The Smart Steering Wheel Cover Design: A Case Study of Industrial-Academic Collaboration in Human-Computer Interaction

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Abstract. The transition to a knowledge-based economy has placed expertise and innovation rather than physical resources as the assets driving economic growth and international competitiveness [1]. The result is a relentless pursuit by businesses to innovate as a means to gain competitive advantage in their industry. However, with shorter product lifecycles, increasing product complexity and rising research and development costs, even large firms are struggling to develop new products on their own. Whereas there is a strong demand from businesses to obtain external research and development resources [2], academic institutions represent a large body of knowledge that often sees no practical implementations. This paper discusses the integration practices in new product development on the case study of The Smart Steering Wheel Cover design. A research team from Delft University of Technology collaborated with a mobile solution firm, MOBGEN, to design a system to enhance the safety and fuel-efficiency of drivers. Analyzing the risks and benefits, challenges and opportunities in industrial-academic collaborative projects, recommendations are presented on optimal collaborative practices in the field of human computer interaction.

Keywords: Industry-academia collaboration · Human-computer interaction · Automotive interfaces · Persuasive technologies · Internet of things

1 Introduction

The mobile industry has seen constant growth in the past decade. Mobile phones, especially smartphones, are now considered ubiquitous. In the majority of countries worldwide, personal handsets have become so well integrated in people's daily lives that they are found to be as essential when leaving home as keys and a wallet [3]. Added to this, the exponential advances in mobile computing power and the inclusion and accuracy of the sensors in these devices have broadened the potential use of smartphones. Such growth in the industry exposes mobile-oriented companies to a vast amount of opportunities along with challenges for these companies to keep up with the demand for innovation.

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Mobile innovations are the core business of MOBGEN, a leading mobile solutions specialist, headquartered in Amsterdam, the Netherlands [4]. MOBGEN leverages its expertise in the mobile space by extending its capabilities to disruptive technologies in various industries. MOBGEN:lab is the research division at MOBGEN, set up to investigate disruptive innovation with a focus on mobile technology and internet of things. The company's aim is to identify and map the trends across the design industry that will create changes in the way products and surroundings influence our behavior and performance. In these initiatives, MOBGEN:lab collaborates with universities to research and develop innovative products and services with the end-goal of creating enhanced user experiences.

The Smart Steering Wheel Cover Design project was an example of industry-academia collaboration, initiated by MOBGEN:lab in collaboration with the Faculty of Industrial Design Engineering (IDE), Delft University of Technology (TU Delft). With the research and development capabilities from Delft University of Technology [5] and the business-oriented designer mentality of MOBGEN we have the aim of designing interactive technology for drivers' safety and efficiency with the help of mobile solutions. Building on this case study, we analyze collaboration between academia and industry and its influence on the design project. The aim of the paper is to identify challenges and opportunities of such an approach to creating a product while providing practical recommendations for improvement.

The paper is organized as follows: In Sect. 2 we present previous literature on the topic of collaboration, and Sect. 3 describes the design process and approach implemented in the project. The design case study is introduced in Sect. 4 with results and evaluations. We present our reflections on the industrial-academic collaborations in Sect. 5 and conclude with Sect. 6.

2 Related Work

External research has played a critical role in firms' innovation process. The last two decades have seen a surge of collaborations between firms and its external partners. These external agents include sources as customers, suppliers, universities, research institutions, industry consortia, and even rival firms [6]. Particularly, a popular form of collaboration is the one between an industrial firm and an academic institution. While there are various reasons for firms to collaborate with universities, generally major motivations are access to complementary resources, speeding up of the process of innovation including market launch, and financial benefits [7]. As businesses want to capitalize on knowledge, obtaining the resources from academic partners is beneficial for processing their innovation. Accordingly, universities have their own interests in these collaborations, mainly consisting of intellectual capital sharing, knowledge dissemination, exposure to business problems and access to funding [8].

Current academic literature states that such complementary resources provide potential opportunities for the firms to explore new and different ideas about product design, concepts, and development, as well as to break away from previously specified rules and procedures [7]. This not only increases the efficiency, but also the effectiveness of the activities and tasks throughout the innovation process [6].

While these are significant benefits of such industrial-academic collaborations, these projects also face several challenges, such as:

Differences in the nature of projects. Academic research is focused on contribution to the community (process-oriented approach), whereas industrial firms base their research and development on achieving a product that can be capitalized (result-oriented approach) [8]. Literature suggests that academic research often does not directly translate into new products or services for industrial organizations [9].

Conflict of interests. Academics are concerned that too close a university-industry collaboration might affect their academic freedom and integrity [10]. University researchers prefer to choose their own research topics, which are often driven by what is perceived to be interesting and valuable in their field of work. Companies, however, prefer to research the fields that are trendy or profitable [11].

Knowledge Sharing. Academic success is often measured in the amount of publications [12]. University researchers often have to engage in 'status competitions' with their peers, based on publication records, institutional affiliations and prizes [8]. In contrast to the open nature of the science system, the knowledge creation process in the private sector is characterized by tendency to appropriate the economic value of firms' knowledge in order to gain competitive advantage [13]. Moreover, due to the high investment costs, unpatented innovation in asset-intensive, high-technological industries is kept under non-disclosure agreements [14].

Uncertainty of outcome. Particularly commercial companies have the pressure to deliver a certain viable product as a result of the project. With collaborative initiatives, there is a certain risk for them not to be able to do so, along with risks of possible spillovers [15].

The purpose of this paper is to analyze these and other challenges, along with benefits of industry-academia collaborations on the example of designing for automotive safety and efficiency.

3 Design Process

The design process of the project involved collaborative design, a process defined as co-operated efforts undertaken by multiple parties [16]. Co-creation was the main approach in the design process of this collaboration project. We define co-creation similar to Sanders and Stappers [17] to be the act of collective creativity of people working together in the product-service development process. The project team was comprised of a master program student, two academic supervisors from the IDE faculty of TU Delft, and an industry supervisor from MOBGEN. For the duration of the entire project, the student was stationed at MOBGEN for four days a week and a day a week at TU Delft. The complete team met once every two months for decision-making steps in the design process. Meetings with each of the supervisors were scheduled once every two weeks to report on the progress of the project. The project followed design process as illustrated below in Fig. 1 with multiple iterations within various phases.

Fig. 1. Detailed illustration of the design process of the current project

As suggested by Den Ouden and Valkenburg [18], as the first step of such collaborative innovation process it was important to define a suitable value proposition for future needs of the users. This step involved iterations of exploratory research observing and inquiring drivers to learn about problems and needs in their daily driving activities using contextmapping methods [19]. This process engaged participants from both the academic and industrial background, including colleagues at MOBGEN in either participating in context mapping sessions or inputting into the design of the research tools and materials.

The findings from the user research were translated into design goals that served as a basis for generating ideas and concepts. Both MOBGEN members and university partners participated in ideation sessions to generate concepts. This was to both ensure to get different perspectives on the topic, and to allow different stakeholders be involved in the design process. Creating value by enhancing experiences of all stakeholders and is proven to lead to higher productivity, creativity and lower costs and risks in the project [20]. Hence, this project's collaborative creative design process involved all stakeholders across the spectrum of the design process from concept generation to prototyping and embodiment. The ideation process went through various iterations until a concept that satisfied all the design criteria was developed. The final proof-of-concept prototype was created and evaluated to understand the effects of the design on the behavior of drivers.

4 The Case Study of an Industrial-Academic Collaboration

4.1 Design of the Smart Steering Wheel Cover

With increasing levels of traffic all around the world, more fuel is being consumed and more damage is caused to the environment. Commuters are spending increasing amounts of time in their vehicles as a result of the recent suburbanization process [21]. This results in an increased probability for road accidents, especially considering that 90 % of road traffic accidents is estimated to be caused by human factors [22]. These problems related to safety and fuel-efficiency of driving were recognized by

MOBGEN, who also saw an opportunity for enhancing driving experiences with the possibilities of mobile sensing and computing and internet of things.

The Smart Steering Wheel Cover was designed as a result of collaboration between MOBGEN and TU Delft and is an in-vehicle system to encourage safe and efficient driving using real-time feedback and customizable interface (Fig. 2). The system utilizes acceleration sensing technologies within the driver's smartphone to determine aggressive acceleration and braking behavior. The smoothness of the driving correlates with fuel saving, thus the less aggressive the driver's behavior is, the less fuel the vehicle consumes. Feedback is communicated to the driver in terms of vibration (as warning of poor behavior) and gradual change of light (as a reward to motivate continuous fuel-efficient behavior). Various kinds of in-vehicle tasks other than driving require a high level of hand-eye coordination, leading to an increase in driver distraction. Therefore, the design of the Smart Steering Wheel Cover incorporates tactile buttons that drivers can feel without having to look for controlling some of the most frequently accessed operations on their smartphones, such as (1) control of incoming and outgoing calls and (2) volume and control of a music application.

Fig. 2. The design of the smart steering wheel cover

The accompanying smartphone application records and summarizes the driver's journey in terms of driven distance, time, fuel efficiency and potential financial savings. The combination of The Smart Steering Wheel Cover with the post-analytics application is designed to offer positive reinforcement and influence on the driver's behavior to ensure safety and efficiency.

4.2 Evaluation of the Design

The design was evaluated with drivers, using a proof-of-concept prototype. The main objectives were to evaluate the characteristics of the design in the context of driving and the effects of ambient and haptic feedback on the driver's behavior. Results were analyzed to identify strong and weak points of the system and possible implications of each type of feedback on the drivers' behavior. Distinct groups, both comprised of members from TU Delft and MOBGEN participated in devising the methodology, the user tests and the evaluation of the results. Both parties participated in analyzing the results, defining the benefits and challenges of the design, together with recommendations on improvements.

4.2.1 Methodology

A total of 10 drivers participated in the user tests with an age ranging from 25 to 49 and with at least two years of driving experience. The prototype mounted vibration motors and an LED-strip along the steering wheel cover. It included button straps as controls. Drivers were asked to drive for 20 min along a specified route and received feedback on their driving performance in the form of green light and vibrations. Their experiences were observed and interviewed after the drive.

4.2.2 Results

Iterative user testing of prototypes emphasized the proactive nature of the design to prevent poor driving as opposed to reacting to it. The gradual change of lights in terms of spatial arrangement and brightness worked in an engaging manner, forming an immediate connection between the driver's behavior and its effect on the steering wheel (Fig. 3). Users reported to be motivated to maintain the full green circle. All participants were observed to be more alert and with greater concentration when receiving the haptic feedback (Fig. 4). There was no universal hand placement position observed in the tests. Due to this diversity, we decided for controls to be fully customizable. Nevertheless, location of 2 and 10 o'clock on the wheel will be recommended, as researched to be the most natural position for thumb-controlled input areas [23] (Fig. 5).

4.2.3 Discussion

The team came together for discussing the results of the user validation and its implication on the design. TU Delft supported the analysis with theoretical information on automotive and persuasive technologies, along with knowledge on user behavior.

Fig. 3. The light feedback (color figure online)

Fig. 4. The haptic (vibration) feedback

MOBGEN, on the other hand, contributed in discussion with implications of mobile and peripheral technologies on the human behavior along with expertise on social and gamification components of the design. The user test showed that the real-time feedback of enlarging a green light area and increasing brightness was clearly understood as a reward for fuel-efficient driving, and the vibration feedback was interpreted as a warning. Our participants confirmed the need and preference towards the customizable controls to enhance their safety while being able to control their smartphones. Our work suggests that designing in-car persuasive technologies can help motivate drivers and contribute towards a safer and more efficient behavior. By adapting smart technologies in cars, we hope to encourage small changes in driving behavior in order to save on fuel efficiency and to decrease personal risk. Further research will include confirmation of long-term effects of the Smart Steering Wheel Cover on safety and fuel consumption.

5 Reflection on Industrial-Academic Collaboration

This project required an equally significant input from both the academic institution and the industry partner, as it deviated from the sole expertise of either party. With the complexity of the project involving challenges in information technology, human-computer interfacing, established vehicle driver behaviors and extensive user testing, the combined resources of both MOBGEN and TU Delft were required to achieve the end result.

TU Delft's goal in this project of designing the Smart Steering Wheel Cover involved enabling a positive educational experience for the student and enriching the research and product portfolio of the university. The industry partner, MOBGEN's goal in the project was to endorse the company's expertise in mobile solutions in the design of an innovative product. The project benefited from the collaboration of the research capabilities of the Industrial Design Engineering department of TU Delft, and the entrepreneurial acumen and IT expertise of MOBGEN. This complementary expertise and the two-way knowledge flows from both parties was the major benefit of this collaboration. Consecutively, the availability of resources and facilities from both parties was an important factor influencing the outcome of the project. The thesis student bringing the two parties together played the role of a catalyst in the process, closely linked with both sides and ensuring smooth progress, efficient communication, minimal delays as a result to decision changes, coordination of efforts on either side, bringing together different groups to participate in the testing and evaluation project. The research community and prototyping facilities at TU Delft enabled the thesis student to receive assistance (in terms of both theoretical knowledge and practical skills) from faculty and staff at the university. Similarly, the mobile expertise of employees at MOBGEN helped in identifying the current trends, generating relevant ideas and utilizing the usability lab resources.

This and other benefits of the cooperation between TU Delft and MOBGEN were analyzed based on the industry-universities exchange framework by Balconi and Laboranti [24], and devised into the following framework of tangible and intangible information flow:

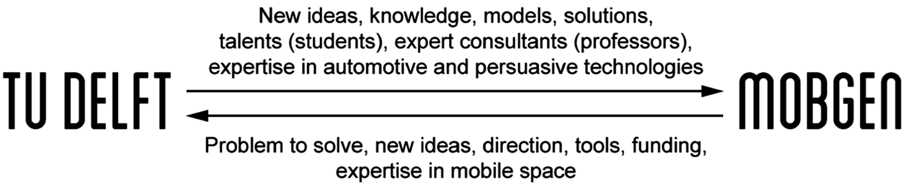

Fig. 5. Two-way knowledge exchange between the industrial and academic parties

Particularly, the following were identified as benefits for MOBGEN as an industrial partner:

- The fresh knowledge and ideas in the form of a thesis student from a university partner.
- Authenticated access to design tools, services and methodologies. This kind of collaboration facilitates a faster transfer of not only ideas, but also approaches and methodologies. Universities have a large database and knowledge of research tools, methodologies and approaches. During this project, the academic team introduced new methods for application within MOBGEN, such as ethnographic research, contextmapping and contextual inquiry. These methods, tools and approaches can benefit the company even in future projects.
- Improved focus on customers or users, such as better dissemination of findings about customers' or users' needs.
- Connections to qualified universities can create future opportunities for recruiting.
- Expertise in persuasive and automotive technologies in the form of professors.

In return, benefits of collaboration for TU Delft were:

- Exposure of students to the real-world problems and opportunity for them to become experts in their topics. The experience of conducting a project at a company gives the student an opportunity to learn about the business side of design projects and prepares them for their future careers, while expanding the research and product portfolio of TU Delft.
- MOBGEN's knowledge and expertise in the current trends in mobile space and information technologies provided necessary direction in the project.

However, such collaborations face challenges as were identified through literature earlier in the paper. As the purpose of this paper was to analyze the opportunities and challenges of such collaborative projects, we have addressed the identified challenges as follows:

Process-oriented vs. result-oriented nature of projects. Indeed, whereas the supervisors from TU Delft were interested in learning points of the design process and contribution to the research community, MOBGEN was interested in achieving results that had the highest potential to be implemented. Furthermore, due to the time pressure by the fast-changing industry and limited resources for research, MOBGEN was often inclined towards development of the first generated idea, whereas the educational background of the student was in favor of conducting thorough research and exploring various areas and directions to make the best idea selection. This challenge was overcome through defining a clear design process at the start of the project and finding a mutual consensus, by obtaining compromise of both sides: allowing space and time for exploration while fitting in the defined context and time restrictions.

Conflict of interests. The collaboration across different bodies of institutions did indeed mean that there were inevitable differences in the requirements and expectations of the partners. For TU Delft, the end-result of the project was a successful graduation of the student in the form of a thesis defense presentation and a proof-of-concept prototype, validating the function and experience of the concept by the use of prototypes and tests. However, MOBGEN as an industrial partner desired a result that is ready to go into a preliminary production phase. An important practice in this situation was to outline clear requirements and align each other's expectations at the beginning of the project for the collaboration to be mutually beneficial and successful.

Knowledge sharing. Both TU Delft and MOBGEN shared the common interest in sharing the obtained knowledge in terms of publication, which resulted in this conference paper. In fact, a considerable number of firms publish academic and technical papers to signal their competencies or to defend against others' attempts to control particular areas of technology [25]. Similarly, MOBGEN recognized the opportunity to publish results of their R&D to expose its work to the academic audience, which could potentially result in further collaborative projects with academic bodies.

Uncertainty of outcome. To face this challenge, various milestones were set and conducted at different stages of the project. The presentations of current findings at each of the milestones kept all parties updated with the progress and upcoming work, and decreased the uncertainty of outcome. As was recognized in the literature [15], breadth of interactions between parties helped to ease the barriers to collaboration.

As a general approach to overcome the challenges, we have found that consistent involvement of stakeholders in all decision making phases in the design process and keeping the process transparent proved to be important in achieving consensus on the design and the project results. These findings hope to contribute to the HCI community in conducting such projects of integration practices in new product and service development. The presented design process is assumed to be applicable as a framework for fellow researchers in other projects with similar nature.

6 Conclusions

In this paper we identified challenges and opportunities of the collaborative approach to creating the Smart Steering Wheel Cover. We have faced all four challenges (nature of projects, conflict of interest, uncertainty of outcome and knowledge sharing) that were identified in this paper, during this project. However we have learned that by identifying these challenges during the early stage of the project most of them can be overcome. To do so, all parties should align expectations early in the process and create clearly defined, mutually agreed objectives and a clear design approach at the start of the project. In addition, we recommend ensuring there is adequate room for flexibility within the process in order to be able to react to changes, but with a high level of importance placed on keeping all parties updated in order to achieve consensus on the design and the project results. Communication between all parties is the key to overcoming these challenges.

TU Delft and MOBGEN shared the common interest in obtaining knowledge and sharing that knowledge by publishing the results. Furthermore, this collaboration provided MOBGEN with the opportunity to explore new ideas about design. The ideation sessions not only resulted in different perspectives on the topic, but also helped MOBGEN employees to break away from previously specified workflows and procedures, creating both a motivating and stimulating environment. The complexity and the open character of the project involved technological challenges as well as challenges in human-computer interfacing that contributed to the self-development of all involved parties, taking mobile user experience to another level.

The industrial-academic collaboration provided a significant mutual advantage in design projects for both parties to benefit from complementary expertise and two-way knowledge flow in achieving successful results. Considering our work suggests that designing in-car persuasive technologies can help motivate drivers and contribute towards a safer and more efficient behavior, it is of interest to MOBGEN to further develop the current product, and to continue further research in collaboration with TU Delft. A longitudinal study will investigate whether there is a behavior change on safety and fuel consumption as a result of the use of the Smart Steering Wheel Cover. Additionally, it will be investigated whether positive reinforcement, or a social component, provided by the mobile application would strengthen the influence of the Smart Steering Wheel Cover on the users driving behavior.

The synergy between the automotive and persuasive technology expertise from TU Delft and mobile expertise on the side of MOBGEN made this project a success, with the result being a working prototype of the Smart Steering Wheel Cover that was successfully tested by potential end-users. Such success would not have been accomplished by either of the parties working independently.

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