TRANSACTIVE MEMORY SYSTEMS AND SHARED SITUATION AWARENESS: A WORLD OF WARCRAFT EXPERIMENT

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1 ABSTRACT

The article discusses the connection between two team mental models – Transactive Memory System and Shared Situation Awareness in virtual, synchronous ad-hoc mission teams. It is argued that both models are interdependent. The research conducted follows a qualitative but experimental approach utilizing the exciting game World of Warcraft as platform. Interesting communication patterns and in-depth analyses of teams playing World of Warcraft are offered.

Keywords: Situation Shared Awareness, Transactive Memory System. World of Warcraft

2 INTRODUCTION

Today's military and disaster response operations are characterized by increasing complexity driven by numerous factors as an increasing influence of media broadcast in areas of disaster, increasing number of involved organizations. Due to this complexity the planning processes become more and more difficult and modern operation planning organizations require team approaches to cover a high specialization of team participants (Essens, Spaans et al., 2007; Plotnick, Ocker et al., 2008).

In contrast to project teams – at least in theory elaborately staffed according to the project's task – mission organizations are to some extent ad-hoc. Particularly in the planning cells, staff elements and command & control organizations work teams together which never did before (Becerra-Fernández, Madey et al., 2008; Huber, Richter et al., 2008; Plotnick, Ocker et al., 2008).

Mission teams are often locally dispersed organizing actions between staff elements and forces on the spot or staff elements and incident commands in the field (Gomez and Turoff, 2007). Additionally synchronous work is commonplace in disaster response operations, albeit asynchronous work of course appears but usually not with long delay times as the units in the field require immediate decisions for work. Thus these teams often use synchronous electronic communication means (the relevance of this issue is also portrayed in Eggenhofer, Huber et al., 2008; Eggenhofer, Huber et al., 2008).

Our research focuses on locally dispersed synchronous ad-hoc teams in complex environments facing complex tasks. We want to understand how these teams develop. Our analysis utilizes two team behavior models (1) Shared Situation Awareness (SSA) (Nofi, 2000; Perla, Markowitz et al., 2000; Harrald and Jefferson, 2007) and (2) Transactive Memory Systems (TMS) (Wegner, 1995; Kanawattanachai and Yoo, 2007). SSA is hypothesized as antecedent for mission effectiveness (Alberts and Hayes, 2007). TMS fosters team's performance (Kanawattanachai and Yoo, 2007). SSA and TMS evolve over time and due to communication – especially task oriented communication (Klimoski and Mohammed, 1994; Nofi, 2000; Kanawattanachai and Yoo, 2007).

3 THEORY

To understand the development of virtual synchronous ad-hoc teams in a mission the analysis of team mental model conceptualizations (Klimoski and Mohammed, 1994) is helpful.

3.1 Transactive Memory Systems

TMS, introduced by Wegner and colleagues (Wegner, Raymond et al., 1991; Wegner, 1995), is a metaphor for a specialized division of labor within a team to encode, store and retrieve knowledge from different domains (Kanawattanachai and Yoo, 2007) within a team. The model's idea is utilizing a computer network metaphor to describe the "working memory" of teams. Teams develop a specialization of memory directories through intensive communication in which not knowledge itself is stored but links pointing to the respective knowledge in the mental model of a team mate. This memory enables teams to store and retrieve information pieces and knowledge efficiently.

Wegner, 1995 discusses directory updating, information allocation and retrieval coordination as three different functions to establish TMS in a group. Directory updating is the process of editing entries in the directory:

- During group development members negotiate their fields of interest and expertise to update and establish their group directories. Initially, so called default entries are saved. Default entries are overgeneralized stereotypes (Wegner, 1995). Through intensive communication these entries are updated and complemented or replaced by negotiated entries.

- Expertise entries point to team mates with interest in special fields and do fast signal that this team mate is expert in the team for that field which not necessarily mean that they are truly experts. Expert entries play a major role for role specifications and specialization within a team. Default, negotiated and expert entries are hierarchically structured and change quickly during team establishment.

- Access entries are entered into team directory when a team mate exclusively, durably or recently has access to information and the team is aware of it (Wegner, 1995).

All these entries as pointers to knowledge pieces organize the team mental model which is copied usually incongruently to all individual mental models of the team members. Directory updating constructs these labels and new information pieces might update the directory after the team has encoded them.

When labels and directory are constructed, a strategy, to allocate information or knowledge pieces to the expert in the team responsible for that knowledge field, is crucial. Through these information allocation strategies the specialization within a team gets stronger (Wegner, 1995).

Retrieval coordination is the last function crucial to organize team knowledge in a TMS. The team and its members need a valid process of retrieving knowledge from each other. Each team member has to examine whether a team member has access to the information or knowledge needed and which access is most suitable. A well established process of retrieval coordination has to be fast and has to ensure a high probability to

find the needed information (when available). Such a process is implemented in established and hardened teams only.

3.2 Shared Situation Awareness

SSA is assessed as one of the key antecedents for success in complex endeavors (Alberts and Hayes, 2007). SSA as model tries to explain how and in which stages and phases teams assess their situational environment and negotiate knowledge about the situation. SSA conceptualizes the overlaps in team members' individual knowledge and information about the situation and the difference in interpretation. Note that overlaps in knowledge and information about a situation are crucial for planning and discussing the courses of action. Note however that these overlaps should be typically small as teams are composed of specialists using the interdependency of knowledge and skills for solving complex tasks (e.g. Cohen and Bailey, 1997, Guzzo and Dickson, 1996).

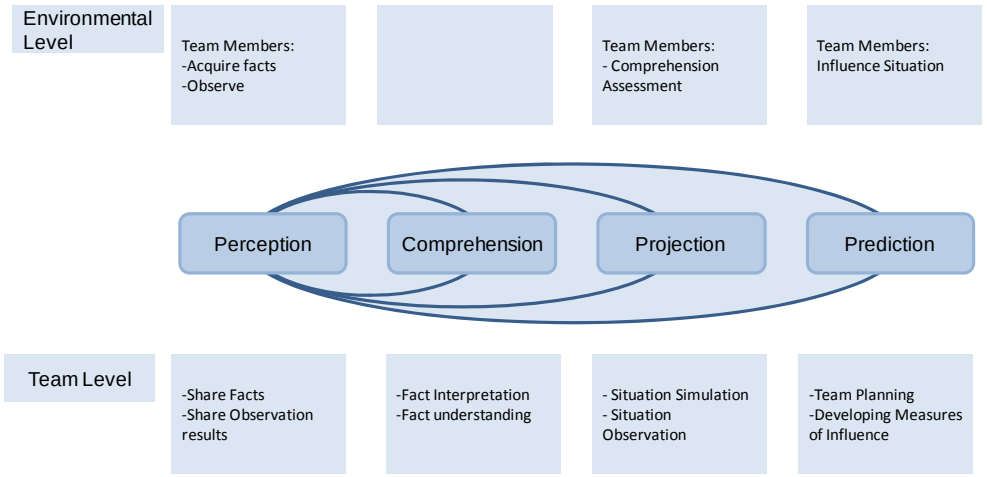

Figure 1: The Stages of SSA Development

Figure 1 depicts the stages of SSA development. These stages are perception, comprehension, projection and prediction (Endsley, 1995; Nofi, 2000).

- Perception: Team members acquire facts about a situation by observing the environment and building individual situational mental models. These facts and models should be shared within the team by human communication or information gathering via machine interfaces.

- Comprehension: Facts and shared mental models should be interpreted by the team. The team should understand the relevant facts and be able to interpret the situation and build a common shared picture of it as basis for the collaborative planning that combines all relevant skills provided by the team members.

- Projection: The team simulates (usually mentally) and discusses how the situation develops in near future under the premise of its common shared picture. Projection is crucial for planning courses of action.

- Prediction: The team discusses influencing actions to rearrange the situation in the sense of the team. It needs measurements to assess and define the changes.

These phases are not ordered sequentially but run in parallel. The mental model of the situation has to fit the perceived facts all the time and is dynamically rearranged.

3.3 SSA and TMS – Do these models describe the same?

SSA and TMS, both are team knowledge models (Cooke, Salas et al., 2000). Both models describe knowledge structures going beyond the individual level and only observable and describable on the level of the team. Thus Rosen, Fiore et al., 2008 state that teams gain an understanding awareness of the situation basing on individual awareness through processes of interaction.

Whereas TMS is a team mental model (Klimoski and Mohammed, 1994) and – once developed – relatively long lasting, SSA is a team situation model that develops when the team is engaged in a task.

We are interested in whether these two models are helpful in the analysis of synchronous virtual ad-hoc teams. As mission teams always interact with the environment, SSA is obviously crucial for task effectiveness. These teams have to care for internal development and TMS development either.

We argue, on the basis of our observations, that TMS development is antecedent to SSA development. SSA only develops in parallel to TMS or when TMS is yet developed. We argue that projection and prediction as most important stages of SSA can only occur on team level with a well developed TMS.

4 METHOD

We conduct laboratory experiments to analyze virtual synchronous ad-hoc teams and utilized the complex and exciting gaming platform World of Warcraft (WoW) to task teams of five German Armed Forces Officers. Figure 2 shows a WoW fighting scene screen shot during our experiments.

Figure 2: A Fight in the Instance Ragefire

The team task is to kill two so called end-bosses, i.e. two very dangerous monsters with special capabilities in the cave Ragefire as fast as possible with as few own deaths of team members' characters possible. Ragefire is a separated area within the game, once entered; the players are not disturbed by other gamers. This cave is playable for lowly skilled characters. One end-boss is located in the middle of Ragefire, one at the end

(Figure 3). In Ragefire all teams face single monsters or enemy-teams of two, three and four monsters.

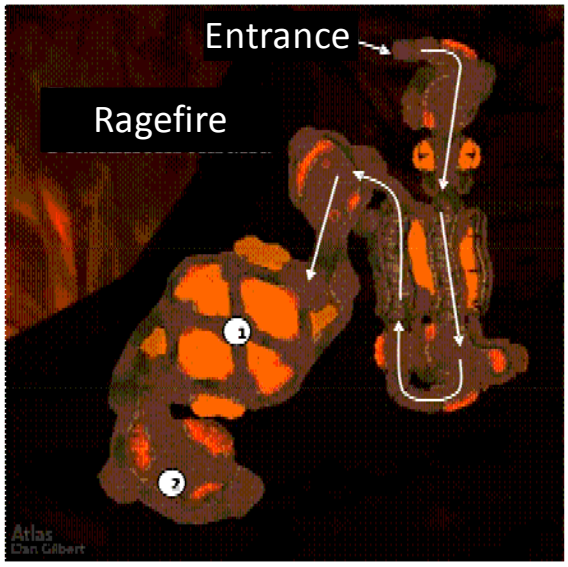

Figure 3: Map of Ragefire with End-Boss (1) and (2)

The experiments took place at the Universität der Bundeswehr München in April and May 2008. The experiment participants were volunteers without WoW experience. Only one of 30 participants was slightly experienced in WoW but he did not know Ragefire and never played his experiment character before. The task was new and the teams ad-hoc. The experiment members practiced with their WoW-characters in individual games before the team task. The teams' WoW characters were priest, druid, shaman, magician and warrior. The usability of WoW as experiment platform and the experiment set-up are discussed in Dannecker, Richter et al., 2008.

	1 Shows solidarity, raises other's status, gives help, reward	7 Asks for orientation, information, repetition, confirmation	
Social-Emotional Area: Positive Reactions	2 Shows tension release, jokes, laughs, shows satisfaction	8 Asks for opinion, evaluation, analysis, expression of feeling	**Task Area: Questions**
	3 Agrees, shows passive acceptance, understands, concurs, complies	9 Asks for suggestion, direction, possible ways of action	
	4 Gives suggestion, direction, implying autonomy for other	10 Disagrees, shows passive rejection, formality, withholds help	
Task Area: Attempted Answers	5 Gives opinion, evaluation, analysis, expresses feeling, wish	11 Shows tension, asks for help, withdraws out of field	**Social-Emotional Area: Negative Reactions**
	6 Gives orientation, information, repeats, clarifies, confirms	12 Shows antagonism, deflates other's status, defends or asserts self	

Figure 4: IPA Scale Categories (Bales, 1950)

We observed, video and audio recorded six teams of five players each, during runs of approximately two hours. Communication was transcribed and classified using the IPA-scale (Bales, 1950). The classes of the IPA-scale are depicted by Figure 4. The team behavior was clustered in distinct fighting scenes and a selection of these fighting scenes is described as sketches.

Five out of six teams achieved the overall team task. We consider in this paper only the successful teams.

The first three teams played supported by voice chat, the second three teams by text chat. The teams performed circa 50 fights in Ragefire to fulfill the overall task. All teams experienced so called wipes and part-wipes. A wipe is the defeat of all team characters by an enemy (team). A part-wipe is the death of some of the five characters.

In our analyses we focus three fight scenes. The first scene we analyzed was selected because all teams experienced a wipe or part-wipe as it was the first fight against a team of three monsters. The second scene is the following next scene against three monsters. The third scene is the first situation where teams fought against an enemy team of four. The first two situations took place during the first quarter of the run, the third in the last quarter.

We hypothesize that the teams' progress is significant in the second scene. The third scene is new and more complex. The teams should be able to learn from their fights against three-enemy teams and that the first fight against three monsters (scene one) needed an adoption in fight processes to succeed. We expect to be able to observe directory updates and retrieval coordination according to TMS. We furthermore expect to observe the development of SSA in the situations regarding to the SSA-stages.

We measure success depending on the accomplishment of the mission (killing both bosses) and on the number of own characters' deaths in the team (a character can be reanimated after been died) during the whole task in Ragefire. Table 1 gives an overview of the experiment teams.

Table 1: Team Overview

Team	Number of characters' deaths	Communication mean	Mission accomplishment
1	7	Voice chat	Yes
2	17	Voice chat	Yes
3	19	Voice chat	Yes
4	13	Text chat	Yes
5	41	Text chat	No
6	22	Text chat	Yes

Our analyses comprise a brief comparison of communication of four teams and a more detailed analysis of the most successful team. Note that we do not consider team five as it failed the overall task.

5 TEAM COMMUNICATION COMPARISON

As communication enables team mental model development (Klimoski and Mohammed, 1994; Rosen, Fiore et al., 2008) we first describe the communication for four teams (Team 2, Team 3, Team 4 and Team 6). The descriptions are ordered as the experiments were conducted.

The analysis of a team comprises the three scenes described above. We distinguish planning, fight and assessment phases. In each phase we provide the number of chat chunks (cc) and selected information on IPA classification. For fight phase we provide duration and average length of cc. We furthermore provide a brief sketch of each scene, additionally information whether the team was successful or unsuccessful (wiped).

Team 2 – Voice chat:

Scene	**Planning Phase**	**Fight phase**	**Assessment phase**
One	7 cc; 3 socio-	Duration: 60 s; cc: 26; Average	66 cc; 18 cc class 3; 15 cc

unsuccessful	emotional; 4 directions	number of words: 4.6; seconds per cc: 2.3; 30 % of cc socio-emotional; 6 cc class 5 and 6 each	class 6; 9 cc class 4
Planning: Little communication. Given directions are contradictious and misleading. Team has no fight plan. Fight: Expected communication quantity. Lacks of directions and coordination. Analysis and given information is mostly about team's internal status. Low Communication quality. Assessment: Extensive quantity. The high amount of class 3 (acceptance) is an effect of virtual communication as questions like 'ready?' produces usually four answers. Albeit high communication quantity, team negotiates few capabilities. Low TMS development. No fruitful enemy analysis. Situation assessment and SSA development are poor.			
Two unsuccessful	66 cc; 27 socio-emotional; 15 cc class 5	Duration: 94 s; cc: 26; Average number of words: 5.8; seconds per cc: 3.6; 12 cc (46 %) negative socio-emotional	87 cc; 60 % about Buffs (supporting spells usually conjured before fight) ➔ side topic
Planning: Adequate communication volume. High amount of analysis (class 5) but lack of deepness. Only abstract process planning without distinct roles. Little capability negotiation, low TMS development. No discussion about enemy. Fight: Quantity and quality of communication is low due to very high amount of negative socio-emotional communication. No directions, no coordination. Information about enemy is only perception - not suitable for courses of action development. Assessment: Voluminous communication but little progress. Again, no enemy communication and little capability negotiation. Main communication topics are Buffs and location of fight for placing totems. Both not unimportant but not most important for being successful.			
Three Success - priest died	50 cc	Duration: 87 s; cc: 17; Average number of words: 5.4; seconds per cc: 5.1; 7 cc negative socio-emotional	30 cc
Planning: No analyses (class 5). Team's capabilities still not adequately negotiated. TMS still low. No enemy communication. SSA still low. Fight: Chaotic - team survives (without priest) luckily – what is communicated. Obviously warrior still does not know the function of essential team curses. TMS still low. Again, enemy communication is only negotiating perceptions. Assessment: Although fight was chaotic, assessment is weak. No analysis and future fight planning.			

Team 2 was not able to develop a coordinated process during game play. The communication during fights is characterized as highly negative socio-emotional albeit the overall mood in the team was very good. Communication was mainly about Buffs and other side topics. Planning and assessment of processes played are hardly dealt with in communication. The team negotiated only little information about crucial capabilities of teams' characters and its differences as e.g. curses or healing capabilities and how to work with them. We assess TMS poorly developed as some directory updating was observable but too few entries are available in teams' directory. The directory contained hardly more than initial entries (overgeneralized stereotypes) as the team roughly distinguishes healer and fighter.

The team neither understood how the enemy reacts and fights nor was it possible to define clear and distinct roles coping with the enemies. SSA development strongly lacks of projection and prediction. It is not observable that the team was able to anticipate the enemies' courses of action, neither in planning nor in fight. Overall, SSA is assessed as low.

Team 3 – Voice chat:

Scene	Planning Phase	Fight phase	Assessment phase
One unsuccessful	25 cc; 19 socio-emotional	Duration: 128 s; cc: 50; Average number of words: 6.2; seconds per cc: 2.6; 21 cc (42 %) socio-emotional – 13 negative; 1 cc class 4; 11 class 5	87 cc; 35 cc (40 %) socio-emotional;
Planning: High amount of socio-emotional communication during planning. Some coordinating rules are			

discussed (all players have to confirm an attack's start). No discussion about courses of action or processes to fight. No capabilities negotiation. No enemy communication. Fight: 11 analyses (class 5). Only 1 direction (class 4). Additionally high amount of negative socio-emotional communication. ➔ High stress level. No coordination. No leadership. Assessment: Task oriented communication concentrates on connections of enemies: Does an attacked enemy tag along other enemies standing near? (Yes.) No communication about capabilities or roles. No futures fight coordination. Low TMS development.			
Two unsuccessful	37 cc; 9 socio-emotional; 8 cc class 4; 10 cc class 5	Duration: 91 s; cc: 29; Average number of words: 4.9; seconds per cc: 3.1; 19 cc (66 %) socio-emotional	59 cc; 24 socio-emotional; 17 cc class 4; 14 cc class 3 (agreements); 8 cc class 5
Planning: High amount of task-oriented communication. Lots of analyses and directions. TMS development due to capability negotiation. Capabilities not interlinked with enemies (how to affect the enemy?). SSA is still low. Weak Prediction. Only the engagement phase is planned. Planning is better but still insufficient. Fight: Extreme amount of socio-emotional communication. Directions, analyses and information not qualified to coordinate fight. Fight coordination would be necessary as prediction and projection in planning was too weak. No communication to improve process, coordination or awareness of situation. Assessment: Characterized by lots of directions and long and content intensive analyses. Often agreements (class 3). ➔ Democratic and harmonic mood within team. Again high investment in TMS development. Negotiation and analyses of many capabilities. Unfortunately no investment in SSA. No communication about enemy.			
Three unsuccessful	13 cc; 4 socio-emotional; 0 directions	Duration: 93 s; cc: 31; Average number of words: 4.7; seconds per cc: 3; 33 % socio-emotional	20 cc; 10 socio-emotional
Planning: Little communication. Albeit it is communicated that all four enemies will engage the team does not reflect that the situation is fundamentally new. No role planning, prediction or projection observable. Fight: Only two directions. Additionally more than one third of cc is giving information (class 6) and one third socio-emotional communication ➔ directions and analyses clearly underrepresented. Team not able to utilize negotiated capabilities. Unclear whether TMS is still too low or team's SSA too weak to utilize capabilities. Assessment: Takes not really place. Focus on easing tensions. No communication about enemy or future planning.			

Team three failed all three fights. Social-emotional exchanges have a high impact on communication as in nearly all phases and situations the share is nearly 50 %. We observe an intensive assessment phase in scene two regarding capability negotiation and teams' fight process analysis. However, these directory entries updated during assessment could not observably been retrieved in planning or fight. We assess that TMS developed concerning directory updating but lacks in strategies to retrieval coordination.

Team members were aware of their individual capabilities. The team attempt to plan but never reached a planning level with clear character-enemy responsibility distribution and sequences of actions combining the negotiated capabilities. The assessment was on capabilities not on the effects on the enemy as communication about the enemy especially after scene two did not take place. Thus prediction and projection are assessed to be low. The team lacks of clear coordination and command mechanisms during fight as a result of low SSA.

Team 4 – Text chat:

Situation	Planning Phase	Fight phase	Assessment phase
One Success – Shaman died	7 cc	Duration: 121 s; cc: 5; Average number of words: 2.6; seconds per cc: 24.2; 1 socio-emotional	42 cc; 10 of 14 socio-emotional in class 3 (agreement); 16 class 4;
Planning: Insufficient communication. 4 directions that shaman should wait (of 7 cc). No communication about capabilities or enemy. Fight: Little communication as expectedly team members mostly decided to fight instead to write. Nevertheless, communication is efficient. Team's process is already well developed. Shaman died			

quickly as he enters the enemy group alone. Team adopted experiences from previous fights very well. Clear role model developed. TMS already high. Assessment: Voluminous and process oriented. High amount of directions underline team's ability to transform observations in courses of action. Magician and warrior utilize well negotiated capabilities for planning purposes. TMS is already remarkably highly developed.			
Two Success	12 cc; 6 cc class 4	Duration: 89 s; cc: 3; Average number of words: 2; seconds per cc: 30	12 cc; 2 socio-emotional; 5 class 4;
Planning: Expectedly little communication as assessment short before was voluminous and constructive. Numerous directions reflect well developed TMS as team knows who can do what and is able to direct capabilities in planning. Fight: High TMS and well developed processes call for little coordination. High SSA observable by reactions of single players ➔ Usually no communication for help necessary as team members react before requested. Assessment: The sound process does not need much assessment. Assessment is focused on enemy ➔ Discussion about enemies' abilities and courses of action. Obviously no necessity for talking about own capabilities anymore but investment in projection and prediction.			
Three Success	19 cc; 2 socio-emotional; 4 class 4; 5 class 5	Duration: 86 s; cc: 5; Average number of words: 2.6; seconds per cc: 17.2	10 cc;
Planning: Intensive analysis of enemy team. Team recognizes warlock as new unknown and dangerous threat. Thus team perceives essentials of situation before engaging. No communication about own capabilities as they are known. Strong prediction and projection. Fight: Elaborated plan was put to practice. Very little communication for example a short 'help' from priest is enough for fast and adequate reaction of magician to ban the threat. TMS is guarantee that high SSA turns to effectiveness. Assessment: Adoption of new spell curse spelled by magician and observed by warrior. Due to short communication by warrior after fight team assessed curse as precious. Thus, awareness of the situation enables the team to adopt new capability and to further develop TMS.			

Team 4, a text chat team was astonishingly effective and succeeded in all scenes. The fighting process in the first scene is assessed to be mature, since team members take advantage of individual capabilities and react adequately to the enemy. The assessment of scene one is characterized by the high amount of directions. Team members were able to retrieve information from TMS as they can combine individual capabilities by directing others.

In scene two the good individual awareness of the team members is remarkable as they help others without requests as they observe e.g. that the priest is attacked. The assessment of scene two focuses already on discussing the enemy's possibilities to act and lesser on team's own capabilities as they are already updated in TMS. Therefore we assess SSA as high with regard to projection and prediction.

As TMS's directory is developed regarding the team's capabilities and retrieval coordination works, the team concentrates on discussing the enemy's options to fight. They observe that a new and dangerous threat – a warlock is within the enemy's team. The team projects correctly and underlines good prediction as the planning is precisely adjusted to the enemy. We assess TMS and SSA as highly developed.

Team 6 – Text chat:

Scene	Planning Phase	Fight phase	Assessment phase
One Unsuccessful	5 cc	Duration: 61 s; cc: 2; Average number of words: 3.5; seconds per cc: 30.5	25 cc; 2 socio-emotional; 7 class 4;
Planning: No awareness that all three enemies will engage. No capability negotiation. No process development. Fight: No real communication. Team was completely overwhelmed by the three enemies and died fast. Assessment: 7 directions. Volume of communication is too low. Communication is constructive and democratic. Focus on enemy. Little capability negotiation. No profound plan or process development.			
Two Success	4 cc	Duration: 163 s; cc: 1; Average number of words: 1; seconds per cc: 163	12 cc; 4 positive socio-emotional;

Plan: Too less communication. No role model and no curse enemy coordination. Fight: Very long phase – one word: 'help' by priest. Good job by each team member but as a whole, team still lacks in stable processes. Due to consequent sheep-curse use, magician was able to ban one character constantly and the fight was successful. After the priest's call for help, druid immediately reacted – proof for awareness. Assessment: Focus – tension release. Happiness about success. Sheep-curse adopted as extremely helpful spell but it is still unclear that the sheep must not be attacked or it turns back to enemy. Team communicates too less.			
Three Success	6 cc	Duration: 97 s; cc: 1; Average number of words: 1; seconds per cc: 97	3 cc all positive socio-emotional
Planning: Overall process very clear due to fights between situation two and three. Team did not realize warlock within enemy team as long-distance fighter and dangerous threat. Fight: Good fight. Indeed, warlock the only problem. After being turned into sheep and been banned, warlock began to spell curses after turning into enemy again. Short confusion in team but magician banned warlock again. Assessment: Not needed. No team mate died until the end of Ragefire from that point.			

This text chat team was successful, too. Remarkable is the small number of chat chunks throughout all planning and assessment phases. During first scene the team was surprised by the attack of all three enemies and died fast. The second scene was a lucky success after a long heart racing fight. The team adopted the very precious sheep-curse and agrees in using it extensively.

Although in situation two assessment was very short the team was able to further develop its processes by fighting until situation three. In situation three the fight was feasible with little planning. Albeit we cannot observe it from communication we conclude that TMS is well developed as the team has a successful fighting process. The individual awareness of the situation is high as plenty acts of helping team mates were observable. Whether SSA was high cannot be concluded.

6 THE MOST SUCCESSFUL TEAM

In this section, voice chat Team 1 as most successful team regarding mission accomplishment and its number of characters' deaths is analyzed focusing on communication, TMS and SSA development. As in the previous section three scenes are selected. We again distinguish planning, fight and assessment phases.

Scene one was mastered by Team 1 but two team members (priest and shaman) died. The scene was new and unclear for the team. Table 2 depicts the phases of the scene in detail.

Table 2: Team 1 - Scene one

Planning Phase:	
Buffs:	Partly set– no communication
Planning Process:	No established fight process developed up to this situation but team does not communicate for organizing the fight except for defining the position of fight. No reflection about new level of complexity.
Capability planning:	None
Communication about enemy:	Comprehension: Three opponents are in area of interest Projection: Unclear how many of these three engage in the fight Prediction: None
Communication patterns:	7 cc; 3 socio-emotional;2 cc class 5 (analyses); Communication not adequate (quantity & quality)
Fight Phase: Duration: 105 s; cc: 16; words (avg): 5.7; seconds per cc: 6.5	
Team-centric communication:	Priest is attacked. Informs team too late. Dies immediately after information. Shaman informs about own death.
Enemy-centric communication:	Fight starts - information about the engagement of all three opponents (unexpected). Warrior analyses that one opponent is long distance spelling

	magician.
Request handling (request and reaction):	Priest and shaman die without requests. Warrior requests heal at the end of fight (health status was really critical). Priest, shaman and druid are healers, thus only druid was able to heal – no reaction.
Coordination / Leadership:	None
Communication patterns:	8 cc socio-emotional; 7 cc class 6 (giving information); 1 cc class 5 (analysis) No coordination, decisions or analysis. Insufficient communication due to the surprise of new situation.
Assessment Phase:	
Communication about resources (buffs, Mana, etc.):	Team talks about Buffs, renews all Buffs and confirms the actions explicitly. Shaman wants to use totems more efficiently.
Fight assessment:	Warrior asks explicitly if tactics for fight was suitable. As tactics is cloudy, priest analyses that all enemies engaged, have to be bound by characters strongly armored. Otherwise priest will be attacked after healing. Warrior and shaman inform that they can bind enemies (druid was not mentioned).
Future fight planning:	Warrior suggests that warrior, shaman and druid fight close combat to bind enemies. Magician and priest support from behind. Furthermore the team should concentrate in defeating enemies bound by warrior first (As warrior have special spells to bind enemies stronger, they will not attack the lightly armored characters). Shaman plans to utilize totems better.
Capability negotiation:	Priest: Ability to reanimate characters after fight (asked by warrior); Shaman: Availability of totems; Magician: Availability of sheep-curse (bans enemy 30 s) but sheep must not be attacked; Warrior and shaman engage in close combat (druid forgotten).
Communication patterns:	54 cc; 17 cc class 5; 14 cc socio-emotional; Voluminous and highly task oriented. Warrior gives five directions - all of them confirmed by the team. Focus is on analyses as the team has to understand its capabilities and to assess the situation. Team discusses an abstract process which is not very clear but plenty capabilities are negotiated.

In scene one the team was luckily successful after a relatively long fight. The scene's communication is characterized by few chat chunks in planning and fight and a voluminous assessment. The team did not plan the fight and was not able to add plenty of entries to update its TMS directory during planning and fight. However, in the assessment phase the team invested plenty communication to negotiate and explain capabilities and to update TMS directory. The negotiated capabilities immediately became part of the team's fighting process.

As planning simply did not take place, projection and prediction are assessed as low as the team was surprised by the attack of all three enemies.

In the second scene two fights later the fight against three enemies was mastered without problems. The observations are depicted in Table 3.

Table 3: Team 1 - Scene two

Planning Phase:	
Buffs:	Complete – no communication
Planning Process:	Fight position planned that shaman can place totems. No explicit team member-opponent allocation except that magician shall spell sheep-curse on second enemy. Unclear who binds which enemy.
Capability planning :	Sheep-curse
Communication about enemy:	Comprehension: Three enemies in a group Projection: Enemies will engage as team Prediction: Magician turns second into sheep, reducing the enemies' power severely
Communication patterns:	5 cc; As situation one was well assessed (1 minute before) communication is sound. Fight position and sheep curse are main content.
Fight Phase: Duration: 94 s; cc: 34; words (avg): 6.7; seconds per cc: 2.8	

Team-centric communication:	Druid requires sheep-curse for second enemy at beginning. Warrior and druid request for healing during fight. Priest informs that heal spells take some time. Priest immediately informs when attacked. Magician turns priest's enemy into sheep. He coordinates with warrior not to attack sheep. Druid informs that bear (one Gestalt of the druid) can stand lots of hits.
Enemy-centric communication:	Druid and warrior bind one opponent each (information). As sheep-curse failed - third then unbound enemy attacks priest. Warrior and magician immediately help priest and warrior binds enemy quickly. Warrior informs that his purpose was to protect weakly armored characters.
Request handling (request and reaction):	Druid / warrior request for healing. Priest and shaman immediately react. Priest informs that heal spells take time. Sheep-curse is known in the team but magician was not yet able to use it successfully.
Coordination / Leadership:	Team coordinates which character binds which enemy. Magician informs which enemy he tries to turn into sheep and thus must not be attacked. Healing is coordinated.
Communication patterns:	11 cc socio-emotional; 7 cc class 4; 4 cc class 5 Sufficient and efficient fight communication. Team invests in negotiating character-specific knowledge as healing time, sheep-curse or armor of bear. Indicated by directions the fight was well coordinated.
Assessment Phase:	
Communication about resources (buffs, Mana, etc.):	None
Fight assessment:	Magician clarifies that he tried to use the sheep-curse for the wrong enemy. As warrior attacked a sheep to help priest, he informs that he is aware not to attack a sheep but he has spelled a curse already when the sheep appeared.
Future fight planning:	Only little coordination regarding the next visible enemy-group. No process reorganization.
Capability negotiation:	None
Communication patterns:	16 cc. Short and harmonic assessment. No directions. As the process worked well the necessity of a long assessment is not given. Focus is on analysis to find out why some planned things did not work.

The team succeeded in scene two in shorter time and communicated twice as much chat chunks during fight than in scene one. Team's Buff handling is particular and illustrates the team's ability to learn. In scene one Buffs were only sporadically set but during assessment Buffs were discussed, set and confirmed. In scene two no more communication about Buffs is necessary, all players set them individually.

Due to the fight process planning in the assessment phase of scene one the team does not communicate a lot in planning of scene two as only approximately one minute is between. But the team explicitly planned to ban the second enemy with magician's sheep-curse.

During fight a lot of new entries updated the TMS directory. The team negotiates and explains plenty capabilities. Furthermore it becomes obvious that retrieval coordination is well developed as players request actions from their team mates explicitly. We assess TMS as already highly developed in that scene.

As the magician and warrior immediately reacted when the priest was attacked, the individual situation assessment was high. But the priest requested the sheep-curse from the magician and the warrior tried immediately to bind priest's enemy. This is proof for the ongoing analysis of the enemies' courses of action and a highly developed capability to project and predict as all actions by the team seemed to be appropriate to defeat the enemy. We assess SSA as high in that scene.

The third scene increased in complexity as the team faced four enemies. Observations are depicted in Table 4.

Table 4: Team 1 - Scene three

Planning Phase:	
Buffs:	Complete – no communication
Planning Process:	All four enemies are marked with signs to discriminate. Enemy – team member – capability assignments are coordinated. Priest: responsible for healing the warrior. Magician: sheep-cursing skull-marked enemy. Warrior, Druid: binding one strong opponent each, Shaman: binding weak servant of warlock.
Capability planning :	Sheep-curse; druid's character switch; priest's healing capability with priority to warrior
Communication about enemy:	Comprehension: Four enemies in a group Projection: All enemies will engage; Analysis of each opponents strength Prediction: Detailed team member – enemy assignments.
Communication patterns:	26 cc; 2 class 5; 8 class 4; 8 class 3 (acceptance) Due to high TMS and excellent projection and prediction communication is characterized by long and profound directions and acceptance of it. The planned combination of team capabilities is oriented on the capabilities of the enemy.
Fight Phase: Duration: 97 s; cc: 38; words (avg): 7.2; seconds per cc: 2.6	
Team-centric communication:	Priest is attacked and requests sheep-curse for that enemy. Magician informs that curse can be withstood but enemy was successfully banned. When enemy turned back priest instantly informs magician.
Enemy-centric communication:	Warrior, druid and shaman have enemies to bind (see planning). Druid informs his enemy is long distance warlock and he cannot bind him. Thus magician uses sheep-curse for warlock. Warrior has two enemies to bind and requests healing. Shaman asks how many enemies have died and druid answers correctly (2). During whole fight team was informed where, with which capabilities and how many enemies are engaged.
Request handling (request and reaction):	Warrior / druid request for heals during fight. Priest cannot heal fast enough but shaman immediately supports priest. When priest is attacked he asks magician to sheep-curse his enemy. Magician more than ones helped out and druid immediately bound enemy when his enemy was defeated.
Coordination / Leadership:	The plan was not completely executed but team perceived the situation and adopted the plan quickly and successfully. Focus in coordination was protection of priest as main healer. Team has no single leader but first player realizing trouble give directions.
Communication patterns:	8 cc socio-emotional; 16 cc class 6 (information); 7 cc class 4; 4 cc class 5 Team communicates very constructive and task oriented. Considerable is that communication is lesser about the team than the situation. As TMS is high and the process within the team clear the team is able to inform about situation and enemies. Focus is to find ways to react properly.
Assessment Phase:	
Communication about resources (buffs, Mana, etc.):	None
Fight assessment:	No explicit assessment; only tension relief, joking and compliments
Future fight planning:	None
Capability negotiation:	None
Communication patterns:	7 cc;

Scene three was mastered impressively. The highly developed TMS is already observable during planning. As entries were added during scene one and two and the TMS's directory was updated, retrieval coordination can be observed due to the explicit capability planning. Warrior and magician the prevalent planners in the team are able to task team members and to use their capabilities for an excellent team fighting process. We assess TMS as highly developed.

As the team analyzes enemies' opportunities and strengths in an outstanding way, projection is impressively high. Additionally prediction is high as well as the team is

able to define the right capabilities to react on enemy's future actions. We assess SSA as very high.

7 DISCUSSION & CONCLUDING REMARKS

The analyses of our teams illustrate the variety of team collaboration approaches and that specific processes and behavior emerges. We observe that the teams differ in the amount of communication and in which issues they consider in the planning, fight and assessment phases.

For Team 1 – the most successful team – we assess TMS and SSA to be high, distinguishing is the team's ability to adapt and to integrate assessment results into planning directly. TMS and SSA in Team 2 is assessed as low as the team never developed a feasible fighting process due to the lack of understanding of enemy's behavior and the lack of a well developed TMS's directory. The TMS of Team 3 is better but SSA is also low. Team 4 has both – TMS and SSA – well developed and is pretty successful. Team 6 is successful but TMS and SSA is not clearly assessable as the team communicates very little.

We hypothesized to observe directory updating and retrieval coordination regarding TMS development. Furthermore we hypothesized to be able to observe stages of SSA development. TMS and SSA, both developed in our teams but very different. In successful teams directory updating and retrieval coordination as well as the stages of SSA development in distinct scenes are observable due to the communication of the teams. Unsuccessful teams lack of highly developed team mental models.

Furthermore we argued that SSA can only develop parallel to TMS or after TMS developed. Our observations and SSA and TMS assessments of our teams indicate support for our hypothesis. The influence of media and even communication volume seems to be marginal on both models in this particular setting.

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