Social Interaction, Team Tacit Knowledge and Transactive Memory: Empirical support for the Agile approach

Sharon Ryan, Dublin City University, Ireland
Rory V. O'Connor, Lero - the Irish Software Engineering Research Centre, Ireland

Abstract

The agile principles of social interaction and tacit knowledge were examined in this survey study of 48 software development teams. It was proposed that that team tacit knowledge is created through frequency and quality of social interactions and through the development of a transactive memory system. Results supported the hypothesis with quality of social interaction playing a greater role than transactive memory in the creation of team tacit knowledge, although transactive memory did not mediate the relationship. This study provides empirical support for the cognitive processes involved in tacit knowledge creation, which underlies the agile approach to software development.

1. Introduction

The increasing popularity of agile methods makes it important to test its underlying principles and thereby enhance our understanding of human factors in the software development process and provide stronger empirical support for the agile approach, particularly in its advocacy of social interaction. Tacit knowledge has been linked to team performance, in that teams with more tacit knowledge, are thought to be efficient and effective relative to other teams that members have known [Ryan & O'Connor, 2009]. In addition, tacit knowledge has been hypothetically connected to informal social interaction. However there is little research on the measurement of tacit knowledge, with most research focussing on the measurement of individual tacit knowledge, while quantified field measurements of the quality social interaction are rare. The aim of this paper is to empirically examine the importance of social interaction, in the development of a transactive memory system and subsequent tacit knowledge in agile software development teams.

2. The Research Context

Traditionally plan-based approaches to software development rely primarily on managing explicit knowledge, whereas agile methods mainly rely on managing tacit knowledge [Nerur & Balijepally, 2007] and recognise the importance of human interaction in the software process over written knowledge in formal documentation. Interaction is a necessary component in agile development and is tacit, informal and predominantly face-to-face [Sharp & Robinson, 2010].

According to the Standish Group CHAOS Report [2011] "(T)he agile process is the universal remedy for software development project failure. Software applications developed through the agile process have three times the success rate of the traditional waterfall method and a much lower percentage of time and cost overruns" (p.25). However some researchers point to the lack of statistical and empirical studies to support agile claims [Dyba & Dingsoyr, 2008] but despite the small amount of empirical evidence the agile approach seems to fit well with practice [Chow & Cao, 2008]. A Forrester Research study [West & Grant, 2010] found that agile adoption has reached mainstream proportions, with over a third of respondents reported that Agile most closely reflects their development process, 30% stated they do not use formal methodology, and 34% of the respondents to the survey stated they continue to use either iterative or waterfall development process.

This paper explores the role of social interaction, an internal team relationship process, in the creation of tacit knowledge within software development teams. It is proposed that tacit knowledge is created through a team transactive memory system (TMS) developed from the team's social interactions. A TMS is a type of shared team mental model and a form of socially shared cognition.

3. Social Interaction, Expertise and Team Tacit Knowledge

Informal interpersonal communications are considered to be the principal way in which information flows through organisations with face-to-face interaction considered the richest medium for transferring knowledge because it allows for immediate feedback and the embodiment of tacit knowledge cues [Koskinen et al. 2003]. The goal of much face-to-face interaction is to disseminate information and pool diverse knowledge to make informed decisions [Stasser et al. 2000].

Social interactions between people may be the route through which we acquire tacit knowledge, in that new knowledge is thought to be created through iterative social interaction [Nonaka &Tackeuchi, 1995], but not as first advocated, by making tacit knowledge explicit. Instead, a better explanation may be that 'new knowledge comes about not when the tacit becomes explicit, but when our skilled performance, our praxis-is punctuated in new ways through social interaction' [Tsoukas, 2003].

Members of software development teams represent intellectual capital and these knowledge workers have specific individual expertise characterised by their job title, but there is also a cross-over of knowledge boundaries and 'because software development is knowledge work, its most important resource is expertise' [Faraj & Sproull, 2000, p.1554].

Theory (and common sense) states that very experienced experts have more work related implicit knowledge than those who are less experienced. Experts possess specialised skills and task relevant knowledge. They solve problems and make decisions based on internalised skills and schematically organised knowledge which sometimes operate without conscious awareness [Chi et al. 1998]. Tacit knowledge is therefore related to expertise in that tacit knowledge distinguishes more practically successful individuals from less practically successful [Sternberg et al. 2000]. Polanyi [1966] defines tacit knowledge as 'we can know more than we can tell' and posits that we cannot separate the knowledge from the knower.

There has been much debate in the literature as to how tacit knowledge can be conceptualised and operationally defined. In a previous study [Ryan & O'Connor, 2009] we operationally defined and developed a measure of Team Tacit Knowledge (TTK) for software development teams and demonstrated that team tacit knowledge was positively related to good quality social interactions and predicted effective team performance. The development and validation of the Team Tacit Knowledge Measure (TTKM) for software development teams was an extension of individual-level, tacit-knowledge research to consider team-level behaviour. Team tacit knowledge was defined as: *The aggregation of articulable tacit, individual, goal* *driven, expert knowledge to the team-level, where different members of the team possess different aspects of tacit knowledge.*

4. Transactive memory

One construct especially relevant for understanding team knowledge processes is a form of shared mental model called a transactive memory system (TMS). Transactive memory involves the awareness of specialisations (or expert knowledge) and coordination of this differentiated knowledge. Specialised knowledge and its coordination may be acquired through experience of working in a domain.

TMSs were conceived by Wegner [1987], who observed that members of long-tenured groups tend to rely on one another to obtain, process, and communicate information from distinct knowledge domains. A TMS is the cooperative division of labour for learning, remembering, and communicating relevant team knowledge, where one uses others as memory aids to supplement limited memory [Hollingshead, 2001; Wegner, 1987]. By specialising knowledge in a group and having a shared awareness of who knows what information, cognitive load is reduced, greater access to expertise can be achieved, and there is less redundancy of effort. Retrieving the information stored in another person's memory, however, depends on transactions (communication, interpersonal interactions) between individuals [Lewis, 2003]. This specialisation needs to be coordinated, which resolves task dependencies that result from work differentiation [Crowston, 1997]. TMSs develop as team members learn about one another's expertise [Wegner, 1987], accomplished predominantly through interpersonal communication [Hollingshead, 1998]. Evidence for the relationship between transactive memory and social interaction is found in the field study by Lewis [2003] who measured functional or 'task-relevant' communication and found that it was related to transactive memory. Laboratory studies have also consistently shown TMSs to predict higher performance in work teams [Liang et al. 1995; Moreland & Myaskovsky, 2000] than non-interacting dyads. Furthermore, in a review of the research into TMS [Lewis & Herndon, 2011] cited results from field based studies which found that group member familiarity, communication volume and frequency, and task characteristics of interdependence, cooperative goal interdependence and support for innovation were related to higher TMSs in work groups.

In a study of 218 individuals across 18 work teams Yuan et al [2010] found that at the individual level the relationship between location of expertise and expertise exchange was mediated by communication tie strength and moderated by shared task interdependence. Team-level variables also were significantly related to individual-level outcomes such that individual expertise exchange happened more frequently in teams with well-developed team-level expertise directories, as well as with higher team communication tie strength and shared task interdependence.

5. Linking Social Interaction, Tacit Knowledge and Transactive Memory

Social interaction was seen as necessary for the development of TMSs [Lewis, 2003]. Social interaction is also related to tacit knowledge, where face-to-face interaction is considered to be the richest medium for transferring knowledge because it allows for immediate feedback and the embodiment of tacit knowledge cues [Koskinen et al, 2003]. Face-to-face conversation is best suited to transmitting knowledge that is fundamentally tacit, because it can use a much wider variety of metaphors than conversation through information technology [Tsuchiya, 1993]. Furthermore Granovetter [1973] from his studies using Social Network

Analysis (SNA) stated that strong ties identified by close relationships (among other things) are ideal for the sharing of tacit, complex knowledge. Nonaka and Takeuchi [1995] posited in their SECI (Socialization, Externalization, Combination, and Internalization) model that new knowledge is created through iterative social interaction, where tacit knowledge is made explicit. However, a more appropriate explanation may be that rather than making tacit knowledge explicit through social interaction, evidence of tacit knowledge acquisition may be seen in skilled performance [Tsoukas, 2003]. We propose that tacit knowledge acquisition is a reciprocal process, which originates with individuals and becomes group as a result of social interaction [Berman et al., 2002; Leonard & Sensiper, 1998].

5.1 Social Interaction and Tacit Knowledge in Agile Teams

The processes of communication, coordination, and collaboration are at the heart of, and key enablers of, software development processes [Layman et al, 2006]. In agile methods communication is the imparting or interchanging of thoughts, opinions, or information by speech, writing, or signs [Mishra et al. 2012]. Communication is an essential component of all software development coordination and collaboration practices and processes, with face-to-face communication is found to be the most effective in software teams [Olson & Olson, 2000; Crowston et al. 2007]. In support of this the Agile Manifesto calls for collaboration and social interaction, emphasises people over processes, working software over documentation, and adaptability to change more than following a fixed plan [Beck et al. 2001]. Indeed agile methods suggest that most written documentation can be replaced by informal communications among team members internally and between team and the customers with a stronger emphasis on tacit knowledge rather than explicit knowledge [Chau et al. 2003].

According to Chau et al. [2003] it is unlikely that all members of a development team possess all the knowledge required for the activities of software development. Therefore different people will have different aspects of knowledge, as posited by transactive memory theory. Melnik and Maurer [2004] argued that knowledge is socially constructed and held, and conducted a study to demonstrate the importance of face-to-face interaction in sharing abstract or complex knowledge. The authors concluded that the higher the complexity, the more is the need for interactive knowledge sharing via direct verbal communication, citing the richness of face-to-face communication in providing information through physical cues and voice inflection, which are important when there is ambiguity [Melnik & Maurer, 2004].

In another study, Bahli and Zeid [2005] explored knowledge sharing in an eXtreme programming (XP) project and a traditional project and found that the creation of tacit knowledge improved as a result of frequent interactions.

5.2 Present study

Social interactions are essential to the acquisition of team tacit knowledge and to the development of a TMS. Software development teams with a well-developed transactive memory system will have higher levels of team tacit knowledge than teams with less developed transactive memory systems.

Based upon the preceding discussion the following hypotheses are forwarded:

- *H1: It is predicted that social interaction (quality and quantity) will predict team tacit knowledge above and beyond transactive memory*
- *H2:It is predicted that transactive memory will be a mediator between social interaction and team tacit knowledge.*

6. Research Study and Method

The study variables and other demographic variables were incorporated into a larger online survey for software development teams. Forty eight teams in 46 small-to-medium enterprises (SMEs) from Ireland and the UK completed the questionnaire consisting of 75% (N=121) males and 25% (N=60) females. Team size varied from 2 to 12+, with the mean team size being 4.91 and an average within team response rate of 81.86% which was deemed acceptable.

6.1 Measures and Scoring

Team tacit knowledge was measured using the Team Tacit Knowledge Measure (TTKM) [Ryan & O'Connor, 2009]. The TTKM was scored by comparing the individual score on each of the 14 bipolar constructs items with an expert profile. Individual scores were then aggregated to form a team score, and the r_{wg} (agreement within group measure) for the TTKM scale was .96, indicating homogeneity and that aggregating members' scores to the team-level of analysis was statistically justified.

Quality of Social Interaction was assessed by a self-report questionnaire regarding two perceived outcomes of social interactions across team members, resulting in an index of social interaction. This measure was adapted by [Ryan & O'Connor, 2009] from [Chiu et al. 1995].

Quantity of social interaction was measured using the method by Levesque, et al. [2001] in 62 student software development project teams. Each person rated how much they had worked with each other member of their team, using a 6 point scale that ranged from 0 = 'not at all' to 5 = 'a lot'. The total interaction score was calculated by dividing the actual amount of interaction by the total possible interactions with other members of the team. A team interaction score was calculated for each team by taking the mean of its members' interaction scores.

Transactive Memory was gauged using the 15 item field measure of transactive memory developed by Lewis [2003] where the TMS is a latent, second order factor (transactive memory systems), indicated by three manifest, first-order factors (specialisation, credibility, coordination), each of which was indicated by five items.

In relation to the TMS measure, a weighted composite score was computed as this was deemed suitable for the sample size [Hackman, 1987]. The TMS score was weighted by regressing the TMS factor on its sub-factors and items, while still taking into account the hypothesised measurement model. Scale weights are given by the regression coefficients. In this study the scale weights were as follows: specialisation: $R^2 = 0.53$, credibility: $R^2 = 0.79$, coordination:$R^2 = 0 .67$. The scores for each sub-factor were multiplied by their scale weight the three were added together to make the weighted composite.

7. Results

To test the first hypothesis a hierarchical regression was conducted to ascertain the extent to which quality and quantity of social interaction in software development teams accounts for unique variance in team tacit knowledge ratings (Table 1).

Table 1 *Hierarchical regression for TMS and Social Interaction in predicting tacit knowledge (N = 48)*

Variables	Step 1 β	t	Step 2 β	t	Df	R^2	F	ΔR^2	ΔF
Step 1: Control Variables									
TMS weighted composite	.30	2.11*	.06	.31	1, 46	.09	4.44*		
Step 2: Social Interaction									
Quality SI			.43	2.52*					
Quant SI			-.04	-.23	3, 44	.20	3.76*	.12	3.20*

* p<.05

It was found that the overall model was significant accounting for 20% of the variance in team tacit knowledge. Quality and quantity of social interaction significantly describe 12% of variance in team tacit knowledge above and beyond transactive memory. However, transactive memory is also a significant predictor of team tacit knowledge (9% of variance).

Hypothesis 2 predicted that social interaction (quality and quantity) and team tacit knowledge will be mediated by the development of a transactive memory system. To test this hypotheses a four stage analysis was conducted to test whether the conditions for mediation were satisfied. If the mediator is a complete mediator of the relationship between the independent variable and the dependent variable, the effect of the independent variable when controlling for the mediator, should be zero [Baron & Kenny, 1986], or at least not significant [Miles & Shevlin, 2001].

Table 2 *Mediation Analysis for Transactive Memory*

Conditions to Demonstrate Mediation in Three Stages	**Independent variable**	**B**	**t**	**p**	**R^2**
Stage 1					
Does quality of social interaction significantly predict *team tacit knowledge*?	Quality of social interaction	.59	3.41	<.01	.20
Does quantity of social interaction significantly predict *team tacit knowledge*?	Quantity of social interaction	.02	1.15	>.05	.03
Stage 2					
Does quality of social interaction significantly predict *transactive memory*?	Quality of social interaction	1.40	5.22	<.001	.37
Stages 3 & 4					
Does transactive memory predict *team tacit knowledge* when quality of social interaction is controlled?	Transactive memory Quality of social interaction	.02 .56	.21 2.55	>.05 <.01	.20

In stage 1, team tacit knowledge was regressed on quality of social interaction and quantity of social interaction, respectively. Quality of social interaction satisfied the first condition for mediation (B = .59, p<.01), quantity of social interaction did not, and so was not included in further mediation analyses. Furthermore, it is noted that quality social interaction accounts for 37% of the variance in transactive memory. In stage 2 the second order factor of composite transactive memory were regressed on quality of social interaction. In the final stage, team tacit knowledge was regressed on transactive memory, while controlling for quality of social interaction. The mediators ceased to exert a significant influence on team tacit knowledge when quality of social interaction was controlled. Therefore, the third condition for mediation was not met. Therefore social interaction (quality and quantity) and team tacit knowledge are not mediated by transactive memory.

8. Conclusions

Transactive memory and quality of social interaction both contribute to team tacit knowledge, with quality of social interaction playing a more important role. Transactive memory is not a mediator between social interaction and tacit knowledge. Social interaction and transactive memory provide a reasonable model to explain the development of team tacit knowledge, with the quality of social interaction being key.

It is concluded that tacit knowledge is acquired and shared directly through good quality social interactions and through the development of a TMS. TMSs are important for the acquisition and sharing of team tacit knowledge because they enact 'collective minds' of teams. Quality of social interaction is however a more important route through which teams can learn and share tacit knowledge than is transactive memory. The frequency of interaction indirectly aids the acquisition and sharing of tacit knowledge since it leads to better quality interactions and a more developed TMS. This study treated quality and quantity as separate entities, which provided a more in-depth analysis of the influence of social interaction.

A recurring theme in studies on software development and agile development in particular, is human and social factors and how these factors affect, and are affected by, agile principles [Dyba & Dingsoyr, 2008]. Research into the agile approach to software development has developed in the past five years. Nevertheless, a number of open questions remain, and the relevance and implications of certain fundamental organisational concepts are still not fully understood in this context [Abrahamson et al. 2009; Agerfalk et al. 2009]. One such concept is team communication and effective tacit knowledge transfer.

Agile methods suggest that most written documentation can be replaced by informal communications among team members internally and between team and the customers with a stronger emphasis on tacit knowledge rather than explicit knowledge. Much store is placed in face-to-face interaction but not much explanation of the cognitive processes involved in the creation of team and individual tacit knowledge. The findings from this study provide empirical support for these agile principles.

8.1 Limitations and future research

This study has the limitations associated with most field research. The research design was non-experimental and used a self-report survey. Regardless of the sophistication of the statistical techniques, causal inferences must be treated with caution when using non-experimental designs. The survey measure was deemed to be a valid and reliable instrument for use in teams and for the purposes of the present study and was constructed to eliminate common-method variance by following the recommendations of Podsakoff et al. [2003, 1986].

In this study we did not differentiate between agile and non-agile teams but focussed instead on software teams in general. It is recommended that future research distinguishes more agile teams from less agile teams. In addition, further research into geographical distribution of teams and the impact on TMS development, tacit knowledge sharing and subsequent team performance is necessary to understand fully the best team configuration for successful software teams.

References

Abrahamsson, P., Conboy, K. and Wang, X. (2009),'Lots done, more to do': the current state of agile systems development research, European Journal of Information and Systems, 18, 281–284.
Agerfalk, P.J., Fitzgerald, B. and Slaughter, S.A. (2009), Flexible and distributed information systems development: state of the art and research challenges, Information Systems Research, 20, 317– 328.
Bahli, B. and Zeid, E.S.A. (2005), The role of knowledge creation in adopting extreme programming model: an empirical study, in: ITI 3rd International Conference on Information and Communications Technology: Enabling Technologies for the New Knowledge Society, pp. 75-87.
Baron, R. M., and Kenny, D. A. (1986), The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51, 1173-1182.
Beck, K., Beedle,M., Van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., et al., (2001), Agile Manifesto, retrieved from http://agilemanifesto.org/
Berman, S.L., Down, J. and Hill, C.W.L. (2002), Tacit knowledge as a source of competitive advantage in the National Basketball Association, Academy of Management Journal, 45(1), 13-31.
Chiu, C., Hong, Y., Mischel, W. and Shoda, Y. (1995), Discriminative facility in social competence: Conditional versus dispositional encoding and monitoring-blunting of information, Social Cognition, 1(1) 49-70.
Chow, T. and Cao, D.B. (2008), A survey study of critical success factors in agile software projects, Journal of Systems and Software, 81(6), 961-971.
Crowston, K., Howinson, J., Masango, C. and Eseryel, U.Y. (2007), The role of face-to-face meetings in technology-supported self-organizing distributed teams, IEEE Transactions on Professional Communications, 50(3), 185–203.
Dyba, T. and Dingsoyr, T (2008) Empirical studies of agile software development: A systematic review, Information and Software Technology, 50(9-10), 833-859.
Faraj, S. and Sproull, L. (2000) Coordinating expertise in software development teams. Management Science, 46(12), 1554-1568.
Granovetter, M.S. (1973), The strength of weak ties, American. Journal of Sociology, 78(6) 1360–1380.
Hackman, J. R. (1987), The design of work teams, in J. Lorsch, (Ed.), Handbook of organizational behaviour (pp. 315-342), Englewood Cliffs, NJ: Prentice-Hall.
Hollingshead, A.B. (1998), Communication, learning, and retrieval in transactive memory systems. Journal of Experimental Social Psychology 34, 423-442.
Hollingshead, A.B. (2001) Cognitive interdependence and convergent expectations in transactive memory, Journal of Personality Social Psychology, 81(6) 1080-1089.
Koskinen, K., Pihlanto, P. and Vanharanta, H. (2003), Tacit knowledge acquisition and sharing in a project work context, International Journal of Project Management, 21, 281-290.
Layman, L., Williams, L., Damian, D. and Bures, H. (2006), Essential communication practices for extreme programming in a global software development team, Information and Software Technology, 489, 781–794.
Leonard, D. and Sensiper, S. (1998), The role of tacit knowledge in group innovation, California Management Review, 40(3), 112-132.
Levesque, L.L., Wilson, J.M. and Wholey, D.R. (2001), Cognitive divergence and shared mental models in software development project teams, Journal of Organizational Behavior. 22, 135–144
Lewis, K. and Herndon, B. (2011), Transactive memory systems: current issues and future research directions, Organization Science 22(5), 1254-1265.

Liang, D.W., Moreland, R. and Argote, L. (1995), Group versus individual training and group performance: The mediating role of transactive memory. Personality and Social Psychology, 21(4), 384-393.
Melnik, G. and Maurer, F. (2004), Direct verbal communication as a catalyst of agile knowledge sharing, Agile Development Conference, 22-26 June, Salt Lake City, Utah.
Miles, J. N. V., & Shevlin, M.E. (2001), Applied regression and correlation analysis in psychology: A student’s guide. London: Sage.
Mishra, D., Mishra, A. and Ostrovska, S. (2012), Impact of physical ambiance on communication, collaboration and coordination in agile software development: An empirical evaluation, Information and Software Technology, 54 (10), 1067-1078.
Moreland, R.L. and Myaskovsky, L. (2000), Exploring the performance benefits of group training: Transactive memory or improved communication? Organizational Behavior and Human Decision Processes, 82(1), 117-133.
Nerur, S. and Balijepally V. (2007), Theoretical reflections on agile development methodologies, Communications of the ACM, 50, 79–83.
Nonaka, I. and Takeuchi, H. (1995), The Knowledge Creating Company. Oxford University Press, New York.
Olson, G.M. and. Olson, J.S. (2000), Distance matters, Human–Computer Interaction 15, 139–178.
Podsakoff, P. M., MacKenzie, S. B. Lee, J. and Podsakoff, N. P. (2003), Common method biases in behavioural research: A critical review of the literature and recommended remedies, Journal of Applied Psychology, 88(5), 879-903.
Podsakoff, P. M and Organ, D. W. (1986), Self-reports in organizational research: Problems and prospects. Journal of Management, 12, 69-82.
Polanyi, M. (1966) The Tacit Dimension, Routledge, London.
Ryan, S and O’Connor, R.V. (2009), Development of a team Measure for tacit knowledge in software development teams, Journal of Systems and Software, 82, 229-240.
Sharp, H. and Robinson, H. (2010), Three ‘Cs’ of agile practice, in T. Dingsoyr et al. (Eds.), Agile Software Development: Current Research and Future Directions, Springer, Berlin, pp. 61–85.
Standish Group International, CHAOS Report 2011 available: https://secure.standishgroup.com/reports/reports.php
Stasser, G., Vaughan, S. I., & Stewart, D. D. (2000), Pooling unshared information: The benefits of knowing how access to information is distributed among members, Organization Behavior and Human Decision Processes, 82, 102-116.
Sternberg, R.J., Forsythe, G.B., Hedlund, J., Horvath, J., Wagner, R.K., Williams, W.M. Snook, S.A. and Grigorenko, E. L. (2000), Practical intelligence in everyday life, Cambridge University Press, Cambridge.
Tsoukas, H. (2003), Do we Really Understand Tacit Knowledge? In M. Easterby-Smith, M. Lyles (Eds.), The Blackwell Handbook of Organizational Learning and Knowledge Management, Massachusetts, pp. 410-427.
Wegner, D.M. (1987), Transactive memory: A contemporary analysis of the group mind, in: B. Mullen & G. R. Goethals (Eds.), Theories of Group Behavior, Springer-Verlag, New York, pp. 185-208.
West, D. and Grant, T. (2010) Agile development: mainstream adoption has changed agility, Forrester Research, Inc.
Yuan, Y.C., Fulk, J., Monge, P.R. and Contractor N. (2010), Expertise directory development, shared task interdependence, and strength of communication network ties as multilevel predictors of expertise exchange in transactive memory work groups. Communication Research 37(1), 20–47