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Design of user-centred wireless sensor technology in sports: An empirical study of elite kayak athletes

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Abstract: 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 five 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 mode (Ericson et al., 2007). Prior studies have shown that being able, during the research and development process, to capture and integrate potential customers and user insights and needs is a key to product market success (Jacab, 2006; Gemünden et al., 1992). This pushes the boundaries of how to support customer driven 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 driven product innovation scenario in a university setting*.

This study addresses a market opportunity in relation to flat-water kayak training. Kayaking is a fiercely competitive Olympic discipline. Competition motivates

preparation and training; given the same preconditions it can be expected that the athlete with the better training (physical as well as mental) will gain better performance capabilities 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.

1.1 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' exercise routines not implementing the findings of current research will not be optimal. Athletes and coaches resistant to new insights from sports sciences may miss opportunities for improved training efficiency and performance.

Research at 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 usable and fully functional technological product. It may have been an additional motivator and it may positively contribute to their insight that most members of the research team share a history in sports competitions on an international level.

Furthermore, the athletes during the research and development process so far have shown great interest and supported the invention and innovation process with feedback and their willingness to test prototypes.

1.2 The KTH kayak sensor system

The first prototype of the wireless sensor system (refer to Sturm et al. 2010) measured and analysed kayak paddling performance. Moreover, it was developed in close cooperation with coaches and athletes according to their opinions about measurement parameters of interest. For instance, paddle and foot stretcher force, and especially the

timing between maximum paddle and foot stretcher force, have been identified as variables of high interest.

The developed prototype system, as visualised in Figure 1, is made up of three 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 while still allowing for a rather simple debug interface.

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 facilitate 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 stored the information on the device in its internal memory. Afterwards this performance data can be post-processed on a standard personal computer and analysed by a coach or by a trained athlete him-/herself.

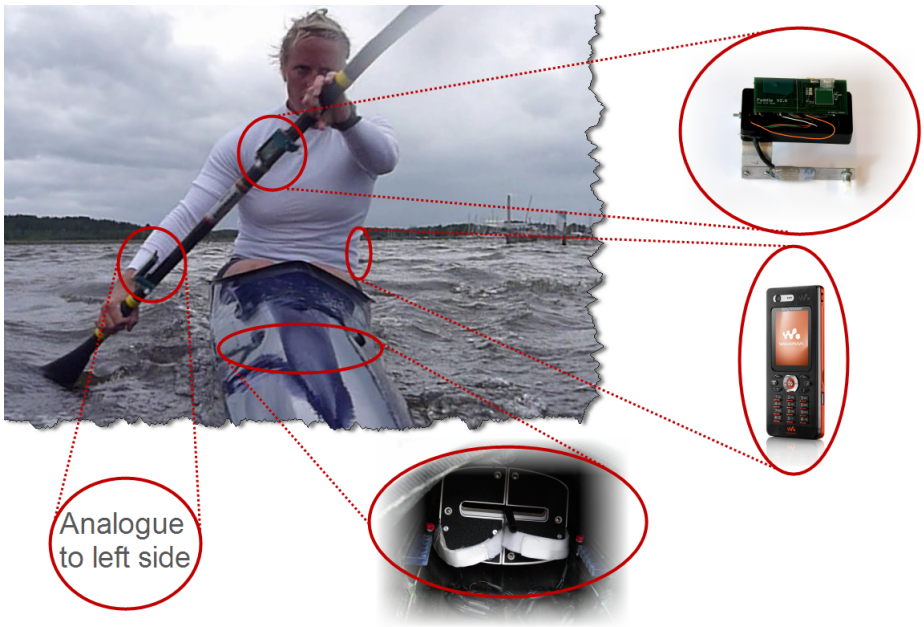

Figure 1 The KTH kayak sensor system V2.0 (with improvements compared to Sturm et al., 2010).

1.3 Research aim

As stated in the introduction, the purpose of this study is to discuss the learning process from conducting a user driven 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. As discussed earlier the market for similar products is rather limited which makes it difficult for researches to find users in practice that have been exposed to similar products. Thus, the attention is drawn to lead users due to their specific characteristics. In the following section a description of lead users and their role in product development will be explained.

1.4 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 ambitioned 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).

2 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).

2.1 Qualitative study

In the early phase of the study a workshop with 10 participants was conducted involving Swedish kayak athletes and coaches which 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 external ideas into the team. The kayakers were all experienced users 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 varying fields of interest and began with pointing the participants' thoughts towards challenges and problems of today's training situation. This introduction was followed by various vision and mind-opening exercises to picture and visualise the desired state. 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.

2.2 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 and equipment data, (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 scales 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.

3 Research findings

3.1 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. One of the ideas that were conceptualized was the use of sensors to monitor and capture the paddle movement and acceleration. Each idea had a realisation strategy ready from day one.

The range of ideas to improve kayaking performance and training were wide, not limited to pure "equipment" but included also less technical concepts, such as ideas about improving social conditions for athletes such as financing, health and well being, and ways to facilitate individualisation of training and competing. The team participating at 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.

3.2 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 not at all 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, 10 out of 13 who answered this particular question 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.

3.3 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.

Five athletes have been identified to have the characteristics of lead users. The group is inhomogeneous concerning gender, age, experience, main profession and, unfortunately, location. These persons have in common 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 perceive that there is a great potential for development in kayaking and can expect a great personal benefit from a more effective training due to new developments.

The rationale for choosing each person follows in brief.

3.3.1 Lead user 1

The only Finnish athlete in this study stuck out not just through her nationality. She had travelled to Sweden for a training session and showed us some customisations on her equipment she had made herself. In the questionnaire she gave many detailed suggestions referring to biomechanics in a kayak, which hardly any other athlete seemed to be conscious about. Many side notes and comments to questions designed for a Likert scale answer gave proof of her intensive thoughts on the issue.

3.3.2 Lead user 2

An athlete, whose understanding and interest in the development of technology for kayaking may be advocated by his engineering studies, has put down a considerable amount of his personal time to aid the research and has trusted us with his own, valuable competition equipment for fitting and testing purposes. Through this communication we have received qualitative important information beside the questionnaire.

3.3.3 Lead user 3

A former national coach with extensive personal competition experience, who initiated the research in cooperation with a senior scientist, was included in the study. 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.

Besides her initial crucial role the coach still had numerous new ideas and gave valuable comments and details in the open questions section of the questionnaire. Not just in her private training but also in her continued work as a coach – now on a personal level – she expects to gain benefit from our work. The coach had also participated and contributed in the workshop discussed above.

3.3.4 Lead user 4

The currently most successful Swedish female kayak athlete has, similarly to lead user 1, adjusted her own equipment to better fit her personal biomechanics. She has contributed in the questionnaire with some unique suggestions to future development for kayak training. Obviously, she perceives that technological aids could be helpful in maintaining her outstanding performance.

3.3.5 Lead user 5

Last but not least we have identified a junior athlete as a potential lead user. Although her experience is not as rich as the rest of the group, she is very successful even when competing against seniors. In her great interest in supporting our research she was prepared to miss on a race when we were present at a competition to demonstrate our sensor system and to gather feedback. We have gained important knowledge through her feedback, both informal and through the questionnaire. It should be noted that the athlete's parents may have a strong influence and interest in supporting and pushing her daughter to success.

4 Discussion and conclusion

4.1 Discussion

We have found indication that the majority of the Swedish competing athletes in our study group have lead user characteristics and we have chosen to work closer with a dominant group of 5 of these users. Some of them have innovated by altering their own boat setup and they have a very deep insight in the sport. Their own commitment has enabled these users to gain knowledge and to identify problems and trends beyond the perception of the average athlete.

The workshop was a crucial step in the research project. The concrete outcome of the workshop was the validation of the research project as it was found to be valuable and relevant to the needs of athletes. Although, others prospective topics for further research were also identified 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. Once the area of interest was clearly visible after the workshop the development of a quantitative study was conveniently achieved.

In the quantitative study, it was striking that one very successful athlete stuck out of the group examined in the quantitative study by showing a negative attitude towards the introduced research. An interview to identify the reasons for this athlete's proclaimed disinterest to collaborate with researchers and profit from their work and findings still lacks an evident explanation. Competition thinking and/or the close temporal relation of the interview and questionnaire to an important national competition may have been confounding factors.

The industry, which sells the most related products, has not identified Olympic style kayaking as a field of interest. There are no products on the market for normal users to relate to, when interviewed for marketing purposes in the early design stage. The information we have been able to extract from the involvement of lead users is indicative and unique to this group.

Involving users and especially lead users has improved 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 characteristic 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.

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.

4.2 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.

4.3 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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