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THE BIG FIVE AND VISUALISATION OF TEAM WORK ACTIVITY TECHNICAL REPORT 581

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The Big Five and Visualisations of Team Work Activity

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Abstract. We have created a set of novel visualisations of group activity: they have been designed to mirror the activity of the individuals and their interactions, based upon readily available authentic data from the groups. We evaluated these visualisations in the context of a semester long software development project course. Data from these was used to build visualisations of the activity of each person in each group. We report our theoretical analysis of the design of our visualisations in the framework defined by the "Big 5" theory of team work as well as a qualitative study of the visualizations in relation to the student's reflective reports. We conclude that these visualizations provide a powerful and valuable mirroring role which has the potential, when well used, to help groups learn how to improve their effectiveness.

1 Introduction

Recent studies on computer-supported collaborative learning (CSCL) show that the expected beneficial outcomes of teamwork (such as high motivation, deep involvement in learning, and substantial knowledge gains) often do not materialize. An increasing number of studies and observations is reporting low participation rates, low levels of communication and collaboration (both in terms of quantity and quality of contributions), small knowledge gains, and little satisfaction with the group learning situation (e.g. [1], [2]). Kreijns, Kirschner and Jochems [3] have identified the tendency to assume that social interaction will occur automatically once the environments makes it possible, and the tendency to forget the social and psychological dimension of social interaction as two major pitfalls in designing and deploying collaborative learning systems.

We take the position that a group of students, in order to learn to work collaboratively, need to put effort not only in task-work, but also in *teamwork*. Teamwork can be defined as "...a set of interrelated thoughts, actions, and feelings of each team member that are needed to function as a team and that combine to facilitate coordinated, adaptive performance and task objectives resulting in value-added outcomes." ([4], p. 562). It is teamwork that ensures the success of teams at the workplace, and there is no reason to believe that this would be different for teams whose focus is on learning. The question of what processes and components comprise teamwork and how teamwork contributes to team effectiveness has received much attention in social psychology. A recent review of this body of research resulted in the identification of the "Big Five" components of teamwork [4]. The elements that make up teamwork, independent of the task a team has to perform, are ([4], p 560):

- 1. Team Leadership: Ability to direct and coordinate the activities of other team members, assess team performance, assign tasks, develop team knowledge, skills, and abilities, motivate team members, plan and organize, and establish a positive atmosphere.
- 2. Mutual performance monitoring: The ability to develop common understandings of the team environment and apply appropriate task strategies to accurately monitor teammate performance
- 3. Backup behavior: Ability to anticipate other team members' needs through accurate knowledge about their responsibilities. This includes the ability to shift workload among members to achieve balance during high periods of workload or pressure.
- 4. Adaptability: Ability to adjust strategies based on information gathered from the environment through the use of backup behavior and reallocation of intra-team resources. Altering a course of action or team repertoire in response to changing conditions (internal or external).
- 5. Team orientation: Propensity to take other's behavior into account during group interaction and the belief in the importance of team goal's over individual members' goals.

Teams that enact these five competencies will enjoy improved performance. However, in order to fully realize this performance improvement potential, research shows thatthree *coordinating mechanisms* need to be in place in addition ([4], p. 564):

- Shared mental models: An organizing knowledge structure of the relationships among the tasks the team is engaged in and how the team members will interact.
- Mutual trust: The shared belief that team members will perform their roles and protect the interests of their teammates.
- Closed-loop communication: The exchange of information between a sender and a receiver irrespective of the medium.

In our approach to support online (learning) teams, we trace students' interaction behavior along these dimensions and provide visualizations which are mirrored back to the groups. It is important to note that at this stage in time we are not attempting to provide groups with *feedback* in the strong sense that we could identify and visualize differences between optimal performance and a group's actual performance; rather, we *mirror* information pertaining to the components of teamwork for the groups (see also [5]). We believe that groups will profit from 'only' mirroring information, provided that this information speaks to the right points. Building on the theoretically and empirically well grounded "Big Five" framework, we hope to have identified the right points.

We have created a set of novel visualisations of group activity: they have been designed to mirror the activity of the individuals and their interactions, based upon readily available authentic data from the groups. We have been evaluating these visualisations in the context of a semester long software development project course. The students worked in teams of 5 to 7 and were assessed on the demonstrated quality of the software product and the effectiveness of the software and group processes in achieving that product. Students were required to make use of Subversion (SVN) to maintain the versions of their software and Trac to support group communication via a Wiki as well as a Ticket system which supports allocation of tasks and tracing them against milestones. Data from these was used to build visualisations of the activity of each person in each group.

The two main questions that this paper addresses are: How well do the visualizations capture information relevant in the context of the Big Five framework? Is there a relation between patterns identifiable through these visualizations and group performance outcomes (overall mark as well as group-work mark)? In the next section, the visualisations are introduced. Next, we analyze to what extent these visualizations allow one to assess the Big Five components. Finally, we describe relations between patterns as revealed by the visualizations and group performance. We conclude with a comparison to similar approaches.

2 Overview of visualisations

2.1 Activity Radar

As shown in Figure 1, this representation (inspired of [6]) consists of a circle, representing the range of participation, and colored dots, each representing an entity for which we want to compare participation levels: often a dot is a team member but it could also be a classroom or a group. Each dot is placed on a radius (always on the same one) and moves to the centre as the member's level of participation increases: a person whose dot is right in the centre has the highest level of participation whilst a person whose dot is on the perimeter has the lowest level of participation. The inner, darker purple circle perimeter represents the average level of participation. The unit of the participation depend of the medium (which explains why we have three different graphs associated with the three media, mixing different units in a single graph would not be meaningful). For the SVN and for the Wiki media, the amount of participation is the number of added lines. For the Ticket medium, it is the number of ticket events performed by the member. The highest participation (the center) and the average (the perimeter of the dark purple circle) values can be defined separately, thus changing the scale. Therefore the scale can be relative to the group only or to the whole class.



Figure 1. Activity Radar for SVN and Wiki

For instance Figure 1 shows that the bulk of the SVN activity (on the left) is done by three students (blue, yellow and red). Whilst the blue dot was still very active on the Wiki medium (on the right), the red and yellow dots were much less engaged. The most active person on the Wiki (light green dot) was fairly inactive on the SVN.

2.2 Interaction Network

This representation is based on Social Network Analysis [7], which is concerned with capturing relationships and flows between entities. It assumes that these relationships reveal some important features of the group. The network is modeled as a unidirectional graph (although we have introduced some direction for one medium), consisting of a set of nodes and edges, where each node represents a user and an edge represents an interaction between the two corresponding users. In our context, we defined the notion of interaction between two members when they modify the same resource (in a specific interval of time or not). The width of the edge is proportional to the number of interactions between them.



Figure 2. Interaction Network for Wiki

Figure 3. Interaction Network for SVN

Figure 2 shows an (ideal) case of a group where all team members interacted a lot with each other over the Wiki medium. In contrast, Figure 3 for SVN shows a different pattern of participation for a group where only three team members interacted.

2.3 Timeline of events: Wattle Tree

Figure 3 shows a novel graphical representation called the Wattle Tree. Each user's activity is shown in a climbing vertical "tree" (timeline): the tree starts when the user first performs an action in any of the three media considered. The left axis indicate the day number.



Figure 4. Wattle Tree of a well-functioning group

Wiki-related activity is represented by yellow "flowers", which, like the flowers on a wattle tree, look like yellow circles, in this case, appearing on the left of the trees. SVN-related activity is similarly represented, as (light and dark) orange flowers on the right of the trees. The size of the flower indicates the size of the contribution. Tickets-related actions are represented by leaves (lines in our current representation): a dark green (left) leaf indicates a ticket was open by the user whilst a light green (right) leaf indicates a closed ticket. The length of the left leaf is proportional to the time it remained opened. Those still open are shown at a standard, maximal size, as in the case of the bottom ones of Figure 4. A well-organised, efficient group should have many leaves, of small to medium length, on either side, with lots of activity (Wiki and/or SVN) in between. A small number of left leaves, especially if they are

of maximal length, indicates that users work on very chunky and large tasks, and do not use the ticket system to good effect, (eg. forget to close their tickets).

The group represented in Figure 4 shows that the group members used the Ticket system moderately well. Early in the project they used the Wiki often, whilst the SVN activity kicked in a third of the way into the project. The overall activity is quite well spread in time, except for the clearly visible semester break. The distribution of workload seems show a greater burden taken by the two left-most members but all members much sustained a quite steady load. This is very consistent with a normal, well involved group.

3 How the visualizations can relate to each Big5 factor

We seek here to investigate how the five important factors of successful team work and their respective behavioral makers can be assessed through our visualizations. We will address each "Big 5" element in turn.

3.1 Team Leadership

This factor is easily observed in the Tickets actions: the team leader typically assigns many tickets (which can be seen on AR/T), to each team member (reflected on IN/T). S/he also interacts with all team members, through ticket activity and Wiki medium. We expect a good team leader to be close to the centre in AR/T within the average circle in AR/W¹, and to see thick connections from the leader to all other team members in the IN/T. The IN/W may also show important connections involving the team leader, but not exclusively. We also expect to see in Wattle Tree that the team leader has a continuous activity throughout the project, and to see a rise in ticket and Wiki activities before the deadlines.

Behavioral Markers	Activity Radar			Inter	raction work	Net-	Wattle Tree
	Т	W	S	Т	W	S	
Facilitate team problem solving	+	++		+	+		Continuity in time
Provide performance expecta- tions and acceptable interaction	+	+		+	+		Continuity in time
patterns Synchronize and combine individual team member con- tributions Seek and evaluate information that affects team functioning	+	+		+	+		Continuity in time Esp. before deadlines

Fable	1. '	Team	Leaders	hip
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¹ AR stands for Activity Radar, T for Ticket. Similarly we denote AR/W and AR/S, as well as IN/W, IN/T, IN/S for the three Interaction Networks

Clarify team member roles Engage in preparatory meetings and feedback sessions with the team T = Ticket; W = Wiki; S = Subversion

3.2 Mutual performance monitoring

This factor can be partially assessed by the Interaction Networks. A very low level of interactions between team members on all media may indicate that they do not monitor each other nor pick up mistakes and lapses. Another indication may be given in the Wattle Tree, by observing the laps of time between team members' actions. Members of a monitoring team are quicker to respond to each other, and tickets do not remain open for a long time without reassignments.

Table 2.	Mutual	performance	monitoring

Behavioral Markers	Activity Radar			Inte	raction N	Net-	Wattle Tree
					work		
	Т	W	S	Т	W	S	
Identifying mistakes and lapses in other team members' actions Providing feedback regarding team member actions to facili- tate self-correction T = Ticket; W = Wiki; S = Subverse	sion			+	+	+	laps of time between interactions. Opening time of tickets.

3.3 Backup behavior

A main aspect of backup behavior is the ability to shift workload amongst team members to achieve balance during periods of high workload and pressure. The IN/T would give an idea of how well tickets were distributed by the team leader. Activity Radars, on all media, are an indicator of how much each member participated on average. In particular the assignment and re-assignment of tickets gives a good indication of how tasks are distributed. However the most information is given by the Wattle Tree, as it shows, at any given time, the amount of activity for each team member. Whilst the actions captured may not precisely reflect the amount of work done by the participant (e.g. a small Wiki entry may in fact be the result of several hours work), there is a good indication of how workload is distributed. A week before an important deadline for instance, where there is usually a burst of activity, a team that practices backup behavior would shift tasks at that time to the less busy members. So we would expect to see an even workload during these periods of pressure, even if they are preceded by a short, uneven period.

Behavioral Markers	Activity Radar			Interaction Net- work			Wattle Tree
	Т	W	S	Т	W	S	
Recognition by potential backup providers that there is a workload distribution problem in their team.	+	+	+	+			Distribution of work- load, re-balancing of
Shifting of work responsibili- ties to underutilized team members	+	+	+	+			workload
Completion of the whole task or parts of tasks by other team members							
T = Ticket; W = Wiki; S = Subverse	sion						

Table 3. Backup behavior

3.4 Adaptability

This factor is difficult to assess as its absence does not imply that the team is not successful. For instance the task, team and resources may be problem-free, hence the team does not have the opportunity to show its adaptability. However if we know of a problem or a change then we can observe how the team reacted. One team, for instance, had an inactive "team leader" so one member informally took the lead and the team managed to complete the task. Whilst all the visualizations may show a problem (such an inactive team member), the reaction of the team may not be always observable on the visualisations. When the time of these changes is known, then we can gain cues from the Wattle Tree since it is time-based. For example, we could see when the other team member took informal leadership of his team and how long it took the others to respond to his actions. Importantly, the team members, having deep knowledge of the dynamics and situation may recognise evidence of such shifts.

Table 4. Adaptability

Behavioral Markers	Activity Radar			Interaction Net- work				Wattle Tree	:
	Т	W	S	Т	W	S			
Identify cues that a change has occurred, assign meaning to that change, and develop a new plan to deal with the changes Identify opportunities for im- provement and innovation for habitual or routine practices Remain vigilant to changes in the internal and external envi-	+	+	+	+	+	+	If char acti serv Tim	moments nges are kno ons can be /ed. ne between act	of own, ob- tions

3.5 Team orientation

This is defined by the "propensity to take other's behavior into account during group interaction and the belief in the importance of team's goals over individual goals". The Wattle Tree provides a nice picture of the degree of involvement of each individual during periods of high pressure, such as the completion of a project milestone. All Activity Radar and Interaction Network diagrams give an indication of how much the members participate overall, how much they interact and in which direction. Thick, even-colored links between team members show that they interact a lot, on average in a symmetric two-way fashion. Reassignment of tickets, tickets closed by other members are also evidence that other team members participate in a task.

 Table 5. Team orientation

Behavioral Markers	Activity Radar			Interaction Net- work			Wattle Tree
Taking into account alternative solutions provided by team- mates and appraising that input to determine what is most correct	Τ	W	S	Τ	W	S	
Increased task involvement, information sharing, strategiz- ing, and participatory goal setting T = Ticket; W = Wiki; S = Subvers	+ sion	+	+	+	+	+	Coinciding actions in time

4 Relation to group performance

Here we only describe relationships between the visualizations and observed team performance, in particular relationships with the quality of outcomes (as reflected in grades for group management). Our first, and most important, source for gaining an understanding of student perceptions, was the final reports that students submitted for the project. Each group was required to write a brief (1-2 pages) reflective statement about its achievements, the limitations of these and what had been learnt. In addition, individual students had to submit a statement of their contributions and a reflective statement. Nine of the ten groups had access to the diagrams to use for their reports and six did so.

The second main source of evidence was the complete set of information in the Subversion and Trac repositories: whenever we wished to understand more about a group, we could examine these in detail. Indeed, it is this huge collection of information that our visualisations are intended to summarise and overview.

The following analysis is based around the elements of the Big Five model and reports our observations of the role of our visualisations, for the ten groups studied, in relation to those parts.

4.1 Team leadership

Facilitate team problem solving

In the effective groups, there were several indications of these activities: the team leader had a striking pattern of Wiki use, with very regular postings which appeared as many yellow flowers at the left of their Wattle Tree. There was also a strong indication of the leader's interaction with all group members in the Wiki Interaction Network, with no such interaction for other people.

For the most groups that functioned least well, there are clear indications of problems. At the most extreme was a nominated group leader who had absolutely no interactions with anyone through the Wiki or the tickets.

Another important feature of the wattle diagram is that the pattern of SVN submissions and Wiki activities for each member would have been a gross indication of people performing assigned tasks. This would have been very valuable when combined with scrutiny of the details in the system.

The marker of the reports noted that the wattle diagram was particularly useful in the case of some students who failed to report all of their contributions (even though this contributed to their individual part of the course mark). The wattle diagram gave a very clear indication of overall activity and enabled the marker to find work that had not been reported. This would be equally useful for team leaders if their team members failed to report to them.

Provide performance expectations and acceptable interaction patterns

In the final reports, it was striking that in all 5 groups which referred to the diagrams, the team leader was one of the people who did so. They referred to them in relation to just these aspects of performance and interaction. One of them noted that they were unreliable in relation to one team member who did not make their own SVN submissions, but clearly showed that this aspect of the visualisations presented a very clear pattern.

Synchronise and combine individual team member contributions see and evaluate information that affects team functioning

For some groups, this was visible in the SVN interactions which seemed to occur when individual code was integrated. Our visualisations are complemented by the information that is presented by Trac/SVN on the history of each document.

Clarify team member roles

Although we had not expected the visualisations to play a major role here, they are extremely useful for a team member. For example, a person who is supposed to be creating tests sets and writing code should have a solid series of SVN flowers. In some student reports, claims of having had this role were not supported by such a pattern and this would be an excellent starting point for a leader to discuss the issue. Equally, some roles should produce a steady series of Wiki contributions and in some cases, such as the person doing research into existing systems, this was very clear. One striking example was the case of the person claiming to write meeting minutes for several meetings per week: one would have expected this to be reflected by many small Wiki flowers for that person.

Engage in preparatory meetings and feedback sessions with the team

This should be evident from good use of Wiki (but determining this requires consulting the Wiki in conjunction with the diagrams)

4.2 Mutual performance monitoring

Identifying mistakes and lapses in other team members' actions

In the case of extreme social loafing, the Wattle Tree (and to a lesser degree, the participation diagrams) made this very clear. The students tended to avoid criticising each other in their reports but two leaders pointed to the pattern in these diagrams as clear indicators of failure to contribute. The individuals involved made no comment on them (even though they should have read the whole report, including the leader's comments critical of them), perhaps because they had nothing to offer to refute this. In the case, mentioned above, where the group leader did the SVN commits for another person, that person mentioned this in their report and pointed to comments in the commit which indicated this. This case clearly shows that the displays made lapses evident.

Student reflections included several mistakes, such as doing the wrong job, but these were not visible in our displays. However, there were cases where students reported a task being taken over because the person initially allocated it had problems and, somewhat surprisingly, this was reflected in a change in the Wattle Tree with a shift from SVN to Wiki activity.

Provide feedback regarding team member actions to facilitate self-correction This was hinted from ticket reallocations were sometimes visible in the ticket Interaction Network diagrams, but this was only so where the group made good use of the tickets.

4.3 Backup behaviour

Recognition by potential backup providers that there is a workload distribution problem in their team. The size of the flowers and their frequency are an indication of this. Although we were only able to make the diagrams available at the end of the course, they would have made an excellent basis for a group discussion earlier. For example, where a person was not active, this could be explored by the group.

Shifting work responsibilities to underutilised members

As described above, this was sometimes visible in the change in pattern of SVN/Wiki activities of the individuals involved as well as interactions on the SVN for code from tasks taken over.

Completion of whole task or parts of tasks by other team members.

This is also similar to the above and, from reading the student reports, the diagrams often supported the claims of this being done. Of course, the indications from ticket activity, interaction, subversion/Wiki interaction would require additional knowledge and digging into the details in SVN/Trac.

4.4 Adaptability:

Identify cues that change has occurred, assign meaning to that change, develop new plan to deal with the changes

This is similar to the issues of back up described above under backup.

Identify opportunities for improvement and innovation for habitual or routine practices.

One group devised a contract of behaviour and contributions. Such a contract could easily include elements, such as timing of Wiki/SVN contributions, which are visible on the Wattle Tree.

Remain vigilant to changes in internal/external environment of team

If this is a task of person, their actions on the Wiki should indicate this, in part. For example, three groups had an external client who was overseas and sometimes was difficult to contact. There was usually one person with primary responsibility for client contact. This was reflected by their regular Wiki submissions and their interaction with the client on the Wiki.

4.5 Team orientation:

Taking account of alternative solutions from teammates and appraising that input to choose what is most correct

There was considerable evidence of this being better or worse done in the reflective reports but this did not appear to match the diagrams except that individuals who seemed most unhappy about failure to have their views properly considered also appeared as low contributors on the displays. One would also have expected high levels of interaction on the Wiki as issues were discussed and again, people in this situation, of feeling left out of decisions, seemed to have low interaction on the Wiki. A tutor or a leader observing this pattern might use this to trigger exploration of such problems.

Increase task involvement, information sharing, strategising and participatory goal setting.

In successful groups, this seems to have been reflected in high Wiki activity early in the semester. It is also reflected in the Interaction Network diagrams with the most successful groups having quite rich interaction on the Wiki, with all members having some interactions with all others. There was also one group where the division of work meant that half the group had high interaction on the Wiki and the other half had high interaction on SVN. This matched their individual reflections.

5 Conclusion

We have motivated our approach to visualizing team interactions with the Big5 model of teamwork [4], and demonstrated that the visualizations can express various aspects of the components of teamwork. A qualitative analysis revealed a number of relations between patterns observable in the visualizations and team performance. Our work is similar to that of, for instance, Donath et al. [8], but geared towards small work-ing/learning teams, not large on-line communities, and Erickson [9], but focusing on asynchronous contributions rather than chat presence.

As mentioned in the introduction, it can be seen as a limitation that the visualizations do not communicate normative information; they do not show how a group or a team member ought to perform. The main reason for refraining from providing feedback and guidance information for us is that it is not clear from research what the optimal values for the five components plus the three coordinating mechanisms should be. It is also unlikely that a generally optimal combination of values can be identified because of the specificities of the task a group is engaged in, the situational demands a group finds itself in, as well as the history of the group (e.g., how well the group members know each other) will affect what can be considered 'optimal' (cf. [9]). One way around this problem is to work purely inductively and base feedback on what worked for teams in similar situations (e.g, [10]). This, however, requires analysis of a great number of similar situations and taking into account the right parameters. In our approach, the interpretations are left to the team members themselves or to those who are very familiar with the specifics of teams, such as their managers or, in instructional settings, tutors. This does not only have the advantage that we can avoid providing team members with potentially ill-founded feedback and advice; it can also be argued that leaving the normative decisions to groups themselves has positive motivational effects and has the potential to eventually lead to more stable and satisfied groups [11].

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