Understanding Software Testers in the Automotive Industry
A Mixed-method Case Study

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Abstract: This paper presents the results of a mixed-method study performed in the software department of a large automotive supplier operating in a global software engineering setting. The aim was to understand the social dimension and human aspects involved in software testing in an intercultural setting. Qualitative and quantitative analyses of testers' perception regarding their day-to-day activities and collaboration with other teams was conducted. The findings suggest the testing team is motivated but recurrently affected by external factors such as late input for testers, improperly or missing requirements, and unrealistic project planning. Testers identified human factors, such as openness and attitude of people, as relevant for effective collaboration. Combining the findings of the quantitative and the qualitative studies, our research suggests that the approach that testers take to their work can be characterized by a silo focus, i.e. rather than focusing on the overall goals their perception revolves around their subunit of the organization.

1 INTRODUCTION

With the growing complexity required for producing large software systems, software testing has been acknowledged by the industry to play a critical role in the development of useful software systems (Deak, 2012). Therefore, a considerable amount of effort in the development of any large and useful system is invested in testing (Martin, Rooksby, Rouncefield, and Summerville, 2008). Nevertheless, the current testing practices rely on experience gained in the field rather than on a rigorous and systematic approach (Engström and Runeson, 2010). The scope of testing has broadened: instead of testing a single piece of software, nowadays, either an entire system or a system of systems is often tested. Hence, testing has undergone several transformations. For example, it has increasingly become a professional team activity and is being made accountable throughout the entire organization. Technology transfer from research to the work performed in the industry has demanded the acquisition of new skills and consequently, a restructuring in the current practices (Martin et al., 2008).

Additional to the technical challenges, testing faces difficulties on the human and organizational levels, e.g. regarding the social perception of software testers within the organization or the technical impact of their role in the software development process (Whittaker, 2000; Deak 2012). Nonetheless, software testing has been increasingly recognized as a key activity in the production of software systems, the social perception of software testers has not been equally acknowledged.

2 RELATED RESEARCH

The study presented in this paper is based on research and findings regarding human aspects of software testing, tester-developer relationships, testing as a profession, and the specifics of software in the automotive setting. The following sections give a brief overview of the related research in these areas.

2.1 Human Aspects of Software Testing

Albeit research has strongly focused on studying the technical components of software testing, there have been prior efforts on studying the human factors related to testing as well as a mean to better understand software-engineering processes. By using

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qualitative interviews, observations, etc. social constructions and the inner view of social subjects on their environment becomes accessible. Shah and Harrold (2013) performed an ethnographic study in a large software company in India to understand the human dimensions that influence software testing. Shah and Harrold concluded that junior testers, when mentored well, can develop a positive attitude towards software testing and do not view it as a secondary activity. They found that participants view testing as a monotonous activity – especially manual testing. Nonetheless, a factor that enhanced motivation, despite the monotonous nature of the activity, was the feeling of responsibility and ownership. Furthermore, a relationship between responsibility and power suggested higher enthusiasm in participants over those who had responsibility with no power. Likewise, studies conducted to software developers found that effective leadership, a reasonable level of responsibility, a positive working environment, and a sense of being involved were factors influencing their motivation (McLeod and MacDonell, 2011). Both the organizational context as well as the composition and the culture of the software project team were equally found as factors influencing motivation (Oz and Sosik, 2000).

2.2 Tester-developer Relationship

Even though software testing is a technical subdiscipline of software engineering, where tools and automated methods are used, it is branch that depends on the interpersonal interactions of the people involved in the production of software. It has been found that conflict between testers and developers is inevitable and management has to ensure conflicts are dealt with constructively (Cohen et al., 2004). But where does this conflict stem from? According to the perception of a tester, the tester mindset is completely opposite to the developer's since the former has to break code while the latter creates it (Shah, Nersessian, Harrold, and Newstetter, 2012). According to Cohen et al, while developers create software "the way it should work", testers develop tests not only considering a software engineering perspective but also taking into account an understanding from the business and from real-life use cases.

Moreover, frequent conflicts between testers and developers arise when they do not share common work goals (Cohen et al., 2004). To align the different mindsets, individual goals should be connected to process metrics. Greater emphasis on shared team goals rather than individual ones and subsequent reward of the former, motivates people to work together (Patel, Pettitt, and Wilson, 2012). Shared knowledge and awareness should be promoted for effective collaboration as well as for a better understanding of the roles, responsibilities, and skills of others. Collaborative awareness is influenced by, and has an influence on, communication, coordination, and organizational culture: the shared attitudes, beliefs, and values that emerged from the organization's vision and objectives and which influence employee behavior (Patel, Pettitt, and Wilson, 2012). Past experience: how successfully developer and tester teams have worked together in the past should also be taken into account as a factor influencing successful collaboration (Patel, Pettitt, and Wilson, 2012). Also, structured work activities to promote tester-developer acquaintance, as well as testers' early and consistent involvement in the requirements are recommended.

The tester-developer relationship is important not only because it is related to job satisfaction of the involved parties but also because it influences the quality of the software produced. Pairing one tester to one developer leads to positive changes as higher job satisfaction for the people involved (Zhang et al., 2010).

2.3 Testing as a Profession

Additional to the conflicts identified on the tester-developer interactions, there are other challenges that testers often face within their own organizations and with the perception of testing as a profession. For example, one of the key problems testers often experience are the shortened times for testing. Often development phases overrun into the time allocated for testing. (Martin et al., 2008) From the research performed to 127 software professionals to discover the factors with negative influence on software testing practices, reduced time for testing was also identified (Fernández-Sanz, Villalba, Hilera, and Lacuesta, 2009). The shortened time for testing stems from delays of the previous development phases, the common practice to perform testing at the end of the project and only once the code is available, the impossibility to postpone the delivery to the customer, or due to financial problems that arise along the project (Fernández-Sanz et al., 2009).

Lack of specific testing training both while attending University and as an IT professional were highlighted as negative factors for the software practice. Moreover lack of education on software

testing of other stakeholders also poses a negative impact. For example, many managers did not obtained a good training on software testing; thus, do not value its potential for efficiency and quality. On the academic arena, few teachers have in-depth knowledge of the correct philosophy and techniques for testing. To understand the software practice in Canada, Garousi and Zhi (2013) surveyed software professionals –including Project Managers, Software Testers, Business and Systems Analysts and QA Specialists and Leads. They wanted to know if people had received testing training programs (including university or on-site training courses, but excluding self-study hours based on online resources or books). From the 206 respondents, more than half received at least 20 hours of formal training of testing in a year -which showed an increasing awareness of the importance of software testing training. Nonetheless, 39% of the respondents mentioned that they received no training on testing before the survey was performed. Cost and time as well as lack of support from high-level management were identified as obstacles for not providing training (Garousi and Zhi, 2013). Earlier research from Cohen et al. (2004) identified that the lack of support and status that testers face also make their job more difficult and time consuming.

Regarding the perception of testing as a profession, Deak (2012) assessed both students and professionals. Her findings showed that students had a negative attitude towards testing as a career: testing translated into correcting other people's work and being a failed and denominated developer (Deak, 2012). Testing is also viewed as an activity which needs less qualification than other sub-disciplines in the production of software systems (Fernández-Sanz et al., 2009).

To comprehend the complexity of software testing on its own, Taipale and Smolander conducted a qualitative research in 26 organizations of high technical level producing real-time software with above than average criticality. From their findings, they suggested several improvements and stressed the importance of the early involvement of testing and and planning of testing so testers could give their contributions earlier (Taipale and Smolander, 2006). Their recommendations depict the importance of equally considering software testers as part of the software development lifecycle, promoting effective interaction and communication between testers and developers.

Another challenge software testers face is the need to find solutions to ill-defined problems and shape their work to changing organizational demands (Martin et al., 2008). One of these organizational demands is the involvement of the customer in the decision-making process regarding testing (Shah and Harrold, 2013).

2.4 Software in the Automotive Setting

Especially in the automotive industry, all these challenges have had vast impact on the development of software systems (Broy, 2006). Software has provided more and more functionality to the car; yet, software development had to fit into a predominantly vertically-organized automotive industry where historically, mechanical engineers strove to build cars with a set of independent sub-systems. This independence allowed car manufacturers to outsource production to third-party suppliers. In his study about software engineering challenges on the automotive industry, Broy found that requirements management is a major challenge between the car manufacturers and the suppliers. In many cases the requirements, which are developed by the car manufacturer, are often not complete or precise enough for the supplier to implement. Additionally, the complexity of the solutions needed and the hardware-dependent implementations hinder the reuse of code from one car generation to the other. Even though models of software engineering are progressively influencing the mechanical engineering in the automotive field, processes are still not adapted to the software and intensive systems development demands.

From the findings from Fernández et al. (2009) regarding shortened testing phases due to committed delivery dates to the customer, this constraint is particularly strict in the automotive industry. All the suppliers of a car manufacturer, such as the company in our research, are responsible for delivering their component to the car manufacture on-time so that the end goal of assembling and producing the car is achieved as planned. Thus, since testing is the last phase the supplier has before it signs-off to production, delays in development cut time for testing with no opportunity for extension.

3 THE RESEARCH PROBLEM

Current research suggests that software testing – especially in the automotive sector– is a complex task, not only regarding the technical skills required, but also regarding human and social aspects and the personal ability of dealing with complexity.

The research presented in this paper aims to understand the situation of testers in an automotive setting. While there has been research addressing the social and human factors that affect software testers in other contexts, this study takes a closer look at the challenges that a team of senior software and system testers, working in a matrix-organization, deal with in the extremely time-constrained and safety-critical automotive industry. We focused on highly qualified testers, all having a university degree – thus to preempt the view of testing as a profession that is done by failed and denominated developers or as an activity which needs less qualification (Deak, 2012; Fernández-Sanz et al, 2009).

The present study was triggered by a request of the managers of a software testing team in the automotive industry. The concerns and perceptions of the testing managers pointed to social problems between testers and other stakeholders. Considering for this research as well, we decided to analyze the problem from the testers' point of view. We aimed to understand how testers conceptualize their most recurrent problems and their collaboration with other departments. Thus, this research is guided by the following questions:

- RQ1: What are the most recurrent problems that testers face in their day-to-day activities?
- RQ2: How do they collaborate with other teams?

4 STUDY METHOD

In this section we present the details of our study by first outlining the organizational context in which this study takes place, then describing the participants, and finally presenting the mixed-method approach taken in this research.

4.1 Organizational Context

The testing group being examined in this study is part of the automotive passive safety business unit of a large multinational engineering company. The goal of this testing group is to perform black box tests on both software and system levels. Specifically for the tests done on the system level, implicit hardware tests are carried out since software and hardware integration is needed for performing them. This is relevant from the organizational perspective because it implies the testing team not only interacts with software stakeholders but also with other departments such as technical project management – within the hardware team – and crash detection algorithm development teams.

The organizational structure in place is a functional matrix: employees are full members of a functional department and project managers are limited to coordinate their efforts while participating in a project. Thus, testers are part of a (functional) testing team and report to their testing line manager but are also part of a particular customer project where they also report to the project manager. The project manager is responsible for the execution of the project from beginning to end and receives the resources allocated from each functional or line manager.

Regarding communication: telephone as well as computer-mediated communication tools (e.g., email, web conferencing, and enterprise social network software) are available as means to interact with people throughout the entire organization. Interaction with the customer or car manufacturer occurs via telephone, email, or face-to-face meetings. This interaction is conducted by a single person: usually the project manager. The requirements management process is tracked with a requirements management tool that connects both the customer and the supplier.

The supplier develops and manufactures safety-critical software for the electronic control unit of automobiles. Specialists from hardware, software, and crash detection algorithms work in the development of the product throughout its different phases. Although generic software and hardware platforms are used to leverage the development of specific customers' requests, customized development is further needed.

Due to the real-time and safety-critical nature of the systems, they have to undergo rigorous tests and re-validation including requirements validation reviews, design and code reviews as well as component and integration testing. Testers can take several weeks to develop the test specification, based on the requirements, execute the test cases, and finally find and log defects for a given feature.

4.2 Participants

During the five-month study period, there were numerous informal interactions with testers, test leads, and managers in the department (e.g., during lunch, meetings, talks, and workshops). The participants were members of a testing team co-located in Germany and India. For the study presented here, 15 members located in Germany participated.

- 11 testers

- 4 managers (either team leaders, line managers, or department managers)

For the first part of the study, 6 testers were interviewed using a semi-structured interview and the 4 managers were interviewed using diverse customized interviews. For the second part of study, we surveyed 11 testers –6 of them had already been interviewed on the first part of the research.

The testing group in Germany has 15 members, one of them is the section manager (line manager), and 2 are team leads. From the 12 testers in the team, one person deliberately declined to participate in the study for privacy reasons so we studied the remaining 11 testers. These are developing and running test cases, remotely coordinating other testers working in India, or doing test tool development. Regarding their experience, 14 of them are seniors ranging from 7–25 years of experience in the company. Just one of them has one year of experience – all of which was completed in this company. All of the group members speak German as their native language and English as a second language. Their age ranges from 30 to 50 years old; there are 1 female and 14 males. They all hold a university degree in electrical engineering, physics or computer science.

The German group collaborates with an Indian group of testers remotely. The German members play a leading role and the Indian team a supportive one. The Indian testing group, which is not included in this study, has 69 members, one of them is the Section Manager, and 5 are team leads. There are 63 testers that are developing and running test cases.

4.3 Procedure

To gain a deeper understanding of the reality lived and perceived by the testers, an ethnographically-informed study was performed. This study intended to discover the opinion of the studied group and did not aim to generalize or provide a statistically valid view of a certain population. Therefore the sample size was determined, as frequently done in qualitative studies, in a non-probabilistic fashion (Guest, Bunce, and Johnson, 2006). Saturation, or the point at which no new information or themes are observed in the data, was used to determine the sample size.

The procedure adopted for conducting this study was exploratory sequential design, a mixed methods approach, using a combination of qualitative and quantitative methods (Creswell and Clark, 2007). After the collection and analysis of qualitative data, a second quantitative step – built from the exploratory results – to test or generalize the findings from the first qualitative research was taken. The key purpose of this two-phase sequential design is to triangulate the data. By involving more than one method to gather data, an alternative perspective allows to validate, extend, or challenge the initial findings (Turner and Turner, 2009).

The following sections describe the four phases completed in this study as part of a mixed-method exploratory sequential design: qualitative data collection, qualitative data analysis, quantitative data collection, and quantitative data analysis.

4.3.1 Qualitative Data Collection

In exploratory sequential design, the first step performed is a qualitative study. The qualitative data collection tools in this study consisted of a combination of informal conversations, interviews, and document analysis. The first couple of months were the phase of immersion: accompanying the day-to-day activities of the testers, we learned as much as possible about their daily operations, their processes, their interactions, and the organization itself. Based on the analysis of the details of the observations, interview questions were developed. The interviews performed were semi-structured, this means that a set of similar questions were asked to the participants, following an interview guide (Bernard and Ryan, 2010). With this guide, a set of basic questions were asked to all participants but depending on how the interview progressed, more detailed questions were asked to gain more insight in a topic of interest. The guide (presented in Appendix A) covers questions about testers' most recurrent problems and collaboration, as well questions on academic background, qualifications, and their profession's self-perception.

Participants were approached via email. At the meeting, before the interview started, the participants were informed once again of the goal of the talk and reminded that the information shared would be kept anonymous. Throughout the interview, continual paraphrasing of the participants' answers was done to confirm that the researcher had correctly understood what the interviewee aimed to communicate. The participant was requested to give acknowledgment and feedback. During the interviews, the answers were typewritten in a simple text file. Due to the company's privacy policy the interviews were not recorded. The interviews lasted from 80 up to 120 minutes. Once an interview was over, the answers were reviewed. If needed, to confirm our understanding and findings, we conducted follow-up

meetings or emailed participants and asked for feedback or clarification.

In general, the participants showed an open and cooperative attitude in the interview. Even though the interviews were scheduled for one hour, in all cases the interviews extended, mainly due to the participants' interest in talking about their vast experience.

4.3.2 Qualitative Data Analysis

For analyzing and putting together all the collected data, each interview was re-read several times – through the analysis phase – in order to identify patterns that could allow the data to be grouped in meaningful ways (Denzin and Lincoln, 2005). Categories and sub-categories emerged around the first four interviews. An important fact is that most of the interviewees have been working for a significantly long period of time in the company and in some cases only in this team since they joined. In spite of starting in the company at distinct moments and having different backgrounds, the collective opinion was relatively similar. The number of times the categories and subcategories appeared on the interviews was counted. Similar categories and subcategories were stacked together in order to create a more meaningful, summarized, and concise system of categorization. In order to visualize all this information, a mental map with relationships interpreted from the data was built from the findings. This mental map was built in two steps. The first consisted on summarizing the categories and subcategories in a spreadsheet. The second one was building a graph, using the DGML (Directed Graph Markup Language) specification, taking as input the categories and subcategories from the first step. The categories that were mentioned by most of the participants combined with the most meaningful topics from the interview were the ones chosen as input for the survey.

4.3.3 Quantitative Data Collection

In line with the exploratory sequential design the collection and analysis of the qualitative data were followed with quantitative methods to build on the qualitative findings (Creswell and Clark, 2007). For the quantitative step, a questionnaire with five-point Likert-scaled answering options was created, ranging from strongly disagree to strongly agree. The questions of the online questionnaire matched the questions performed in the face-to-face interview performed in phase 1 of this study. Whereas the Likert items in the online survey corresponded to the highest mentioned and most relevant topics categories/subcategories identified as answers from the qualitative study. In contrast to the open-ended questions from phase 1, the answer domain on the survey was constrained to the selected categories and subcategories.

The identified categories included motivation, training provided (by the company), recurrent problems, collaboration on the same team and with other departments, and perception of processes and their adherence.

The online survey was posted through the intranet of the company. An email was sent to all participants and a period of five days was given for people to answer it. The survey was anonymous and all testers – except for one who explicitly declined to participate – answered it. Thus, 11 of the 12 testers participated in the survey.

4.3.4 Quantitative Data Analysis

The results from the survey were analyzed by frequencies. Since the goal of the quantification was to receive an overview regarding the agreement to the items identified and proposed with a five-point Likert scale, the two selections of "agree" and "strongly" agree were taken together as markers of agreement regarding the item. To see the summary of the identified categories and subcategories as well as the percentage of agreement versus disagreement, please refer to Appendix B.

5 FINDINGS

The findings presented in this section are from both the qualitative and the quantitative studies. We describe the most important categories or themes we obtained from the qualitative study as well as the overall agreement regarding these topics gathered in the survey from the quantitative study.

Motivation was a key theme to understand since it would depict how testers felt about being testers. Both in the qualitative and the quantitative studies, testers agreed on feeling satisfied with their job. They have a positive attitude towards software testing and do not consider it a boring and monotonous activity. 91 % of the participants described testing as an interesting job that allowed them to work on a broad variety of topics. One participant explained that "Testing is a very interesting job because it requires a very complete view of the software. If you have a broad view then you can do a whole range of tests: with a bigger overview a better test variety."

Another participant added,"It's very interesting because of the variations. You cover many different subjects and you keep learning."

91% of the testers agreed on having responsibility and ownership to do their job – which previous research acknowledged as factors for enhanced motivation and enthusiasm among testers. Additionally, 91 % of testers shared that they had enough skill to perform their job and the same percentage said they enjoyed working with their testing team; 73 % of the testers felt satisfied as a tester. "I feel happy to be a tester […] Support is really good and then it is easy to feel comfortable working with this team."

One tester shared how he felt connected to her/his job: "I was once in a meeting with higher management, and they said that the work of each of us had helped to save in average thirty lives. I felt really connected to my job and why it really mattered."

To sustain the fact that this testing team is technically qualified, we learned from their line manager, that almost all testers hold a Tester Certification from the ISTQB. Therefore, according to our findings, the testing team is highly qualified and motivated to test the electronic control unit software.

So in line with findings in motivational psychology (Deci and Ryan, 2012), our findings regarding motivation show the importance of intrinsic motivation – the participants are able to relate their testing activities to individual experiences of autonomy, competence and relatedness and thus experience high quality forms of motivation and engagement.

Regarding the training the company had provided to the testers, 91 % agreed on receiving some kind of training since they joined the company. Most of the testers shared that the training was of technical nature: 82 % received either the foundations for understanding concepts related to the product (Electronic Control Unit, hardware and software or sensors) and 73 % received even more specific technical training to perform their daily job. When asked about the training, one of the participants who had worked in another department before (within the same business unit), said: "The trainings [I received] were very specific and role-oriented. When I changed from role 1 to role 2, my view on the organization changed and I started to understand which were the pain points of each role and why were they colliding. I think that roles are focused on a very narrow and specific scope. So I think, it strongly depends on how managers are leading by goals and that these goals are not only looking at the role's self-optimization." According to this participant in one meeting he once argued about task responsibility and the answer from the colleague was: "Are you sure this is part of my role description to do?" Another participant added: "Sometimes I had to convince the group leader of another person to allow him to work with me. Seems we have different goals between groups and that's why the members of a team seek mostly their own."

Regarding cross-functional training within the department that would bring awareness to the importance of shared goals we found that only 36 % had received training that allowed them to understand how each of the departments contributed to the development of the product; 45 % of testers had receiving organizational training or information on how the company worked. When asked about their role scope, one tester said: "The role is clear: to find and log defects." Later when we asked this participant about the overall goal of quality to the product he asserted: "Yes, the overall goal is to close as many bugs as possible. In the past we [testers] introduced scripts to help the developers but this didn't work because there was no time and not enough resources."

Testers mentioned that the start of production is a date agreed between the suppliers and the customer that is virtually immovable. This is a constraint in the automotive industry that specifically affects testers: Since they are the last step before the product is signed-off to production, delays from previous phases reduce their time to perform testing.

Among the most recurrent problems they face, 82 % of the testers mentioned late inputs needed for testing (software, hardware, or requirements), 73 % of testers pointed to improperly specified requirements, 73 % to unrealistic project planning and estimation and 55 % mentioned reduced time to perform testing.

Regarding properly specified requirements, one participant shared: "I think writing good requirements is difficult. But in one project we got really good requirements when the customer reviewed them directly, the results were better."

Another participant said: "The problem is that sometimes the OEM (customer) had the requirements and they were making changes which were not easy to track on our side."

For these four recurrent problems, their complementary percentages were all acknowledged, so there was an overall agreement with them. With less salience than the previous four factors, collaboration with other departments was identified by 45 % of the testers, whereas 36 % did not see it as a recurrent problem.

On the interviews participants related the four acknowledged recurrent problems to the lack of understanding of shared goals and to the people's openness and attitude. Nevertheless, when we asked on the survey whether they found collaboration a recurrent problem the answers were mixed. Our interpretation is that the team knows how to do its job; yet exhibited one of the major pitfalls faced on matrix organizations: a silo-focused behavior (Sy and D'Annunzio, 2005). The data can be seen to suggest that the shortage of training provided to learn about how other departments work and lack of communication or training regarding shared goals contributes to the focus on the specific subunit of the organization rather than a common goal. Moreover, we speculate that this behavior is present in other teams and departments as well, thus aggravating the collaboration problem.

Regarding collaboration, when we asked the participants what factors effective collaboration with other departments was based on, two main human factors were identified as most relevant: openness and attitude of the people and the understanding of shared goals and needs with 91 % and 82 % of agreement respectively. Next came priorities as well as schedule and frequency of communication with 73 % each. During the interviews, one tester shared: "Well yes, in extremely critical or urgent cases, I will make sure that things get done, I will contact whoever is necessary to achieve the goal." Another participant added: "Usually because tasks are split [with specialized roles] it is difficult to bring people together. If the situation is drastic and it is close to time of delivery then the project manager ranks the importance as higher since delivery is at risk. There seems to be better collaboration when problems are evident." 36 % agreed that collaboration improves when a task has been escalated; 45 % of the testers agreed that effective collaboration depends on how it is put into practice in the project.

So the data regarding recurrent problems and collaboration seem to hint back at the centrality of the silo focus to understand how the testers are perceiving their work: Collaboration with other departments is not seen as a major issue due to the focus on their own team of testers. The fact that escalation is seen as a possible means to improve collaboration can be interpreted as reinforcing the mindset that it is better to simply focus on the team's goals – and if that does not work any more, escalation can fix it.

Regarding processes and process adherence, we wanted to learn how testers perceive processes in regards to their job. During the interviews, all participants found them useful, while on the survey 73 % agreed, 18 % were undecided and 9 % disagreed. During the interviews, testers mentioned that processes had evolved in a positive way and that served as a reminder to the tasks that they have to –which received mixed opinions on the survey: 45 % agreed, 18 % was undecided, and 36 % disagreed. In general we found that processes were perceived in a positive light. Moreover one participant shared an interesting insight on how to leverage change with the new processes: "The last SPICE assessment was really good and identified the weaknesses. It also specified how we should receive some inputs for verification criteria from the developers and including them in the process should help".

6 CONCLUSIONS AND FURTHER WORK

We performed a mixed-method study in the software department of a large automotive supplier operating in a global software engineering setting. We set out to understand the most recurrent problems testers face in their day-to-day activities and how they collaborate with other teams in this setting. According to our findings testers most recurrent problems are of external nature: they receive late inputs – software, hardware or requirements, improperly specified or incomplete requirements, unrealistic project planning and estimation, and reduced time to perform testing. Unlike findings in previous studies, the studied group of testers is highly motivated. They are satisfied being testers, feel they have the skill and ownership needed to do their job, and enjoy working with their own team. Their years of experience and the training they received, mostly of technical nature, support their technical competence to perform testing. During the qualitative study, participants indirectly attributed their problems to human factors such as people's openness, attitude, and understanding of the shared goals and needs of others. Nonetheless, collaboration was not identified as a major recurrent problem. We believe that this is due to a silo focus of the testing team, i.e. the testers relate mainly to the other testers in their team and focus mainly on their subunit rather than the overall organization. In the matrix organization they work in, they require input from different stakeholders and during their testing they interface with them for clarifications. The lack of clear goals for those interfaces as well as the scarce specialized training to prepare people to develop the skills needed to per-

form in a matrix organization reinforce this silo-focused behavior.

Based on our findings, analysis, and reflections, we suggest that testers should be involved even earlier in the requirements gathering stage. Not only to review the specification but to provide input, awareness regarding testability, and their knowledge. Further research should focus on a validation of our findings and possible effects of reorganizing software testing in the overall process of the production of software systems. The size of the population is not representative of software testers in the automotive industry and we suggest that further research should be conducted in other suppliers. Nevertheless, we are aware that the functional matrix organization, the fixed start date of production, the complex and missing requirements, and the late inputs for the testers are common among other suppliers. We believe this case study sets out a starting point for how software testing practice is carried out by a group of highly qualified professionals. Further research should look into the relationship between the lack of cooperation within the testing team and the impact this has on the quality of safety critical products like the ones analyzed in this case study.

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APPENDIX

A: Interview Guide

1. What are the main challenges of your current project?

2. What can you say about the training you received? Was this training useful on your day to day job?
3. What have you learned from other projects that in a current or future you wish to avoid and how?
4. What are the most recurrent problems that the testing team faces (think of internal factors within your own testing team but also consider other teams)
5. How would you describe the relationship between testers and other teams?
6. How do you perceive the collaboration?
7. How often do you interact or communicate with them?
8. How do you view and feel about your job as a Tester (self-image, skills, motivation, interest)?
9. How do you see testing as a profession?
10. How much responsibility and power do you have regarding the tests you run?
11. How do managers or seniors relate to your team?
12. What can you say about adherence to software processes models (V-Model, SPICE)?

B: Agreement from Online Survey

Category: Recurrent Problems			
Subcategory	Agree	Undecided	Disagree
Late inputs	82%	18%	0%
Wrong or missing requirements	73%	27%	0%
Unrealistic project planning/estimation	73%	27%	0%
Reduced time to perform testing	55%	45%	0%
Collaboration with other Departments	45%	36%	18%
Category: Training			
Subcategory	Agree	Undecided	Disagree
Received training while working in the company.	91%	0%	9%
Technical Training	73%	9%	9%
Product Training	82%	9%	0%
Organizational	45%	27%	18%
Department (Interaction with other Dept.)	36%	18%	36%
Category: Collaboration (depends on:)			
Subcategory	Agree	Undecided	Disagree
Openness and attitude of others	91%	9%	0%
Understanding of shared goalsand needs from others	82%	18%	0%
Priorities and schedule	73%	27%	0%
Frequency of communication	73%	18%	9%
How it is enforced in the project	45%	45%	9%
On task escalation	36%	45%	18%
Category: Motivation			
Subcategory	Agree	Undecided	Disagree
Satisfied as tester	73%	18%	9%
Find testing interesting	91%	9%	0%
Enjoy working with their team	91%	9%	0%
Have responsibility over their work	91%	9%	0%
Have enough skills to do their job	91%	9%	0%
Have power to decide upon their daily tasks	64%	27%	9%
Category: Process and Process Adherence			
Subcategory	Agree	Undecided	Disagree
Processes are helpful	73%	18%	9%
Serve as reminder of their job	45%	18%	36%