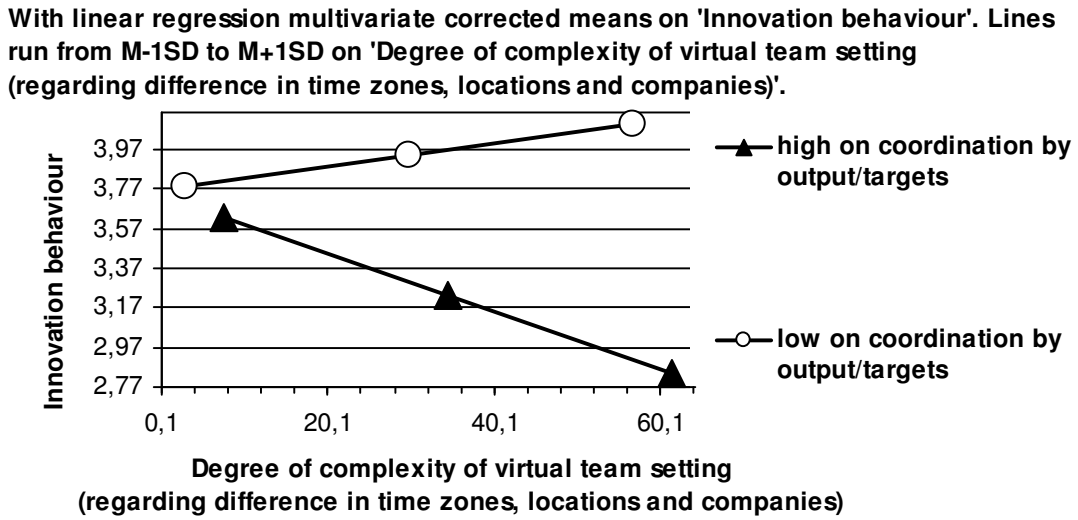
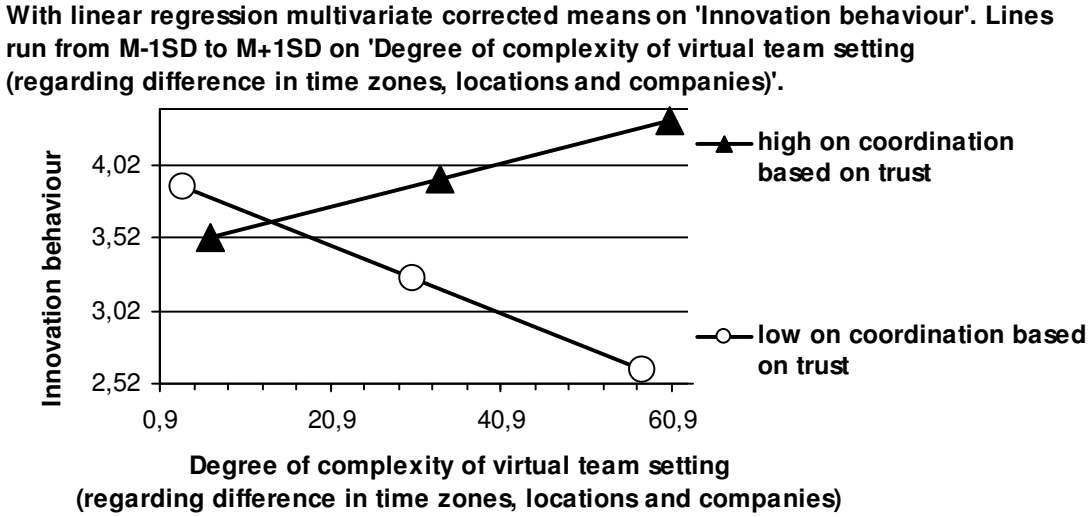
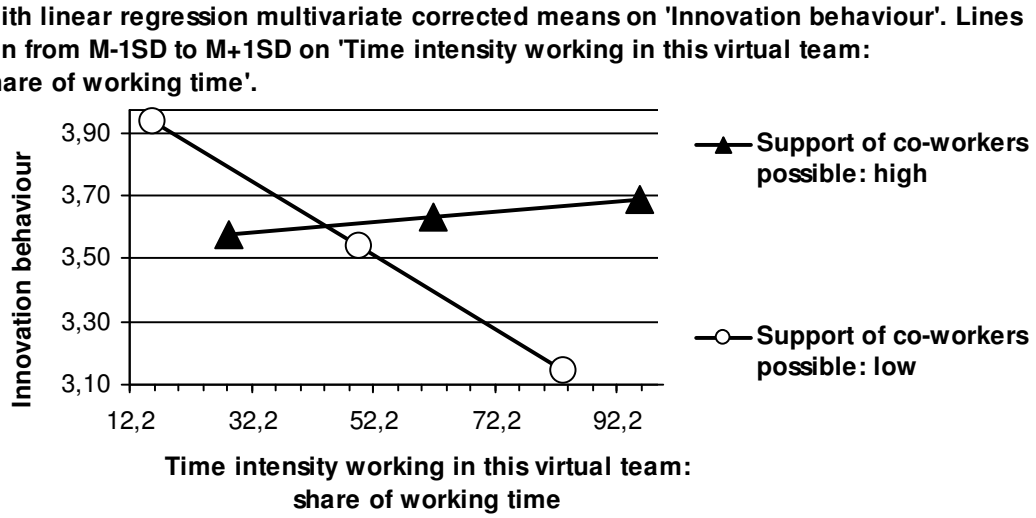


Figure 6: Interaction effect "Degree of complexity virtual team setting * Coordination by trust" with innovation behaviour



Co-worker support is another important issue for innovation behaviour in virtual teams. Figure 7 shows an interaction effect. When a worker spends more time in a virtual team and he or she can get less support from co-workers, then the innovation behaviour turns out to be lower. In other words, low-virtual work – and thus more face-to-face work – can be innovative without much co-worker support available. But if one works in a highly virtual team setting, the possibility to get support form co-workers is necessary to be innovative.

Figure 7: Interaction effect "Time intensity working in virtual team * Support of co-workers possible" with innovation behaviour



Finally we present two interaction effects related to job demands. Figure 8 shows that low quantitative job demands only go along with high innovation behaviour for the low virtual team workers. If teams with low job demands work in a higher complex virtual setting, then they lose innovation power. For workers with high job demands it does not matter whether they work in a low or high virtual team setting: they are equally innovative in such surroundings.

Figure 9 illustrates a somewhat similar interaction effect for the degree of complexity of the virtual team setting. Low job demands are negatively associated with the degree of complexity, whereas high job demands are positively associated. In other words, the busier a worker is in a high complex virtual team, the more innovative. Taken these two results into account, we may maintain that if virtual teams operate in a rather complex context (little face-to-face contacts, more locations, time zones and companies involved), they show more innovation behaviour if they have high job demands.

Figure 8: Interaction effect "Degree of virtual (vs. physical) cooperation * Job demands" with innovation behaviour

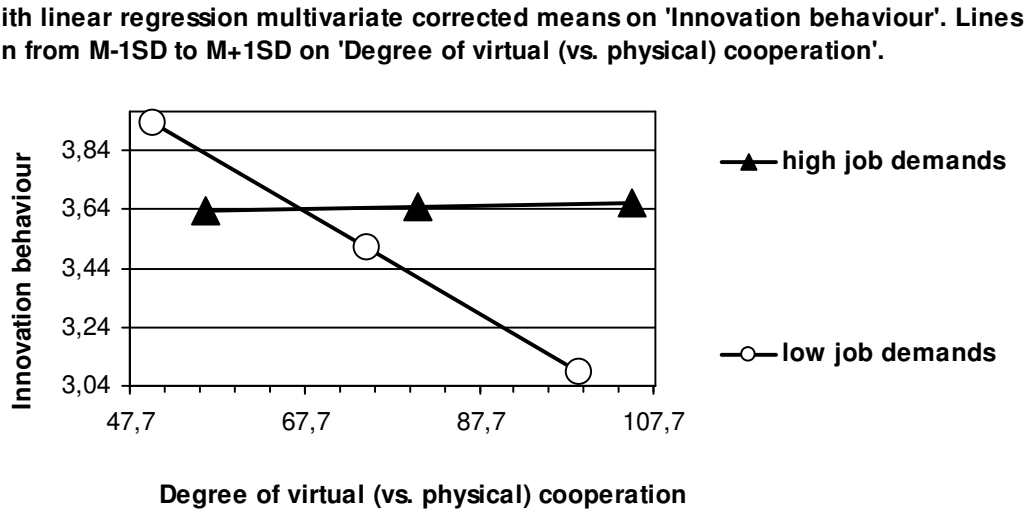
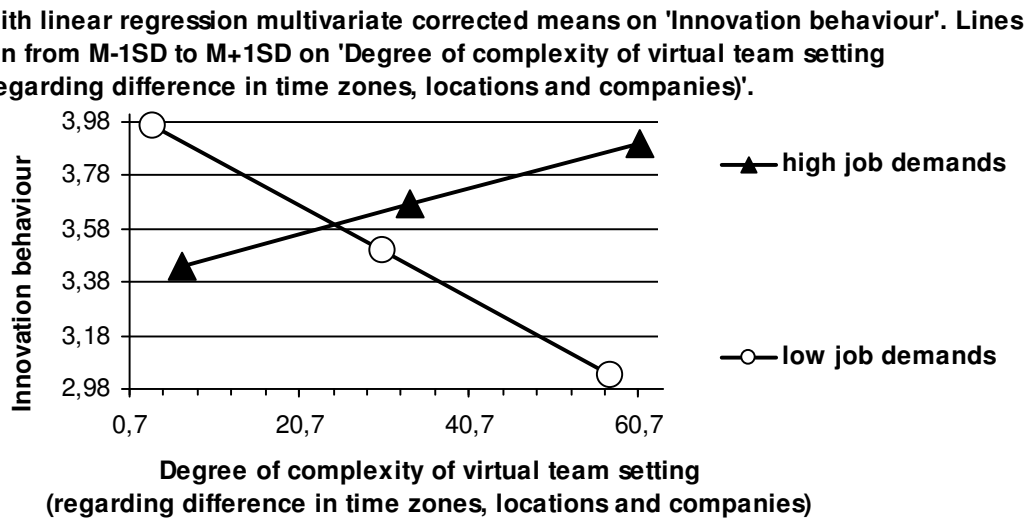


Figure 9: Interaction effect "Degree of complexity virtual team setting * Job demands" with innovation behaviour



5. Discussion

What have we learned from the findings of our study? The first result is that the real world of virtual teams is rather complex. There are no easy or straightforward lessons - for, we found only two univariate correlations and some main effects with statistical significance. Mostly, the results concerned interaction effects, meaning that only in a certain configuration of conditions an association is present. So, the context is an important matter: like all social phenomena also are virtual team processes subject to the

context. Nevertheless, again we found that spending time face-to-face is favourable for innovation behaviour. Virtual team settings as such are counterproductive for innovation. Apparently, all kind of technological and organisational conditions are to be met in order to get the required innovation behaviour. In this discussion section we pay attention to two issues: a) the complex relationship between IT use, diversity and innovation, and b) the issue of trust.

The use of IT tools is important for virtual teams. They have an effect on innovation behaviour. One of the findings of this study is that reciprocal IT tools (being the most advanced types of online, synchronous IT tools, like document sharing) are positive for innovation behaviour; in low complex virtual team settings the use of reciprocal IT is better for innovation behaviour compared to pooled IT. However, in highly complex virtual team settings pooled IT is equivalently positive for innovation behaviour. This finding is in line with other research indicating that virtual team platforms need to incorporate all kinds of collaboration tools, such as online discussions, document sharing and libraries, but also the more standard ones (Precup at al. 2006). Our definition of complexity refers to complexity in terms of team members that belong to different time zones, different locations and different companies. We may safely assume that this will enhance the cultural diversity of team members. Diversity is an extremely difficult subject in promoting innovation. There is conflicting evidence as to the extent to which diversity can deliver innovation behaviour. On the one hand, advocates of the information decision approach (see Ilers & Hayers, 1997) argue that – if diversity is managed well – it can enhance creativity. On the other hand, exponents of the social identity approach (Ely & Thomas, 2001) warn for the negative aspects of diversity. They point on the risks of reduced cohesiveness, communication problems and other negative effects of in-group and out-group behaviour. That is why Fleming (2004) contends the double effect of diversity on innovation outcomes; highly diverse innovation teams are both better and worse: they produce more breakthroughs, but also more failures compared to more homogenous innovation teams.

Coordination by trust is strongly associated with innovation behaviour. Moreover, the other way around, coordination by output is associated with less innovation behaviour. A strong emphasis in the coordination by output implies normally also a stronger intolerance for making mistakes. We know that a climate with little fault tolerance does not stimulate risky behaviour that is needed for innovation. Others coined the term ‘participative safety’ (West & Farr, 1990) or ‘psychological safety’ (Edmonson, 1999) while focusing on the team climate that encourage trusting relations. These safe climates also enable productive disagreements. A psychologically safe environment is one in which people can speak up, without being punished or feeling embarrassed. Edmonson (1999) found in her research on surgical teams that teams whose members were comfortable putting across doubts and disagreements were faster in learning new procedures and were also more effective. She found the same for nursing teams, where the error detection rate correlated with the psychological safety. This finding is consistent with other literature on the role of trust in teams. Trust is one of the fundamental factors that drive the success and failure of virtual teams (Lurey & Raisanghani, 2001; Kirkman et al. 2002; Daassi et al, 2006). We may argue with Meyerson et al. (1996) and

Kanawattanachai & Yoo (2002) that the cognitive aspect of trust in virtual teams is higher than the affective aspect. Cognition-based trust refers to the calculative and rational characteristics demonstrated by trustees, such as reliability, competence, responsibility and integrity. Affect-based trust refers to the emotional and social skills of trustees, such as care and concern for the welfare of team members. Affect-based trust is characteristic for close personal relationships. While virtual teams rely heavily on computer-mediated communication processes, we may assume that trust within virtual teams is more cognition-based. In addition, trust is dynamic by nature: it may develop both positively and negatively (Kanawattanachai & Yoo, 2002; Furst et al., 2004).

Our results on job demands are important as well. In complex virtual teams settings high job demands are associated with high innovation behaviour. High job demands indicate a heavy work load (quantitative demands), in other words, a lot of work to do for the virtual team members. Still, our results indicate this as a positive issue for innovation behaviour. Virtual team members might be able to cope with this. Apparently, they are able to combine the many tasks with innovation behaviour. Other research demonstrated a positive relationship between job demands and innovative work behaviour when employees perceived effort–reward fairness rather than under-reward unfairness (Janssen, 2000). Since we know that too much of a good thing can be detrimental, again we should take into account the time issue.

We need to focus here on the dynamic nature of both innovation processes and virtual team processes. Our study design did not fully acknowledge this fact since we had a one-off cross-sectional survey. The model might suggest that the inputs and the processes are static, but in real-life they are not. We did not include in our measurements the feedback loop which is important in input-process-output models. The current conditions (both inputs and outcome) of the virtual teams in our sample might be the result of past innovation behaviours. We could not take into account this in our study design.

Therefore, further research is needed. In particular, longitudinal research may open up the rather black box of the influence of time and experience on the different variables that influence the performance and work stress of virtual team workers. Longitudinal research is needed to investigate the nature of the conditions, the technology-task fit, the role of the team leader and the social team processes. As assumed by Hertel et al. (2005) and Furst et al. (2004), time and team development is important to understand the success (and failure) of virtual teams. More empirical data are needed, that are gathered in the real-life context and not only in experimental settings with students. The studies of Daassi et al (2006) and Van der Kleij (2007) indicate that virtual teams need time and experience to fully benefit from all the tools. Their studies also showed the dynamic nature of trust, which is associated with collective awareness. So, time and experience are important issues.

Based on this study important research questions arise. Do more experienced virtual team members show a steep learning curve in ICT skills, even if ICT is continuously changing? Do virtual teams develop trust easier and faster once the virtual team members are more experienced in working in virtual environments? How can one learn to trust in

virtual settings? How to cope with cultural differences within virtual teams? How can one make use of these differences and avoid or deal with conflicts? These are important questions to answer before we can safely move forward with innovative virtual teamwork.

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