

DESIGN OF USER-CENTRED WIRELESS SENSOR TECHNOLOGY IN SPORTS: AN EMPIRICAL STUDY ON HOW ELITE KAYAK ATHLETES CAN CONTRIBUTE TO UNIVERSITY RESEARCH

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University research is demanded to be more need-driven and user-centred in order to address and solve problems and needs of the market. In the present study a group of athletes and coaches has been analysed on their lead user characteristics. Some of the lead users have contributed with advanced user insights and aid in trend foresight in this sport. In a combined qualitative and quantitative approach the value of lead users in sports technology was examined and four users were identified as lead users. In consistence with previous research the results indicate that involving lead users will foster superior insight and research.

Keywords: Lead user, sports technology, innovation management, need driven, new products.

1. INTRODUCTION

In recent years, several Swedish universities have initiated research projects targeted towards developing commercially viable, innovative products. This means that doctoral students are expected to not only conduct scientifically relevant research but also to focus on developing innovative products in an entrepreneurial manner (Ericson *et al.*, 2007). Prior studies have shown that the ability to capture and integrate potential customers and user insights and needs during the research and development process is key to product market success (Jacob, 2006; Gemünden *et al.*, 1992). This pushes the boundaries of how to support user-centred and technology driven innovations and the balance between these viewpoints. Thus, the purpose of this study is to *discuss the learning process from conducting a user-centred product innovation scenario in a university setting*. In addition, the focus is on the lead user characteristics of elite athletes and national coaches. The inputs from the lead users are expected to guide the researchers and help in further advancing the development of the technological products and increase the likelihood of market success. The main rationale for focusing on lead users in comparison to generic users is due to the high degree of novelty of the product.

This study addresses a market opportunity in flat-water kayak training. Kayaking is a fiercely competitive Olympic discipline. Competition motivates preparation and training; given the same preconditions it is expected that the athlete with the better training (physical as well as mental) will perform better and will eventually be successful in the competition. In line with the above rationale, a few companies (e.g. sports clothing companies) have started to develop technological products that can measure and improve training efficiency of the athletes. However, the scope of these technological products are limited to only a few specific sports, and given the diversity of sports disciplines there is

a need to develop more customized technological products. Thus, the research in this study will focus on the sport of kayaking, and afterwards generalize on other applications of innovation. Thereby, this research contributes to innovation management and investigates strategic decisions in sports technology research. However, the deductions may apply to many product and design related research projects.

The following sections draw a sketch of the university product research setting and details reviews of the existing literature. The approach of this research, which is both qualitative and quantitative, is described and the results of this combination presented in detail. The work concludes with a discussion of the results and highlights possibilities for future research.

2. BACKGROUND AND LITERATURE

2.1. Research in collaboration with users: studies for innovative design and product development

Technological progress offers tremendous opportunities for pervasive computing and new performance analysis systems in sports (Baca *et al.*, 2009). However, many approaches overburden athletes and coaches with huge amounts of raw data and wear on initial enthusiasm regarding the new tools.

A change of focus to improve sports science research into sports science practice has already been suggested (Bishop 2008). There is a need for an improved communication and knowledge exchange between scientists and performing athletes and coaches. Research without evidence from athletes' actual exercise routines is severely limited, and athletes and coaches resistant to new insights from sports sciences may miss opportunities for improved training efficiency and performance.

Research at KTH Royal Institute of Technology (KTH) into flat-water kayak training was initiated by a former Swedish national coach and the KTH School for Technology and Health. From the very beginning the expected outcome from the project was to develop a practical and fully functional technological product. A pre-study on the relevance of the topic indicated that there is great value in a university driven research project.

2.2. Literature review

Anecdotal evidence, practice and research match the statement that user/customer orientation is rewarded by greater market perfusion and potential business performance. An increasing tendency in designing research to match (and solve) the product and service needs of our time requires researchers to orientate their work using evidence of market demands and opportunities. This study is to support and motivate the development process of the KTH kayak sensor system and to aid in its future development. It is believed in literature that referring to, and by involving, lead users in the planning and need identification process products can be targeted better at a specific market.

Lead users differ from generic users through two characteristics. Firstly, lead users face needs ahead of time. Secondly, lead users are in a position that they will benefit significantly by obtaining a solution to those needs (von Hippel, 1986). Besides this elaborated awareness of the evolution of their market place, a tendency to innovate solutions to the needs identified has been observed amongst lead users (Lüthje, 2004; Shah, 2000).

Due to these characteristics, Schreier *et al.* (2007) as well as Morrison *et al.* (2004) suggest the involvement of lead users in the process of user need identification as well as in the adoption process. Lead users can fuel the contagion process (assisting others in the adoption) through their lower adaption threshold and by acting as a role model for the majority of users (Schreier *et al.*, 2007). Previous research by Lüthje (2004) and Shah (2000) puts further emphasis on this rationale.

In a survey amongst 153 users of outdoor-related consumer products in the sports sector more than 11% of the users were found to have innovated new products while an additional 26% had invented improvements to existing products (Lüthje, 2004). Lüthje's study motivates further research and action to identify and facilitate lead user insight for new products in outdoor sports.

Shah (2000) found in a study of three modern sports that there is no evidence that manufacturers (i.e. non-lifestyle firms, companies with 10+ employees) in general will be dominant developers of

innovations in novel sports. Instead it is ambitious users with a need and users that see an opportunity in a lifestyle business to finance their sport.

According to the definition by von Hippel (1986) elite athletes are in most cases lead users in their sport. They normally face a need at a very early stage, ahead of the majority of recreational athletes, and due to their competition interest elite athletes can be expected to receive the greatest benefit from novel, superior equipment prior to others.

We are interested in evaluating Swedish elite kayak athletes on their lead user characteristics because lead users will be the ones who have devoted the most resources to understanding their field (von Hippel, 1986). Though being aware of Morrison's (2004) construct of leading edge status (LES) we are not interested in a continuous variable to analyse the population but the intention is to identify a few individuals with the highest innovation interest and capability.

The research presented here facilitates a user-centred approach. This is suggested to be the most promising method when aiming at innovations that solve practical problems (Bilgram *et al.*, 2008; von Hippel, 1986).

3. RESEARCH APPROACH

The current study supports a combined research approach for data collection to create an accurate account of reality, which involves taking advantage of both qualitative and quantitative methods (Yin, 2003). These methods are distinct but they can also complement each other. The main method followed in the study is quantitative, with supporting information having been gathered using qualitative methods during the early phase. Thus, it is believed that combining these research approaches will enable the study to comprehensively address the purpose of the study (Denzin & Lincoln, 2000).

3.1. Qualitative study

In the early phase of the study, a workshop with 10 participants was conducted involving Swedish kayak athletes and coaches who were selected based on their interest and experience in kayak competitions. To enrich the team with perspectives and skills, two of the coaches had been selected despite their non-proficiency in kayaking but to share their expert knowledge and reasoning from another sport (cross-country skiing). They were invited to objectively contribute to the work and bring ideas in the team. The kayakers were all experienced sportsmen with the ambition to optimise their training and eventually their performance to the maximum extent.

The workshop was conducted by the researchers and designed to guide the team of athletes and coaches through a series of 30–60 minutes activities. These activities concentrated on various fields of interest and began by focusing the participants' thoughts towards challenges and problems of the current training situation. This introduction was followed by various vision and mind-opening exercises to picture and visualise the desired goal. Towards the end of the workshop, the focus was turned to how the gap between the perceived current state and the described desired state could be reached. The aim was to identify the most promising ways to proceed with development of new and improved aids for kayaking. In the end of the workshop, the three most relevant ideas were described in more detail.

3.2. Quantitative study

Based on the insights from the qualitative study a quantitative study was developed and data collection was undertaken between March to May 2010 from a sample of athletes who were nominated by coaches or other athletes active in the sport. By these means the selection process was social network based. Questionnaires were used to collect data. These were addressed to the selected athletes; all of them were competing at a national or international level or had a history in these competitions. In total 15 questionnaires were filled in by athletes.

Questions were divided into different sections: (a) personal data and equipment, (b) perception of the current status of sport technology in kayaking, (c) presumed development of sport technology in

this sport, and (d) feedback on the proposed kayak sensor system developed at KTH. Each section had multiple open ended questions that were measured on a five-point Likert scale ranging from “strongly disagree” to “strongly agree” or from “not at all” to “a large extent”. In addition some questions were descriptive in nature. Data analysis for the questionnaires was limited to generic statistical analysis as we were able to only get data from a few respondents. However, during data analysis we were able to identify several patterns and trends which will be presented in the following section.

4. RESEARCH FINDINGS

4.1. Initial qualitative data

The raw data from the workshop was documented as well as the description of three ideas that were selected as most relevant to realise. The team participating in the workshop was enthusiastic, yet aware of the effort required to transform ideas and conceptual solutions to real applications and use. The documented workshop results have served as a source of reference when planning for activities to improve kayak training and performance.

The most relevant of these ideas that were conceptualised was the use of sensors to monitor and capture the paddle movement and acceleration for performance measurement. However, this idea exceeded the technical development capabilities of the attending athletes, who would normally only customise their existing equipment.

Moreover, the range of ideas to improve kayaking performance and training were wide, not limited to pure “equipment” but included also less technical concepts.

4.2. Current status of sports technology in kayaking

Reflecting on the current use of technical equipment during training in a kayak, only tools such as a heart rate monitor, a stopwatch and a GPS seem to be used by the athletes when training alone. The majority of the subjects state video as an additional but mainly occasional source of feedback information in the presence of a coach. Simultaneously, two thirds say that they rarely or never train with the help of a coach. In a laboratory environment two athletes report to use lactate measurement for performance analysis. It can be assumed that there is no technology used to control and aid in the improvement of kayak training performance on water beside the first mentioned three methods.

As expected from competing athletes, who in their majority were competing at a national or international level, more than three quarters of the group agreed or strongly agreed to the statement that they had been reasoning on how to improve their equipment. Although almost all interviewed athletes (three were not sure) stated that there is a public interest in new sports technology for kayaking, only 62% had previously been considering technical aids as problem solvers. Only two athletes thought that there were sportsmen or women who push forward the technical development of their own equipment.

4.3. Lead user identification

It has been found that only one of the interviewed athletes has a pronounced disinterest in collaborating with researchers for the improvement of kayak training, the majority “agreed” or “strongly agreed” to our proposition. Nevertheless, it can be expected to be more efficient to focus on a selected group of highly skilled and committed persons in order to target the right and most rewarding problem solutions.

Four athletes have been identified to have the characteristics of lead users. The group is inhomogeneous concerning gender, age, experience, main profession and, unfortunately, location. The common factor to these persons is that they are ranked very high or top in their discipline of kayaking and that they spend a high amount of time on training. Each of these athletes contributed with an over-average amount of information in the open question part of the survey that was undertaken. All appreciate that there is a great potential for development in kayaking and can expect great personal benefit from a more effective training due to new developments. By (1) having the demand for a new tool and (2) having high expectations for their own purposes, these athletes qualify, according to von Hippel (1986) as being lead users. Further rationales for choosing each of these persons are listed in Table 1.

Table 1. Additional reasons from observations and interaction for declaring specific athletes as lead users.

Lead user #	Observations of outstanding behaviour
1	numerous detailed ideas in the questionnaire, many additional side notes, extremely conscious about biomechanics in a kayak, travelled abroad for just one special training session
2	investment of a considerable amount of personal time for aiding the researchers, high understanding and interest in the development of technology for kayaking, initiates discussions about new ideas, gives extensive feedback
3	former national coach with extensive personal competition experience, contributed with numerous new ideas and gives very valuable critique, initiated the research into kayaking in cooperation with a senior scientist (She had not been involved in the project since it had been started and was now given the chance to review the solution suggestions and to give feedback for further development.)
4	currently most successful Swedish female kayak athlete, has — similarly to lead user 1- adjusted her own equipment to better fit her personal biomechanics, very valuable feedback, expresses her expectations of new aids

4.4. Contribution of lead users to sports technology research

It is anecdotal knowledge that engineers have a tendency to work with an overaverage enthusiasm for highly sophisticated and/or technical solutions. Involving lead users in the design process reduces the possibility that a prototype misses real life needs. Lead users are aware of limitations for the target application, usability, lifetime and not at least physical dimensions.

During our work with lead users we learned from their feedback about the importance of the parameters, that the system should measure, we learned about their patience threshold for the first time use of a new technical aid and we learned about the users' requirements for easy and unobtrusive use. Our design suggestions were defined immature until all involved lead users were satisfied in their requirements.

4.5. The mature design

The mature prototype of the wireless sensor system (refer to Sturm *et al.*, 2010) measures and analyses kayak paddling performance. The developed system, as visualised in Figure 1, is made up of three

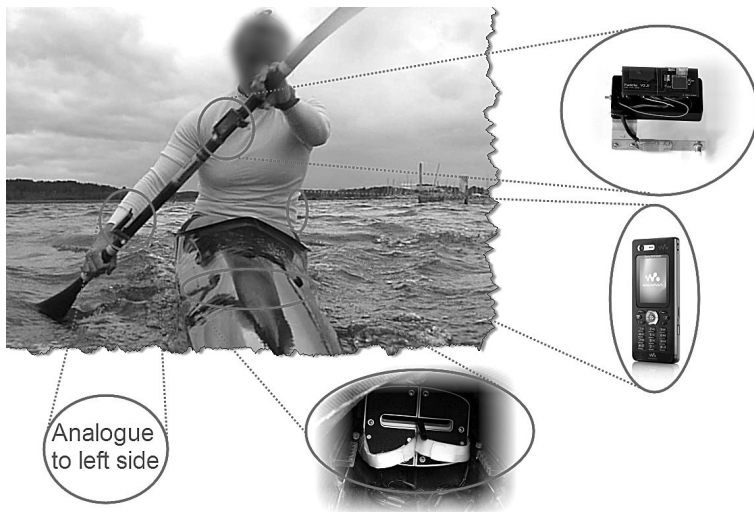


Figure 1. The KTH kayak sensor system V2.0 (with improvements compared to Sturm *et al.*, 2010).

sensor units (also referred to as “nodes”) and one central data recording device. Two sensor units are attached to the paddle and measure the mechanical deviation in the paddle during a stroke for each side respectively. The third node is made up of an electronics part together with a custom built and modified foot stretcher, which encapsulates force transducers. Thereby, it is possible to measure the resultant foot pressure force on the foot stretcher for each foot.

In order to have a system that does not alter the training process more than absolutely necessary, the sensor nodes were equipped with a wireless data link so that the athlete is not affected or disturbed by any cables. The usage of the proposed system should by no means be obtrusive in any way. Weight and size were reduced to a minimum.

A quick and easy setup with a one-screw attachment mechanism on the paddle nodes, a standard installation of the modified foot stretcher and a simple “power-on and go” operation facilitates intuitive deployment of the system. The central unit receiving the sensor data is a standard Bluetooth enabled mobile phone with the ability to execute Java (J2ME) code. Operation of the custom written software is simple and the interface reduced to a minimum of required settings. This software receives the Bluetooth data stream and stores the information on the device in its internal memory for post-processing and feedback.

5. DISCUSSION AND CONCLUSION

5.1. Discussion

This study was initiated with the purpose to discuss the learning process from conducting a user-centred product innovation scenario in a university setting. We would like discuss the findings of the study with respect to three themes: (1) benefits from holding workshops during the early research project stage, (2) the critical role of including lead users and (3) reflections on the entire process.

The first theme highlights the workshop as a crucial step in the research project. The concrete outcome of the workshop was the validation of the research project and that its initiation was targeted correctly and relevant. A lot of attention was given to the respondents which were included in the workshops as most of them could potentially be seen as future users of the end product. Although, other prospective topics for further research were also identified during the workshop they mostly fall outside the scope of the present study. Moreover, during the process we also realised the need for additional data collection from a larger set of samples, which would focus on the detailed development of product. Once the area of users’ interest was clearly visible after the workshop the development of a quantitative study was conveniently achieved.

The second theme presents justifications for the focus on lead users. The quantitative study was initially designed to gain insights from a large number of potential users or customers of the product. However, the respondents could easily be categorized into generic users and as lead users. The groups were largely distinct from each other based on two specific factors: Firstly, lead users tend to be top athletes meaning they have extensive experience of being active in the sport of kayaking and, secondly, they can easily recognise the value of a new product such as the proposed as it could support their training and allow them to improve their performance in competition.

The involved users and especially the lead users provided several critical inputs regarding the development requirements and the authors’ understanding of the current market situation, its demands and needs and probable upcoming trends. This finding correlates with earlier research on lead user characteristics and we have successfully initiated an active role of such users to contribute to university research strategy. The lead users’ knowledge has been communicated through a workshop, a survey and through informal communication to the researchers and is the basis for ongoing innovations. We believe that this collaboration is a crucial contribution to need-driven university research and design strategy as well as we expect it to have major positive influence on the diffusion process of the outcome of our research. Therefore, our findings conform to existing literature (Shah, 2000; Lüthje, 2004; von Hippel, 1986) that user involvement is a critical contributor in the development of highly novel products, which also seems to be true for a university environment as previously confirmed for the industrial setting.

Finally, reflecting on the entire process ranging from the initial workshop via the survey study and to the last development work in the laboratory, the importance of involving users in product development research at a university is clearly visible. To university projects not implementing this method there always is the threat that they may suffer to a large extent, if these projects miss the balance between the work performed in the laboratory and the requirements for interacting with potential users or customers. Moreover, based on the insights from this study we would also like to stress on the lead users' inputs in comparison to generic users' inputs because most university oriented projects aim to develop highly novel products. In many cases, it can be hard to find existing, similar products in the market, this implies that it will be difficult for researchers to find users in practice that have been exposed to similar products. Thus, the attention should be on lead users due to their specific demands and capabilities.

5.2. Conclusion

There are many projects at every university, which are labelled applied research or need-driven research. We can conclude that lead user involvement is an indicative factor in the development of specialised sports technology for elite kayak athletes and we believe that this finding can be generalised for other product design research. The learning from our study suggests that similar research aiming at solving problems or aiming at addressing a market need by the development of a new product can gain from identifying users early in the process. These users can contribute with insights in ongoing trends and market maturity but also such basic information such as handling of a product. Some of the users that we have met have presented us advanced prototypes to satisfy needs, which these users have felt in their training. For potential of later commercialisation it is essential that researcher test their ideas early against reality. Here a mechanism that acts as a layer between researchers and practitioners/users and industry would be interesting to see in order to reach new products on the market.

Involving lead users in university research is a topic of interest both in a practical as well as in a theoretical point of view. Our study should motivate researchers in all related research tracks, especially in but not limited to innovation management research, to begin or continue and deepen their work with users who have the above stated characteristics.

5.3. Limitations and scope for future research

Like any other study, this study also has certain limitations. Therefore, the interpretation of the results needs to take into account these limitations. The quantitative data was collected within a short period of time, leading to a small sample size. This reduces our ability to perform multivariate statistical analysis. Future studies can move towards this research agenda and collect data from a large sample size and test for hypotheses.

The most common characteristic of the respondents under investigation is their nationality. Except for one Finnish respondent all respondents included in the study during the workshop and the questionnaire study were from Sweden. This could be seen as a limitation as the market potential of the product in focus is global and in the present study we are unable to address this issue. A broader empirical field (i.e. an internationally populated) may show advanced and more detailed patterns in an athlete's behaviour and preferences in an international context. This may also lead to an improved identification strategy of lead users and other potential contributors to university innovation management. Finally, we would like to encourage other researchers working on industry oriented project to further validate our proposition that including lead users in their study represents a crucial path to market success.

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