Transactive Memory in Task-Driven 3D Virtual World Teams

Styliani Kleanthous
Citard Services LTD
Nicosia, Cyprus
stellak@citard-serv.com

Michalis Michael
Open University of Cyprus
Nicosia, Cyprus.
michael.michael@st.ouc.ac.cy

George Samaras
Department of Computer Science
University of Cyprus
Cssamara@cs.ucy.ac.cy

Eleni Christodoulou
Citard Services LTD
Nicosia, Cyprus.
eleni_christodoulou@cytanet.com.cy

NordiCHI '16, October 23-27, 2016, Gothenburg, Sweden © 2016 ACM. ISBN 978-1-4503-4763-1/16/10…$15.00 DOI: http://dx.doi.org/10.1145/2971485.2996728

Abstract
Collaboration and knowledge sharing in small teams is very usual not only in education but also in industry, in gaming and in our lives. Interdisciplinary teams are formed and their members are expected to collaborate, exploit their capabilities and know-how towards achieving a common goal. In this work we explore whether parameters associated with the development of Transactive Memory System (TMS) can be reflected in a 3D virtual world. People from diverse background and profession brought together in teams to work towards completing an assigned task within a 3D virtual world. The results show strong associations between the parameters of a TMS, collaboration activities and communication scales examined.

Author Keywords
Transactive memory; collaboration; 3D virtual world.

ACM Classification Keywords
H.5.3 Group and Organization Interfaces; J.4 Social and Behavioral Sciences.

Motivation
Most of the tasks that we engage with in our everyday professional or personal life are performed in a social context. A person does not possess all the knowledge or resources needed for achieving a certain task and

Transactive Memory

TM is concerned with: *"the prediction of group and individual behaviour through an understanding of the manner in which group processes and structures information"* [13].

Figure 1. A lecture room within the CyDigital VW. Participants used this room for their orientation in the VW and for their introduction to the tools and artifacts available.

Figure 2 The quiz tool for self-evaluation of their skills within the VW

usually collaboration is inevitable. A Transactive Memory System (TMS) represents the collective awareness of the group's specialization, coordination, and credibility [13, 10]. The notion of Transactive Memory (TM) and the development of a TMS have proven to be very promising for the functioning of couples, teams and groups at several contexts in face-to-face communication [4,10,13]; and online [1,5,6,14].

Facilitation of a TMS in virtual settings is usually supported by information, communication and technology tools e.g. resource repositories, bulletin boards [2], search, information access and adaptive interventions [8]. The results demonstrated to improve the development of TMS within a virtual team and thus, the team's performance. Furthermore, evidences show that decomposing TM into i) specialization, ii) coordination and iii) credibility of the team provides a better understanding of the aspects that affect the development of a TMS [7].

Although, the above body of work investigated TMS development in collocated and virtual teams, TMS within teams in 3D Virtual Worlds (3D VW) has not attracted much attention, with the exception of the work of Khan and Williams [5] who studied TMS relating to virtual teams in 3D Virtual Games.

A 3D VW environment (e.g. SecondLife[1], OpenSim[2]) provides shared multi-dimensional space that supports synchronous interaction and communication, enhancing the socialization and interaction between users [12]. The avatar use enhances the immersive feeling to its users of actually '*being there*'. Until recently VWs, were mainly used for socializing and recreational purposes, however, the use of such environments have also been adopted for collaboration purposes.

The aim of this study is to investigate: *How the three parameters of TM i) specialization, ii) coordination and iii) credibility of the team are reflected to a collaborative task execution, communication and immersive tools within a 3D VW, when members possess diverse expertise*.

Pilot Study Design

OpenSim platform was employed and a 3D Campus was developed namely CyDigital that consists of: entrance contained information and instruction boards (Figure 3), several exhibition rooms and a lecture room (Figure 1) with an integrated online quiz tool (Figure 2).

Participants

A total of 14 (fourteen) participants – grouped in three teams, were recruited from staff and students of the Open University of Cyprus and other contacts. There were equal female and male participants with a mean age of 27.2 ranging from 22 to 40 years old. It is important to mention that the participants did not personally known each other prior to the study and they first met through the 3D CyDigital environment. They filled-in a simple questionnaire stating their educational level and specialization, other expertise they acquired through hobbies, interests or other activities, demographic data, their familiarity with the use of: electronic devices, the web, 3D VW and basic computing skills. Based on the results of the questionnaire the participants grouped by the authors

[1] http://secondlife.com/

[2] http://opensimulator.org/wiki/Main_Page

Figure 3 The campus map while a participant is interacting with it for teleporting to a specific place.

Figure 4 Brainstorming sessions of one of the teams

Figure 5 There were several exhibition gallery rooms. Each team assigned one room

into three teams. This was necessary in order to impose knowledge diversity and complementarity within the teams created.

Introduction to CyDigital – The 3D Virtual World
Then, the participants introduced to OpenSim and CyDigital and had a briefing on the different tools and artifacts available through this environment (e.g. how to: move around using their avatars, move objects around, use the chat, voice and gesture, communication etc.). They encouraged to experiment and familiarize themselves with the functionality, and if needed to request help from their peers and the facilitators of the study. In order to ensure that all participants achieved an acceptable level of skills in the 3D VW, a quiz was provided to the participants through the 3D VW tools with a pass/fail outcome to self-evaluate their interaction skills (Figure 2). In addition to the oral introduction provided to the participants, information boards were available at the main entrance of the CyDigital giving all the necessary help for interacting with the available tools. After this session the participants moved into their teams and assigned an exhibition room different for each team to perform their task.

Task Selection and Assignment
Based on the tasks taxonomy [9] we selected a Type 1: Planning task in Quadrant I and the cooperation part of the axis. The task assigned to the teams is to "Plan and organize a photo exhibition in the specially designated areas of CyDigital". So, each team had to find a topic for its exhibition, search and find photographs related to the selected topic, arrange the exhibition space using the furniture, stands, tools that are available in OpenSim and upload the photos at the stands provided for the exhibition night (Figure 6). Prior to task execution the members had a session to introduce themselves, to the rest of the team and a second session for brainstorming ideas (Figure 4) on how to approach the task and assign roles among themselves.

The team members did not have any kind of resources that would help them identify the knowledge skills or previous experience each member had in their team except from the above sessions. This was important in order for us to be able to assess whether the communication and interaction means of a 3D VW would have any effect in the three parameters that facilitate the development of TMS.

Methods
Two questionnaires were administered to the participants: i) prior the task assignment [11] and ii) after the completion of the task [7, 11]. From the first questionnaire we were able to understand the participants (demographics, education level) and their previous experience with technology, the web, 3D VW etc. This was necessary and decisive to ensure knowledge diversity during the group formation.

In order for us to evaluate the development of TMS within the groups, we employed the TMS scale items developed by Lewis [7]. This second questionnaire included also questions related to the task execution and focusing on the participants' brainstorming and collaboration experience, role assignment session with respect to the coordination in the team, their sense of team belonging, problem solving strategies, immersive experience, communication tools provided in the 3D VW. In addition to the above, one of the authors acted as an observer within the 3D world while the team

Figure 6 Creating a frame for uploading a photograph in the gallery stand

members were collaborating towards the completion of the task for assessing the overall collaboration culture of the team and identify any problems with the interaction.

Preliminary Results

Demographics and Frequencies

Firstly, let us report some demographic and frequency information collected from the pre-study questionnaire: 57.1% of the participants mentioned that they have a stable job and 100% have previously worked in a team project. 55.1% had postgraduate education qualifications, 28.6% possessed a graduate qualification and 14.3% are currently in university education.

92.2% of the participants are using written messages very often as a tool of communication. Only 50% of the participants had previous experience with 3D VW environments and the same percentage never had previous experience in 3D video games. Interestingly, these were all female participants. On average the participants spent 31.1 hours per week in using a computer. This information was important for understanding the familiarity of the sample with similar environments as the one used in this study.

Transactive Memory System

The analysis of the second questionnaire followed the method described in [7] for extracting a score for each of the three parameters: specialization, coordination, and credibility and for the overall TMS, for each participant in our study. The same approach followed for all the scales that employed (e.g. brainstorming session, role assignment session, their sense of team belonging, problem solving strategies, immersive experience, communication tools and avatar use). The scales have been tested and passed the Cronbach's alpha reliability test, denoting high internal consistency between the items comprising the scales.

Non-parametric analysis was employed due to the small size of the sample. A Kruskal-Wallis test was conducted to determine if there were differences between the three teams. Distributions of TMS and the parameters compose the TMS were similar for all groups, as assessed by visual inspection of a boxplot. The test results show no statistical differences between the teams for the development of TMS ($p = 0.534$) or the individual items comprising TMS: Specialization ($p = 0.431$), Credibility (0.330) and Coordination ($p = 0.315$). This was expected since the authors tried to neutralize all conditions for the three teams e.g. the same task, expertise of members, communication media, virtual space and help available.

Specialization, Coordination, Credibility

A Pearson's product-moment correlation was run to assess the relationship between the three parameters that compose the TMS and the scales assessing the brainstorming session, role assignment session, the sense of team belonging, problem solving strategies, immersive experience, communication tools and avatar use.

The results revealed a significant correlation between the scale of brainstorming session ($r= 0.546$, $p = 0.044$) and team belonging ($r=0.802$, $p=0.001$) with specialization. This is an indication that the diverse knowledge the members had helped in brainstorming ideas on how to approach the task. Similarly, holding unique information and skills might have helped team members to feel valuable to their team for completing the task.

Furthermore, problem solving strategies scale shows strong correlation to coordination (r=0.582, p=0.029). While the teams were executing the task, they confronted with some problems with the tools and/or interpersonal issues. The strategies they followed in their teams for resolving these problems helped them to coordinate the execution of the task better. An important part of the task execution was the role assignment. In the results, the role assignment scale correlated to credibility (r=0.634, p=0.015) and coordination (r=0.565, p= 0.035). This is an indication that the knowledge and skill diversity of the team members allowed them to develop a sense of credibility as persons in the team and also the actual role assignment session added positively to the overall coordination of the team.

	Avatar Use
Brainstorming	0.577
Role Assignment	0.499

Table 1: Pearson correlation results of avatar use with the scales of Brainstorming and role assignment. Note: Statistical significance at $p<0.05$ level.

With respect to communication tools provided to the participants through the VW, we can see a strong correlation to coordination (r=0.756, p=0.002). Interestingly, the immersive experience of the users correlates to credibility (r=0.623, p=0.017) and coordination (r=0.587, p=0.027). The results are implying that chat discussions (the only medium that was available for communication) are adequate for communicating and coordinating a virtual team and the 3D virtual environment along with the avatar and gestures are empowering the development of credibility within the team. A summary of the correlation results of the TMS parameters to the relevant scales is presented at Table 2. With respect to the avatar use in the 3D VW the results (Table 1) of the correlation analysis show strong association with brainstorming (r=0.577, p=0.031) and gives a moderate correlation to the role assignment session (r=0.499, p=0.069).

	Spec.	**Coord.**	**Cred.**
Brainstorming	0.546*	-	-
Team Belonging	0.802**	-	-
Problem Solving Strategies		0.582*	-
Role Assignment	-	0.565*	0.634*
Communication Tools	-	0.756*	-
Immersion	-	0.587*	0.623*

Table 2 Pearson correlation results for main study variables. Note: Spec.=Specialization, Coord. = Coordination, Cred. =Credibility. * Statistically significant at $p<0.05$ level, ** Statistically significant at $p<0.01$ level

Discussion and Future Work

The above results can be an initial indication and inform the design of collaborative group activities within a 3D VW. The diverse knowledge the members had allowed the users to share their ideas better and perform and approach the task and to feel valuable to their team. An important outcome of this short study is that the communication tools provided to the team members (chats) are sufficient for communication and coordination within a 3D VW team. The use of a 3D virtual environment along with the avatar and gestures affect positively the sense of credibility within the team since it allows for immersion.

We acknowledge that there are limitations that need to be taken into account. The preliminary results of this pilot study revealed strong associations of the elements comprising TMS with collaboration tasks. Immediate future work will examine the development of TMS in a larger sample (approximately 100 people grouped in small teams) in a 3D VW setting. Specifically, we are interested to examine TMS development in i) self-formed and randomly assigned teams, ii) face-to-face and completely virtual teams, iii) long-term and short-term collaboration tasks and iv) individual members' evolution within the team.

Acknowledgements

This work was partially funded by the CogniWin project (http://www.cogniwin.eu), EU Ambient Assisted Living Joint Program (AAL 2013-6-114)

References

1. Chen, X., Li, X., Clark, J.G and Dietrich, G.B. Knowledge sharing in open source software project teams: A transactive memory system perspective. *Int. J. of Info. Man. 33, 3* (2013), 553-563.
2. Choi, S.Y., Lee, H. and Yoo, Y. The impact of information technology and transactive memory systems on knowledge sharing, application, and team performance: A field study. *MIS Q.*, *34, 4* (2010), 855-870.
3. De Leoz, G. and Khazanchi, D. Exploring the Influence of Trust in the Development of Transactive Memory Systems in Virtual Project Teams. *Proceedings of MWAIS 2015 (*2015*).*
4. Hollingshead, A. B. and Brandon, D.P. Potential Benefits of Communication in Transactive Memory systems, *Human Communication Research, 29, 4* (2003), 607-615.
5. Kahn, A.S. and Williams D. We're All in This (Game) Together Transactive Memory Systems, Social Presence, and Team Structure in Multiplayer Online Battle Arenas. *Communication Research*, *Dec 2015, 9*, (2015), 1-31.
6. Kotlarsky, J. Van den Hooff, B. and Houtman, L. Are we on the same page? Knowledge boundaries and transactive memory system development in cross-functional teams. *Communication Research*. *42*, *3* (2015), 319-344.
7. Lewis, K. Measuring transactive memory systems in the field: scale development and validation. *Journal of Applied Psychology*. *88*, *4* (2003), 587.
8. Styliani K. Loizou and Vania Dimitrova. Adaptive notifications to support knowledge sharing in close-knit virtual communities. *User Modeling and User-Adapted Interaction*. *23, 2-3* (2013), 287-343.
9. McGrath, J.E. *Groups: Interaction and performance*. Vol. 14. (1984) Englewood Cliffs, NJ: Prentice-Hall.
10. Mohammed, S. and Dumville, B.C. Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries, *Journal of Organizational Behavior. 22, 2* (2001), 89 - 106.
11. Nisiotis, L. A Cyber Campus to Support Students Experiencing Barriers Accessing Education, Doctoral Dissertation (2015) Sheffield Hallam University.
12. De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., Poulovassilis, A. Learning as Immersive Experiences: Using the Four Dimensional Framework for Designing and Evaluating Immersive Learning Experiences in a Virtual World*, British Journal of Educational Technology*. *41, 1* (2010), 69-85.
13. Wegner, D.M. Transactive Memory: A Contemporary Analysis of the Group Mind. *Theories of Group Behavior*. Mullen, B. and Goethals, G. R., Springer-Verlag (1986), pp. 185 - 208.
14. Yoo, Y. and Kanawattanachai, P. Developments of transactive memory systems and collective mind in virtual teams. *The International Journal of Organizational Analysis*, *9, 2* (2001), 187-208.