PERCEIVED MODULARITY: A CASE STUDY OF A GLOBALLY DISTRIBUTED TEAM

Completed Research Paper

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Abstract

Globally Distributed Teams are being increasingly used by organizations to carry out knowledge intensive work and are often engaged in the development of modular products and services. While modularity is always treated as a given property of products and services, the findings of our qualitative research conducted in a GDT in charge of developing a new software product suggest that team members develop different perceptions of modularity, that, in turn, are related to different perceptions of interactions and team configuration. These different perceptions bring about difficulties in coordination and knowledge sharing.

Keywords: Perceptions of product modularity, Globally Distributed Teams, team configuration, team interactions
Introduction

Globally distributed teams (GDTs) are an increasingly common organizational solution to carry out knowledge intensive tasks as they enable the development of products and services ‘around the clock’ (Carmel, 2006) in a ‘24 hours knowledge factory’ environment (Gupta et al., 2009). Most GDTs are engaged in the development of modular products or services: product modularity, that refers to the way a design is decomposed in different modules, enables the development and production of different modules to be assigned to different subgroups located across the globe (e.g. US, Ireland, and India) as product design assembly is built in the modular architecture.

Previous studies on product modularity focused on the interdependences between modules, functions and interfaces to distinguish between ‘modular’ and ‘integral’ product architectures (Ulrich, 1995; Baldwin and Clark, 2000), to assess the flexibility offered by a modular architecture and to delve into the issue of what the best degree of modularity should be. Other studies focused on how modular design should vary according to the product life-cycle development phases (Fixson, 2006) and the different goals of the organizations. Regardless the perspective adopted, product modularity has been treated as a given property of products and services. In this paper we investigate (a) whether and how members of GDTs may develop different perceptions of product modularity; (b) the interplay of such perceptions with individuals’ interpretations of their work environment in the team; and (c) the consequences of these different perceptions. In order to investigate these issues we conducted a qualitative research of a GDT in charge of developing a new software product. Our findings suggest that team members develop different perceptions of the degree of modularity of their product’s architecture that, in turn, are related to different perceptions of interactions and team configuration. These different interpretations increase difficulty in sharing and coordinating knowledge.

Product Modularity and GDTs

The concept of modularity, as a principle for designing complex systems, has gained increasing attention in management studies in the past decade because of the critical role played by design structure in developing successful new products and services and increasing firms’ competitiveness (Campagnolo and Camuffo, 2010; MacCormack et al. 2006). The concept of modularity can be applied at different units of analysis: products, production systems and organizational design (Campagnolo and Camuffo, 2010). In this paper we are interested and we will refer to product modularity.

In a product modular architecture, there is a one-to-one mapping between physical components and functional elements, and the interfaces between components are de-coupled. An integral architecture is instead characterized by a complex mapping between physical components and functional elements, and coupled interfaces between components. A modular architecture entails independence between modules and interdependencies within modules (Baldwin and Clark, 2000). The choice of product architecture is dictated by the company’s product strategy. Ulrich (1995) contends that if a company wants to stress product performances, then the most appropriate choice would be the integral architecture, since global performance characteristics are optimized through this type of architecture. On the other hand, companies wanting to emphasize product change and variety, flexibility and upgradability, may well choose a modular architecture. Brusoni and Prencipe (2001) argued that the definitions of modular and integral architectures as proposed by Ulrich are to be understood as ideal types. Most products do not fully satisfy the requirements of either of them and therefore lie somewhere alongside a continuum that goes from fully modular to fully integral architectures. Modularity is a matter of degree. Correspondingly, the degree of modularity depends on the level of analysis. Products can be decomposed at different levels: sub-systems (e.g. control system), sub-sub-systems (e.g. fuel metering unit), components (e.g. valve), and sub-components (e.g. spring). Accordingly, modularity can be a characteristic of each or only some of these levels. Among the objective metrics for measuring modularity we can recall the fan-out/fan-in visibility that respectively measures the extent to which a product’s element depends on many other elements (high fan-out) and the extent to which an element has many other elements depending on it (high fan-in) (MacCormack et al. 2006).
A recent stream of research problematized the definition of product’s modularity arguing that as products pass through different development stages throughout their life cycles, it would be difficult to infer an unique product modularity as this latter should be guided by specific objectives of the firm (Fixson, 2003). Consistent with this, MacCormack and colleagues’ evidence (2006) testifies how Mozilla’s developers overtime engaged in a deep effort and succeeded to make the product’s architecture more modular.

Empirical literature on modularity investigated not only products’ design strategy but also the implications of modularity for organizational design and the ensuing dynamics of inter-organizational relationships (e.g. Brusoni and Prencipe, 2001; Schilling, 2000). In particular, a number of scholars (Henderson and Clark, 1990; Baldwin and Clark, 2000; MacCormack et al., 2008) suggested that product designs should “mirror” the organizations that develop them or viceversa. Colfer and Baldwin (2010) in their recent contribution reviewed 102 studies to understand the extent to which the mirroring hypothesis was supported and found that this occurred in 69% of cases. In the remaining cases, coordination could be achieved without mirroring, thanks to the development of ‘actionable transparency’ that is to say ‘the extent to which everyone with an interest in improving the design has the right and means to act on both his or her own copy and the master copy of the design’ (page 22). It is worth underlining that the mirroring hypothesis found the stronger support in within-firm samples, less strong in across-firm samples and relatively weak support in open collaborative samples.

Empirical work and managerial literature on GDTs advocated a high level of modularization of products and services in conjunction with a high level of codification of organizational processes and procedures, to create the conditions for GDTs’ positive outcomes (Nemiro, 2004; Duarte and Tennant Snyder, 2006). As an example, Eppinger and Chitkara (2006) suggest that a ‘modular product architecture is very helpful for GPD [global product development] teams in which development of complete subsystems or components is to be carried out by teams in different locations. Clearly defined interfaces between modules facilitate their separate development and eventual integration into the product. Without such modularity, more intense collaboration across design interfaces is necessary’ (page 29). Particular industries with modular products and processes (e.g., software) already exploit the possibilities of the so called 24-hour-knowledge-factory (Mattarelli and Gupta, 2009). The 24-hours knowledge factory is a particular type of GDT, that assigns different modules and tasks to different locations and uses time differences to develop products faster. The project management tools and collaborative technologies used in these kinds of GDTs are developed with decentralized work execution in mind. Gassman and Von Zedtwitz (2003) observe that decentralized work execution emerges if standards for interfaces between locally developed modules are already available and clearly defined: ‘Such standards may give rise to relatively autonomous product development with low system specificity, resulting in modules that can be produced and distributed independently’ (Gassman and Von Zedtwitz, 2003: page 247).

Perceptions in GDTs and perceived modularity

Although the abovementioned studies deepened our understanding of the role that product modularity plays in GDTs, they considered modularity as a given, reified property of the product or service at hand. Also those contributions arguing that the degree of product modularity can and should change overtime according to different firms’ objectives, seem to suggest that ‘visible design rules’ (Baldwin and Clark, 2000) shared widely among the systems’ participants would let them know how each part interacts and relates to the others.

However, in complex, evolving, product development projects, do team members agree in defining the product’s degree of modularity?

We know that professionals in a team tend to develop different perceptions of their tasks, their workplace, their co-workers, and the work object (Wrzesniewski and Dutton, 2001; Metiu, 2006), especially if they work in far and different contexts, like members belonging to various subgroups in a GDT. When working in GDTs, individuals are often not aware of what other individuals are working on (Weisband, 2002) and about the specific characteristics of the product’s other modules. Moreover, in distributed teams, individuals may lack knowledge about the full architecture of the product (Grimaldi et al, 2009). The issue of different perceptions in GDTs has received limited attention in the literature of virtual work so far.
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(Mattarelli and Tagliaventi, 2010). A notable exception is the work of Wilson et al. (2008), who observe that individuals develop different perceptions of proximity and investigate how communication and social identification processes, as well as certain individual and socio-organizational factors, affect feelings of proximity towards coworkers.

Similarly, we may question whether GDT members develop the same perceptions on modularity of the product they develop. This is an interesting issue to explore because, whereas organizations structure work according to how they define the degree of modularity of the product, professionals could restructure the way they work and interact with co-workers according to their perceived degree of modularity. Consistent with Unphon and Dittrich’s (2010) observation that product architecture can be used as a coordination mechanism, situations where professionals develop different perceptions of the architecture modularity could lead to coordination issues.

Hence, our aim is to explore whether different perceptions exist and how they influence or are influenced by other individual perceptions and preferences. Specifically we are interested at the interplay between perception of product modularity and other perceptions in GDTs. The research questions we aim to address are: do members of GDTs develop different perceptions of product modularity and how? What is the interplay of such perceptions with individuals’ interpretations of their work environment in the team? What are the consequences of the interplay between these different perceptions for the GDT?

Data and methods

Research context: The Globally Distributed Team of Flower-Net

Given the exploratory nature of our research question and the still limited evidence available on the topic that we intend to investigate, we decided to conduct a qualitative field study on a globally distributed team (given the fictitious name Flower-Net) in a software multinational (Yin, 2003). We developed a case study on a R&D GDT of IT professionals engaged in the development of a new web-based collaborative technology.

The team, that started working on the product in 2007, is composed of 60 people located in 3 subgroups of 23 people in Boston, US (with 12 males and an average of about 14 years of professional tenure), 20 people in Dublin, Ireland (with 18 males and an average of about 8 years of professional tenure), and 17 people in Pune, India (with 10 males and an average of about 5 years of professional tenure). Most developers are based in the Boston and Dublin subgroups and they focus on a specific module (or component) of the product. Modules are single geography so to limit the interdependencies between different subgroups. Professionals in each subgroup are assigned to different subteams, associated to a specific module or to a specific activity. They are in charge of building different capabilities of the product. More specifically, some capabilities are created from scratch by the developers while other developers are in charge of taking capabilities developed in other divisions of the larger organization and integrate them into Flower-Net online collaborative technology. Most of the time, Pune’s professionals are in charge of the functional testing activity, that is to say they check daily for defects and verify that the task is implemented correctly, and build a verification report. This triggers, in most cases, the need to interact daily with the developers responsible for the specific part of the code that failed the verification process. Developers in turn are supposed to fix issues within a day.

Flower-Net professionals make use of agile software development methodologies that are based on iterative development, where requirements and solutions are not fully planned at the project’s beginning but developed through collaboration between cross-functional self-organizing groups (Erickson et al. 2005). In agile methodologies, tasks are divided into small increments with minimal planning, and regular re-planning. Iterations are short time frames, that in the case of Flower-net last four weeks and engage a team working through a full software development cycle and taking responsibility on how to attain the requirements of the iteration. A new product or a new feature release can need several iterations. Face-to-face communication is emphasized over written documents, especially when team members are collocated. When working across different sites, team members can communicate daily using collaborative technologies such as email, instant messaging systems, videoconferencing, etc. Flower-Net uses the scrum methodology that is heavily focused on project management and collaborative
practices. In particular, all the subgroups make use of short daily scrum meetings, lasting usually 15 minutes, where team members report to each other what they did the day before, what they are planning to do in the actual day, and what the pending problems are.

Data collection and analysis

Our qualitative data consist of semi-structured face-to-face interviews (Gubrium and Holstein 2001) with all the members (56) and managers (4) of the GDT. In December 2009, we interviewed the subgroup in Boston while in March and May 2010 we interviewed all the members in the Pune and Dublin subgroups, respectively. For each informant the interviews lasted between one and one-and-a-half hours and they were recorded and transcribed into field notes. Interviews included questions concerning: the organization of work with co-localized and distant colleagues, the product’s degree of modularity, the process of knowledge sharing, and the subgroup and GDT performance.

In analyzing our qualitative data, we availed ourselves of the guidelines provided by Strauss and Corbin (1998) to build a grounded model and adopt an iterative approach of constant comparison, where data collection, coding and analysis are intertwined. We continuously moved back and forth between our field notes, the theoretical model that we were building and new pieces of data, to find support or to detect inconsistencies between new ideas and our data. This meant that the theory emerging from the analysis of our initial field notes guided further data collection. For instance, since we started to code the first interviews, we came to recognize that beyond the degree of product modularity designed by management, single professionals held differing perceptions of Flower-Net degree of modularity. Therefore, in subsequent interviews we asked our informants to comment more on that and related processes.

Following Strauss and Corbin (1998), we identified recurrent themes and concepts in our data and grouped them to form categories (open coding), we made connections between the categories identifying possible relationships to each other (axial coding) and selected a core category relating major categories to it (selective coding). During open coding, we named some of our categories on the basis of existing literature because they represented well known concepts. For example, we labeled as ‘designed interdependencies’ instances where Flower-Net managers were commenting on the way they assigned modules to sites in order to minimize the number of interactions across locations. In the same way, when managers talked about how they saw and designed Flower-Net as decomposed into different modules, we used the code ‘designed modularity’. Conversely, as a recurrent theme in the data, our informants made comments on their representations of Flower-Net modularity that often differed from the management’s one and from informant to informant. We decided to label that new concept, that would not fit into concepts already present in extant literature, as ‘perceived modularity’. The final outcome of the coding process is represented in figure 1, that shows how individuals developed different perceptions of product modularity and that such perceptions were associated to perceptions of interactions and team configuration. These theoretical categories and their connections are presented next.

Evidence from the field

The following paragraphs, that illustrate our case study, are structured around the aggregate categories emerged from our coding. Figure 1 presents the outcome of the coding process, i.e. our grounded model. We elaborate on the model as we proceed with the analysis.
Modularity: designed, enacted, and perceived

As described in the ‘research context’ section, the organization under study designed Flower-Net as a modular product. Sanat, the manager of the GDT based in Boston, specified that the designed product modularity was reflected in the organization of work. In an interview he told us: ‘Our product is highly modular [...] Some people know only what they need to know for accomplishing their tasks. Some others show more interest in knowing something more, but it is mostly a personal preference’.

However, coherently with what we know from the literature on product modularity, the managerial design was more an ideal objective for the team and Flower-Net modularity changed over time. In other words, the new product development team faced a process of product modularization and at different life-cycle phases the product could have a different degree of modularization. To this regard, Shan, a software developer in Dublin told us that ‘modularity is what we are trying to achieve, so it is difficult to give a clear-cut definition of modularity at a certain point of time, the product is continuously evolving, sometimes in unexpected ways’.

However, given the rapidity with which the market requested product changes and the difficulty of an explicit codification of product details into documents and files, individuals ended up in holding different perceptions of Flower-net modularity. A subset of 25 individuals stated that the product was modular, likewise most software products. For instance, Aaina (tester, India subgroup), told us:

*Flower-Net is a modular product. The basic thing about Flower-Net is that it is created to suit cloud computing. This means that users should be able to customize and combine the modules so to suit their needs. So, this is why you need separate modules, so if you want just one you can just ask for that. [...] There is of course interaction between the modules, you need interconnections. There are...*
interconnections, not interdependencies. [...] As a tester you need to know these interconnections, but they are standardized, so it is not difficult.

On the other hand other professionals (28) recognized that the actual configuration of the software was characterized by strong interdependences between modules, i.e. that Flower-Net was an integral product. In their perception, this may be traced back to the fact that, when approaching the release of the updated modules or the end of an iteration, professionals often need to work on last minute changes of the software code. Due to time pressure, such changes are often done without taking care of interface standardization. To this regard, Neal (Developer, Ireland subgroup) observes that frequent module changes call for the constant need of integration:

*The system collects hourly all the codes checked in by all developers and put them together in a global hourly full ‘build’ (called also checkpoints); if a developer in one location does something that breaks the work done by an engineer in a different location, the whole team is affected and a global solution needs to be found.*

Based on the evidence reported above, we define the perception of product modularity as an individual mental representation of the modularity of a product at a certain point of time, expressed in terms of perceived interdependencies between modules.

Table 1 shows that, in our case, perceptions of modularity were not dependent upon location. In other words, in all locations we find individuals who perceived the product as integral or modular and because roles, as above said, are based upon locations, differing perceptions cannot be traced back to roles’ differences (testers and developers). Moreover, perceptions of modularity were linked, in the words of our informants, to the interactions they enacted in order to accomplish their work, and to their perceptions of the GDT configuration, which we now turn to discuss.

| Table 1. Number of individuals who perceived the product as integral or modular, grouped by: subgroup location, perceptions of interactions, perceptions of GDT configuration (managers are not included)* |
|---------------------------------|-------------------|-------------------|
|                                 | Perceived product modularity |               |
|                                | Integral | Modular |
| Subgroup location               |          |        |
| US (% on Total)                 | 12 (23%) | 10 (19%) |
| Ireland (% on Total)            | 10 (19%) | 8 (15%) |
| India (% on Total)              | 6 (11%)  | 7 (13%) |
| Sum (% on Total)                | 28 (53%) | 25 (47%) |
| Perceptions of interactions     |          |        |
| As positive (% on Total)        | 20 (38%) | 3 (6%)  |
| As negative (% on Total)        | 4 (8%)   | 9 (17%) |
| Both positive and negative (% on Total) | 4 (8%) | 13 (25%) |
| Sum (% on Total)                | 28 (53%) | 25 (47%) |
| Perceptions of GDT configuration |          |        |
| No awareness of others (% on Total) | 8 (15%) | 10 (19%) |
| Limited awareness of others (% on Total) | 20 (38%) | 15 (28%) |
| Sum (% on Total)                | 28 (53%) | 25 (47%) |

* The sum of individuals is 53 instead of 56 because we could not reach agreement in the coding of the field notes relating perceived modularity of three informants.
**Designed, enacted, and perceived interactions**

Formal interdependencies (Thompson, 1967) across locations were designed so that the US and Ireland subgroups were in charge of development of different modules, while the Indian team was mainly in charge of testing. Designed interdependencies were aimed at reducing the number of interactions across locations and at taking advantage of time differences. Here with interactions we refer to any work-related exchange between two or more individuals, face to face or through collaborative technologies (e.g., email, IM). However, the use of agile methodologies amplifies the need for daily interactions between developers and testers and between developers. In other words, in order to accomplish their work, individuals needed to enact many interactions with their local and global colleagues. To this regard, instant messaging was considered as the primary mean through which individuals should keep in touch.

During interviews, we came to recognize that individuals developed different perceptions of the enacted interactions. Specifically, 18 developers expressed their dislike for ‘continuous’ interactions, that they perceived as disruptive, and thus they tried to limit interruptions. 13 of them declared that the fact that the product was modular should have allowed them to work on a specific task at a time, which they preferred to a situation of multitasking. In other words, those who perceived the product as modular tended to interpret negatively interactions across modules. When they were not able to work continuously and uninterrupted on a task, they used different time management strategies, e.g., working from home, turning the IM off, or displaying ‘busy’ on their IM profile. For instance, Matt (architect, Ireland subgroup) told us:

> I prefer to concentrate either on security or globalization issues, even if normally I have to switch back and forth within the same day. Maybe I will keep time either at the very start of the day where I will interact with people for the globalization issue and then concentrate without interruptions and distractions on security and sometimes at the very end of the day will finish certain tasks for globalization. [...] I can adopt these strategies because of the very nature of Flower-Net, which is composed of independent components.

On the other hand, 24 informants consider interactions (and the associated work interruptions) as a positive source of knowledge. Twenty of them also perceive a low degree of modularity and declared that, even though they were engaged in the development of one specific module, they needed to get information from colleagues engaged in other modules. They intensively made use of instant messaging to get access to colleagues and to be accessed by others. Interrupting and being interrupted was perceived as part of regular work and linked to the integral nature of the product. To this regard, John (developer, US subgroup) says:

> Some people simply ignore email or pings, but I don't. I feel obligated to respond. When possible, I stop what I am doing and I try to respond. [...] People cannot work on their components if I do not provide them knowledge on what I did on mine. Components, in fact, are interdependent.

Echoing this statement, Shan (developer, Ireland subgroup), specified that unless he were very sick, he would have ‘come to office everyday and not work from home’ because this allowed him ‘to interact with colleagues more easily’. He also underlined that although ‘product modularity is something that the company is trying to achieve’, there are a lot of interdependencies at the architectural level that bring him to interact with many other people and to move, in one same day, between different tasks.

Finally, a few people (13) had mixed expressions about their interactions in the GDT. While they recognized the importance of interactions, they expressed their preference for working on one task at a time. In their perceptions, time differences play a negative role, because they oblige individuals to extend their working hours in order to find an overlapping window to work with distant colleagues. Table 1 summarizes the relationship between perceived modularity and perception of interactions.

**Designed, enacted, and perceived configuration**

The organization designed the GDT with an even distribution of individuals across three locations in order to get advantage of time and cost differentials. When asked if they were aware of the configuration of the GDT (i.e., the arrangement of members across sites, O’Leary and Cummings, 2007), we were surprised to
learn not only about an enacted configuration of the team somewhat different from what designed, but also that individual perceptions of such configuration were scant and often inaccurate.

In relation to the first point, the enacted configuration of the team was composed by more than three locations, because many individuals worked from home permanently (4 individuals in the US), from home only for a few days a week (30 individuals in Ireland and US), or from different offices of the company (10 individuals in the US). To this regard, Jordan (developer, US subgroup) comments:

*I wouldn't say we are one location here or three locations overall. Here there are people working from home, from Toronto... And, yes, some of us work from the new location and some, like me, don't want to move from the actual office [the previous official location of the Boston subgroup]. It's probably going to change as they move more people there [...] Most people in Ireland seem to have a strong preference for face to face interactions, we don't. I guess they don't work from home. In India, I don't know.*

The abovementioned field note also suggests that Jordan did not know much about the habits of her distant colleagues. For instance, in Ireland many people worked from home at least one day a week. Low awareness of others is common in all locations. Our informants were not able to tell us exactly how many people worked in the GDT, the professional background of distant colleagues, their age, or their personal characteristics. Eighteen of our informants declared that they had no idea of the GDT subgroups apart from their own. On the other hand, 37 of our informants had developed some rough perceptions of their distant colleagues. For instance, the testers Puji and Sati commented that they knew that the US and Irish subgroups were composed of people from different nationalities, while the Indian subgroup was homogeneous. Terence (lead developer, Ireland subgroup), together with many other colleagues, observed that the average age of the US subgroup was much higher than the other subgroups. Martha (product manager, US subgroup) was under the impression that in India there were more women, but not in managerial positions.

During interviews individuals who perceived the product as modular, commented that they were assigned a specific and confined set of tasks and that they did not need at all any type of information about other subgroups. David (Developer, Ireland subgroup) told us:

*I wouldn't be too aware of the overall global team, other than the pocket of people I work with.... Also I know very little of the pocket of people I work with. In the States I know few names, like Jordi, Sanat, who is in charge of the filer but that's all. About India, even less [...]Personally I don't think I need any more information about the configuration of the team. I feel I have all the information I need to do the job.*

On the other hand, people who perceived the product as integral observed that they needed to know more about their distant colleagues, because they depended on them to get precious knowledge related to integration systems, other modules, or testing processes. This resulted in a higher awareness about GDT configuration. For instance Shan, who -as reported above- perceives the product as integral says:

*I know everybody in the whole team pretty much. Of course I tend to interact and have more knowledge of the people I directly work with. It's a working relationship but often we engage in casual conversation on sports, weather also. It is more easy to get deep into technical problems if you know more about the people you interact with. You also need to be conscious, to get a better understanding of how interacting with different people with different personalities.*

Table 1 summarizes the relationship between the perception of configuration and the perception of modularity. Specifically, it seems that people tend to have lower awareness of team configuration when they have perceptions of the product as highly modular.

**Consequences of the misalignment between designed product modularity, the level of product modularization, and perceived product modularity**

The misalignment between designed modularity, the level of modularization, and perceived modularity was associated to difficulties in coordination and knowledge sharing. In relation to coordination, some of our informants, who perceived the product as integral and interpreted in a positive light interacting with
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colleagues, told us that it was difficult to get the information they needed on time, because some of their colleagues did not respond to emails or turned their IM off. For instance, Saparna (tester, India subgroup) told us that, given the integrality of the product, some issues, when not resolved quickly, became ‘blocking’:

*I understand Flower-net has different components, but they are not independent at all and we all need to integrate our efforts. [...] The main difficult issue I face is when a person doesn’t reply to your mails and you are left waiting for a response. You send a reminder, but it is difficult to track them down, because they are busy, they have their own things... Because of the distance and the times zone it is even more difficult. The negative part for me is that issues that can be responded quickly become blocking.*

On the other hand, individuals who perceived the product as modular observed that coordination with individuals in other modules had to be minimal. For instance, they declared a preference for staying focused on their own task and complained about the need to stay overtime in the office without previous notice or about the difficulties in interacting with distant colleagues ‘continuously pinging’ them over the IM.

In relation to knowledge sharing, Jordan (developer, Boston subgroup) told us that there must be an ‘optimal balance between looking for information from others and figuring it out yourself’. Jordan, who perceives the product as modular, thinks that most of the information pieces developers and testers working on different modules may need from one another are already included in the wikis of the project (i.e. on the knowledge storing system of Flower-Net). Thus, when someone asks him an information, the first question he asks is: ‘Did you get some knowledge beforehand?’. The evidence reported above suggests that different perceptions of product modularity are associated to different work-style preferences (e.g. preference for frequent versus scarce interactions). Such preferences generate expectations on coworkers’ behaviors and, when such expectations are not met, individuals face difficulties in coordination and knowledge sharing. In this sense, the perception of modularity seems to act as a reinforcement for individual preferences.

Discussion

Our study of a globally distributed team in charge of developing different modules of a new web-based collaborative technology bears important insights for the way we think about the product modularity and its implications for the design of the work of groups and individuals. Our findings inform us that, besides a level of modularity designed by management and mirrored into formal design of interdependencies and team configuration and an emergent degree of modularization at different stages of the product development, GDT members developed differing perceptions of the product modularity and this, in turn, was related to different perceptions of the interactional patterns and the team configuration. We believe that our research provides the following contributions.

First, our qualitative evidence let emerge a new, interesting construct for R&D GDTs: perceived modularity that we defined as an individual mental representation of the modularity of a product at a certain point of time. We argue that this concept differs from other related concepts known in the literature in the following ways.

Previous studies already acknowledged that the degree of product modularity can and should change overtime according to the firms’ changing aims. However such studies considered modularity as a reified property of a product at specific moment of time that could be measured with specific metrics. In fact, our evidence too testifies to the existence of an emergent Flower-Net modularity. However we also show how individuals develop different perceptions about the emergent product modularity and it is on the basis of these perceptions that they take decisions regarding their work-related behaviors, impacting team-dynamics.

Another construct important to recall is ‘software architecture awareness’ proposed by Unphon and Dittrich (2010). Also the authors’ starting point is that software programs evolve continuously making hard and, at the same time, important for development teams to be aware of the architecture of their product. In their case-study, they show the coordination or awareness mechanisms that companies can put in place to promote architectural awareness among which a central role is played by the walking
architecture. This label refers to the role of a chief architect who is responsible for maintaining and evolving the software architecture but also in charge, in the everyday development process, for constant face-to-face communications with developers to communicate them the software architecture and increase their awareness of potential architectural problems. Their evidence also suggests that wikis can be used to document changes in the software thus increasing awareness. This concept does not take into account the issue of perceptions.

Our informants, while aware of the changing nature of Flower-Net, did not lament a scarce awareness of the product architecture. When interviewed they did not hesitate in defining what was in their opinion Flower-Net degree of modularity and never put into question the fact that other colleagues could hold differing perceptions about the product design. While we agree that they could have been not fully aware of the product architecture, we claim that their behaviors were guided by individual perceptions that were not aligned even if, as specified in previous paragraphs, Flower-Net used wikis, nightly builds, and frequent face-to-face communication as suggested by agile methodologies.

Finally, Brusoni and Prencipe (2001) acknowledge that the degree of modularity depends on the level of analysis undertaken –like the product subsystems, sub-sub-systems, components, sub-components- being modularity a characteristic of each or only some of these levels. We complement and extend this thinking proposing that individuals, regardless of the level of analysis considered, may develop differing perceptions of the degree of the product modularity.

To acknowledge that -also at the same level of analysis- individuals can develop different perceptions of the degree of modularity has important implications for design and coordination theories. Drawing on Unphon and Dittrich’s (2010) idea that software architecture can be used as a coordination mechanism, we argue that the existence of different perceptions on the degree of modularity of the product architecture can lead to coordination difficulties as they entail different interpretations of dependencies, and of coordination needs. As our case study shows, perceptions are related to organizational variables like the preference for managing time, workplace interactions, team configuration.

In particular our results suggest that professionals who perceive the product as integral see dependencies and develop positive attitude toward interactive activities with coworkers while professionals who perceive Flower-Net as modular dislike more to interact and be interrupted and try to limit the number of cross-module interactions and interactions in general.

In terms of team configuration, our data provide evidence of: an enacted team configuration that included more than the three original sites and evolved daily; the existence of differing perceptions, more or less accurate, of such configuration so that informants who saw Flower-Net as a modular product showed lower awareness of the overall team configuration while informants perceiving to work on an integral product were more aware of the initial team configuration and of the fact that configurations emerged dynamically and were far from being stable over time.

Recently Campagnolo and Camuffo (2010) underlined how, in order to develop a better all-round framework on modularity, empirical studies should consider all together product, production systems and organizational design, paying particular attention to their interdependencies and other factors that may influence them. Our study is an effort in that direction as it shows how individual perceptions may complicate the interdependencies between products (perception of modularity), production systems (perception of interdependencies and of interactions) and organizational design (GDT configuration) and need to be taken into account when setting up the context for positive work team outcomes.

Related to this last point, we think that our results are relevant for the current conversation on the mirroring hypothesis. Its proponents suggest that products design should mirror the structure of the organizations that produce them, leading to the appealing indication that modular products should be developed by modular organizations and viceversa (MacCormack et al. 2008). This prediction is thought to apply even more in the context of distributed work where highly modular products could be developed by groups of professionals geographically dispersed. Recent empirical contributions (see the review of Colfer and Baldwin 2010) find some support for such prediction but they also show instances where organizations that develop modular products can be less modular than expected as well as cases where groups of quite independent professionals contributed to the development of an integral product. Our results complement these studies showing different dynamics of the interplay between product
modularity and organizational choices. While the idea of mirroring between the formal structure of the organization and the technical dependencies of the product drove initial managerial intentions and actions in terms of product and team design, as well as managerial efforts toward modularization during the life-cycle of the software, what we witnessed was that single professionals tried to find coherence between their own perceptions of the software modularity, the ties that they developed within the project team in terms of amount and perceived usefulness of interactions and awareness of team configuration. Put differently, the mirroring hypothesis applied at the level of individual perceptions; in turn, different perceptions about product modularity ended up to be problematic within Flower-Net because professionals behaved accordingly to the dependencies that they perceived were in place.

Limitations and future research directions

Our findings and future research should be considered in light of the study’s limitations. It is a single case. Consequently, although the model that we built has theoretical significance (Yin 2003), it does not claim any statistical generalization. More research is required to understand whether the relations that we observed need further refinement or hold in other settings. More specifically, our qualitative data cannot rule out alternative explanations for coordination and knowledge sharing difficulties. Literature on distributed work has investigated why and how distance and the associated social dynamics hamper GDTs’ processes and outcomes (e.g. Weisband, 2002, Metiu, 2006, Wilson et al., 2008) For instance, issues such as time differences and cultural heterogeneity reduce the opportunities to create mutual knowledge and understanding. Our findings are not in contrast with similar considerations. In the case of Flower-Net, the individual construction of the perception of modularity allows individuals to face these very issues, by justifying their own preferences and behaviors and building expectations on the behavior of others. However, our claims need to be investigated in other settings.

For instance, our context is characterized by a high level of discretion, and also young developers are given empowerment and ownership of the modules they develop. This might have increased the opportunity for professionals to develop different perceptions and acted accordingly. It is well known that in contexts characterized by great autonomy, individuals can experiment with changes in relational boundaries (the people they interact with), task boundaries (the number and type of tasks they perform), and cognitive boundaries to modify their meaning of work (Wrzesniesky and Dutton, 2001; Bertolotti et al., 2005).

Related to that, an interesting avenue for future research is to investigate the role played by professional identity in the observed dynamics to understand if different perceptions of product modularity develop as a consequence of developers’ professional identities, that is to say the set of values, beliefs, and attributes that characterize an individual as a member of a professional group (Pratt et al., 2006). For instance, developers defining themselves primarily as ‘brokers’, or ‘integrators’, could find a better fit in working for a product that they perceived as composed of highly interdependent parts. Moreover, our informants were all permanent workers of the larger organization and no one was a newcomer. It would therefore be important to understand if the processes that we observed apply similarly for workers who develop less innovative products and operate in less discretionary contexts or for GDTs characterized by a high number of newcomers and/or a mix of permanent and temporary workers.

Possible paths for future research regard the investigation of some individual differences and how they relate to perceptions of product modularity. For instance, we know that individuals vary greatly in terms of their preferences for focusing on one task at a time (highly monochronic) or working on many things at once (highly polychronic, Kaufman- Scarborough and Lindquist, 1999). Individual polychronicity has been related to a generic positive orientation toward relationships (Hall, 1990). It would be worth investigating if different perceptions of product modularity, and the related interdependencies, are related to individual time management preferences.

To conclude, our work has introduced the new construct of perceived modularity and has linked it to different individual perceptions of interactions and team configuration. To adopt a comprehensive approach, we invite future researchers to explore the issues of perceptions and their interactions with design choices and actual behaviors.
References


