User-innovators and "local" information:
The case of mountain biking

Christian Luthje*, Cornelius Herstatt** and Eric von Hippel***
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ABSTRACT

In a study of innovations developed by mountain bikers, we find that user-innovators almost always utilize "local" information – information already in their possession or generated by themselves - both to determine the need for and to develop the solutions for their innovations. We argue that this finding fits the economic incentives operating on users. Local *need* information will in general be the most relevant to user-innovators, since the bulk of their innovation-related rewards typically come from in-house use. User-innovators will increasingly tend to rely on local *solution* information as the stickiness of non-local solution information rises.

An interesting implication of this finding is the possibility of sometimes predicting the general nature of user innovations *ex ante*. Under conditions where users are likely to rely on local information to develop innovations, it may possible to learn about the general nature of users' needs and available solution information prior to innovation development and so predict the general nature of the innovations they might develop. One could then assist and promote the innovation activities of some.

* *Research Assistant and Habilitation Student of Innovation Management and Marketing, Technical University of Hamburg, Institute of Technology and Innovation Management, luethje@tu-harburg.de*
** *Professor of Technology and Innovation Management, Technical University of Hamburg, Institute of Technology and Innovation Management, herstatt@tu-harburg.de*

***Professor of Innovation Management, MIT Sloan School of Management, Cambridge, MA, evhippel@mit.edu

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1. Introduction and overview

Many studies have explored innovation by users and the characteristics and distribution of user-innovators in fields ranging from open source software projects to physical products used by industrial firms and by end consumers. To date, however, very little work has been done on the characteristics of *information* used by user-innovators. In this paper we report on an empirical study of the sources of information drawn upon by mountain bike users who have developed modifications for their bikes. We find that innovating users in our sample employ only their own existing, "local" stocks of both need and solution information to develop the innovations. Essentially all users utilized need information derived from their own repeated personal usage experiences, and 84% users utilized solution information already in their possession in order to develop their new and modified mountain bikes.

We put this finding into context by explaining why and when user-innovators are likely to focus heavily on local information. We argue that the tendency to draw upon their own individual information fits the economic incentives operating on users and can be understood both in terms of the users' innovation-related costs and in terms of benefits that users can reasonably expect from innovating.

In essence, *all* categories of innovator, users included, will tend to increase their use of local information when the cost of obtaining needed non-local information is relatively high: that is, when that information is sticky. In addition, it is reasonable that as resources available to an innovator drop, the amount of information that innovator will obtain from outside drops when information stickiness is held constant. In the case of user-innovators, there is an additional reason why users will tend to use only their own individual need information. User-innovators often cannot obtain benefits from the diffusion of their innovations to others: their benefit tends to come exclusively or primarily from their own in-house use. Under these incentive conditions, it makes sense that users would utilize only their own local need information for their innovation-related work.

Innovations developed by users have been found to be widely *distributed* among many users rather than concentrated among a few highly innovative user firms or individuals (von Hippel, 2005). This can make it difficult to predict the sources of innovations *ex ante*. Yet, accurate predictions of the likely source and nature of innovations can offer important first-mover advantages to firms interested in rapid commercialization of user-developed innovations. Our finding that user-innovators draw primarily upon local information for needs and solutions in mountain biking points the way to a possible solution to this problem: Firms *may* be able to predict the kinds of innovations users will develop, given good information about the kinds of local need and solution information in their possession.

In this paper we will first review related literature (section 2). Next we review our research context and methods (section 3). Findings are presented in section 4 and implications developed and discussed in section 5.

2. Literature review

We begin with a review of the impact of sticky information on the sources of innovation. We then turn to a review of users' incentives to innovate.

Sticky information and innovation

If information could be costlessly transferred from place to place, this issue would not impact the locus of innovation: all innovators could work from the same sources of information at the same cost. In fact, however, it has been show that much information used by product and service developers is costly to transfer or "sticky." As a consequence, major information asymmetries do exist among potential user-innovators, and these in turn can have a major impact on who develops what.

In any particular instance, the stickiness of a unit of information is defined as the incremental expenditure required to transfer that unit of information to a specified location in a form usable by a specified information seeker. When this expenditure is low, information stickiness is low; when it is high, stickiness is high (von Hippel, 1994).

That information *is* often sticky has been shown by studying the costs of transferring information regarding fully developed process technology from one location to another with full cooperation on both sides. Even under these favorable conditions, costs have been found to be high. Teece (1977) for example, studied 26 international technology-transfer projects and found that the costs of information transfer ranged from 2 percent to 59 percent of total project costs and averaged 19 percent—a considerable fraction. Mansfield et al. (1982) also studied a number of projects involving technology transfer to overseas plants, and also found technology-transfer costs averaging about 20 percent of total project costs. Winter and Suzlanski (2001) explored replication of well-known organizational routines at new sites and found the process difficult and costly.

Why is information transfer so costly? Information stickiness can result from causes ranging from attributes of the information itself to access fees charged by an information owner to the "absorptive capacity" of the information seekers (Cohen & Levinthal, 1990). Tacitness is a cause that is quite relevant to our study of mountain biking. Polanyi (1958) noted that many human skills are tacit because "the aim of a skilful performance is achieved by the observance of a set of rules which are not known as such to the person following them." For example, swimmers are probably not aware of the rules they employ to keep afloat (e.g., in exhaling, they do not completely empty their lungs), nor are medical experts generally aware of the rules they follow in order to reach a diagnosis of a disease. As Polanyi points out, "an art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice. . . ."

When information is sticky, it is reasonable that a bias will be created toward the use of local information over sticky non-local information – simply because local information can be accessed more cheaply. This can in turn affect the character of innovations developed if local information differs in kind from more distant information. In the case of product development, information that is local to a user includes information about that user's new product needs and intended use environment. A manufacturer's local information includes solution approaches in which that manufacturer specializes (for example, a manufacturer specializing in molded plastic parts will tend to know a lot about that solution approach.) Given that this is so, a bias towards the use of local information by innovators would tend to result in users emphasizing product development tasks that draw intensively upon their local need information, while manufacturers would tend to focus on product development tasks that draw upon their local solution information.

Ogawa (1998) found precisely this effect in a study of 24 equipment innovations. All were produced by NEC, a Japanese equipment maker, for Seven-Eleven Japan (SEJ), a major Japanese convenience store chain. Ogawa determined how much of the design for each was done by the user firm and how much by the manufacturer firm. His data shows that innovations requiring a rich understanding of needs (high amount of sticky need information) tended to be carried out by the user, SEJ, while innovations involving rich understanding of new technologies (high amount of sticky solution information) tended to be developed by NEC.

In a related finding, Shane (2000), conducted a case study of 8 applications of a single, MIT-developed technology called 3-D printing. He found each was identified by an innovator with a professional background closely related to that application. For example, a novel application of the 3-D printing process to the manufacture of artificial bones for orthopedic implants was identified by an individual with a background in precisely that field. Venkataraman (1997) is credited by Shane as stating the finding in more general terms: "Each person's prior idiosyncratic knowledge creates a "knowledge corridor" that allows him/her to recognize *certain* opportunities but not others." We may state the matter even more generally: when information relevant to an innovation is sticky, the nature of an innovator's local need and solution information can strongly affect the nature of the information used, and thus the nature of the innovation developed.

User-innovators' benefit expectations

Innovation-related benefits obtained by user-innovators tend to come from in-house use rather than from diffusion of their innovations to others. To benefit financially from diffusing their innovations to others, user-innovators must first protect their intellectual property and then find a licensee that will produce their innovations for the marketplace. Both tasks are difficult to accomplish, in good part because the ability of innovators to obtain effective intellectual property protection is actually quite weak in most fields (Harhoff, Henkel, & von Hippel, 2003, von Hippel, 2005).

In essence, the situation is as follows. In most subject matters, the most appropriate form of legal protection is the patent grant. However, researchers have found that the protection actually afforded by patents is weak in most fields – with the exceptions being chemicals and pharmaceuticals. In line with these findings, firm executives in most fields do not view patents as a very effective form of protection for intellectual property (Taylor and Silberston 1973, Levin et al 1987, Mansfield, 1968, 1985, Cohen, Nelson, & Walsh, 2000).

An alternate form of intellectual property protection is copyright. Copyright is a low cost and immediate form of legal protection applicable to original writings and images – it "follows the author's pen across the page." In the US, courts have determined that the innovation-rich field of software is eligible for copyright protection because software may be regarded as a form of "writing." Unlike the patent grant, copyright protection applies only to the specific writings embodying an innovation rather than to the underlying idea itself. Thus, copyright does not prevent someone from studying the novel functionality embodied in products or encoded in software and then creating an original product design or code to perform the exact same function.

The third major form of intellectual property rights protection is trade secrecy law. As was the case with patents and copyright, only some innovations can be protected by trade secrecy in principle – and the level of protection offered in practice is often weak. Much intellectual property does not qualify for protection as a trade secret simply because it cannot simultaneously be kept secret and exploited for economic gain. Studies show that even innovations that do meet this criterion are unlikely to remain secret for long. Mansfield (1985) studied a sample of 100 American firms and found that the period during which intellectual property can be kept secret in fact appears to be quite limited. He reports that "…information concerning development decisions is generally in the hands of rivals within about 12 to 18 months, on the average, and information concerning the detailed nature and operation of a new product or process generally leaks out within about a year."

In the specific case of sports innovations such as those we will study in this paper, innovators can in general not expect to obtain effective intellectual property protection – and so will not be able to profit from any diffusion of their innovations to others. Copyright does not apply – sports innovations are not "writings." Also, both the effectiveness of patenting of trade secrecy are likely to be poor. Research cited earlier finds that patents are not generally viewed as effective in the case of mechanical innovations – which is what sports equipment innovations tend to be. In addition, sports equipment innovations are used in the open by sports participants, and so are difficult or impossible to keep as trade secrets even if an innovator wanted to do this. Shah (2000) has reported on the frequency and effectiveness of patenting in the case of user-innovators developing new and modified products in skateboarding, windsurfing and snowboarding. She finds few attempts to patent and almost no success in licensing and obtaining royalties among the very few that did patent their inventions.

3. Research context and methods

Research context: mountain biking

The topic of this research is on the relationship between the information that is local to a given user-innovator and the type of innovation that individual develops. We chose to focus our empirical work on this matter on user innovation within the sporting field of mountain biking. Our reason for this choice was that we wanted a large effect size: we needed to see the effect at significant levels in a relatively small sample. User innovation has been shown to be quite frequent among sports equipment users (Franke & Shah, 2002) In addition, user-innovators in these fields are likely to be individual riders who are likely to not have major financial resources to devote to the import of sticky information from outside sources.

Mountain biking involves bicycling on rough terrain such as mountain trails, and may also involve various other "extreme" conditions such as bicycling on snow and ice and in the dark (van der Plas & Kelly, 1998). Mountain biking began in the early

1970’s when some young cyclists started to use their bicycles off-road. Existing commercial bikes were not suited to this type of rough usage, so these early users put together their own equipment out of strong old bike frames with balloon tires to which they added motorcycle lever-operated drum brakes for better stopping ability. They called their creations „clunkers“ (Penning, 1998; Buenstorf, 2002).

Commercial manufacture of mountain bikes began about 1975, when some of the early users of mountain bikes began to also build bikes for others. A tiny cottage industry developed, and by 1976 a half-dozen small assemblers existed in Marin County, California. In 1982, a small firm named Specialized, a bike and bike parts importer that supplied parts to the Marin County mountain bike assemblers, took the next step and brought the first mass-produced mountain bike to market (Berto, 1999). Major bike manufacturers quickly followed and started to produce mountain bikes and sell them at regular bike shops across the US. By the mid-1980’s the mountain bike was fully integrated in the mainstream bike market. At about the same time, bicycle component manufacturers began producing components such as derailleurs, crank sets, tires and handle bars that were specifically designed for off-road use.

Mountain biking enthusiasts did not stop their innovation activities after the introduction of commercially-manufactured mountain bikes. They kept pushing mountain biking into more extreme environmental conditions and also continuously developed new sports techniques involving mountain bikes (Mountain Bike Magazine 1996). Thus, some began jumping with their bikes from house roofs and water towers and developing other forms of acrobatics. As they did so, they steadily discovered needs for improvements to their equipment and, as we shall see in this paper, many responded by developing and building improvements for themselves. Also, users prototyped specialized infrastructure: for example, jumping from rooftops evolved into jumping from platforms specially built for that purpose. Over time, the more generally-valued of these innovations would spread among the user community and some of these would eventually be produced commercially by manufacturers.

During the past 20 years, the commercial market for mountain bikes and related gear has grown to a significant size. In the U.S., total retail sales in the bicycle market were $5.89 billion in 2000, including bicycles, related parts, and accessories through all channels of distribution (National Sporting Goods Association 2002). Approximately 65% of these sales were generated in the mountain bike category. This category is defined by the industry as consisting of traditional mountain bikes and „comfort bikes" - modified mountain bikes featuring soft saddles, a more upright riding position and slightly easier gearing.

Sample selection and data collection methods

Our goal was to find a sample or samples of mountain bikers containing a usefully-large number of innovating users. We knew from our study of the history of the field that innovating users were traditionally found among "off-road" users of mountain bikes rather than among "comfort bike" users. Detailed discussions with experts in mountain biking focused our search still more by informing us that the "North Shore " of the Americas, ranging from British Columbia in Canada to Washington State in the U.S., was a current "hot spot" in mountain biking where new riding styles were being developed and where the sport was being pushed towards new limits.[1]

We next searched the Internet and identified 29 mountain biking clubs that were based in the North Shore region. We also discovered two unmoderated mountain biking forums on the Internet, the Transcend Magazine Forum (www.topica.com/lists/downhill), and the Topica Downhill Mailing List (www.transcendmagazine.com/). These forums were not restricted to North Shore users. However, both forums were founded by mountain bike activists from that region and recruit a significant part of their members from the North Shore. As a result, we decided to try and obtain data from both members of North Shore mountain biking clubs and contributors to the mailing lists of these two on-line forums.

To assemble our sample of mountain bike club members, we randomly selected 10 of the 29 North Shore clubs we had identified. We then attempted to contact the

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[1] To obtain expert advice at various points during the course of our study, we identified a group of expert user informants by posting a request for assistance on the largest internet forums devoted to mountain biking. We then initiated email conversations with 16 who seemed to us to be the most expert. In addition, we gained important contextual information from telephone interviews with bike shop owners, with 2 officials of mountain biking associations, with one 1 small-scale manufacturer of mountain bikes and with 3 active mountain bikers who had recently invented mountain bike equipment.

presidents of these clubs. We succeeded in contacting 8 club presidents, described our study and ask whether they would be willing to participate. Three of the eight contacted clubs were not appropriate for the purposes of this study. Two of the clubs contacted had been founded only recently. At the time we contacted them, they had only a few members each. One club was not appropriate because it was exclusively for children. Thus, from the 8 clubs only 5 were found likely to have innovating users and also agreed to participate.

Data collection from club members was then done with the help of the club presidents. Each was asked to e-mail a cover letter and a link to our online-questionnaire to club members. In the five clubs taken together, 255 users were contacted in this way. We received 112 responses and had to exclude 6 non-usable responses, leading to 106 usable responses (table 1).[2] The gross response rate is 41.6%. This quite high percentage can be explained by the use of the clubs presidents as bridging persons. A request to participate in a survey is more likely to yield a response when a respected insider is asking.

Table 1: Response rates for two samples of mountain bikers

	Sample 1: Members of MTB clubs	**Sample 2: Members of MTB online-forums**	
	all contacted members in the clubs	**All individuals included in the forum mailing list**	**active members of the forum (at least one posting to the list)**
Base	255	1,209	436
Responses	106	185	185
Response rate	41.6%	15.3%	42.4%

In the case of the two Internet forums devoted to mountain biking we began by contacting the organizers of each. Both proved willing to support the survey by posting a request to participate on their forums. Taken together, the two Internet forums had

[2] The 106 respondents were distributed across the five MTB clubs in the following manner: West Coast MTB Club 24.5%, Cheam Cycling Club 6.6%, North Shore MTB Club 44.3%, Comox Valley Cycle Club 15.1%. The fractions reflect the relative size of the clubs.

1,209 members. After posting the request we received 185 answers.[3] The directly-calculated response rate from forum members is therefore 15.3 %. However, viewing all members of the forum as potential respondents may be unduly conservative. Posting of one's name on a forum list is easy and often does not indicate that an individual is an active member or is even continuing to visit the forum. Indeed, many listed "members" have never posted a comment on-line. If we therefore more realistically define active members of the two forums as those having posted at least one message within the six months before the survey, we find that only 469 of the members of the two forums were active. Our response rate among active members was therefore 42.4%. This figure is in the range of response rates achieved with the club members in sample 1. As in that case, the active support of the forum organizers probably was helpful in raising the response rate to this relatively high level.

Online questionnaire

Both of our samples of mountain bikers were asked to respond to an online-questionnaire. When compared to traditional mail surveys, the advantages of an online survey are, among others, higher speed and lower costs. In the instance of our sample members, contact via email and use of an online questionnaire does not raise issues of access or representativeness. The officials of the 5 clubs in our sample reported that almost all members have e-mail and access to the internet. This was (by definition) also true for members of the two online forums contacted.

We designed a draft questionnaire based upon our own research interests as refined by previous research findings and information obtained from interviews with expert users in the mountain biking field (c.f. footnote 1). As a pilot test, we then sent our draft to these experts and asked them to fill it out and then provide feedback on its content and design. Based on this feedback, we then developed a final version incorporating several modifications that improved both the clarity of the questions and the logical structure of the questionnaire.

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3 In total 44 respondents (23.8%) were members of the Topica Downhill Mailing List and 141 respondents (76.2%) were active in the Transcendent MTB Forum.

The questionnaire sent to our sample of users was divided into two major parts. The first part covered questions about each respondent's particular use experiences (intensity of riding, terrain, outside conditions, riding abilities) and technical knowledge (theoretical knowledge, practical skills, knowledge from other fields). The second part was addressed only to users that reported that they had an idea for an innovation or had actually developed one. This section dealt with the characteristics of and circumstances surrounding "the most important" innovation the users had developed. Thus, innovating users had to describe the problem they had identified and the type of solution they had conceived of to solve the problem. Finally, respondents also were asked to rate their ideas with respect to a number of criteria (e.g. newness, usefulness, market potential).

Open-ended questions were used to collect much of our information because, as was revealed in our exploratory interviews, there is a great diversity in user experience, technical knowledge, and user-developed innovations as well.

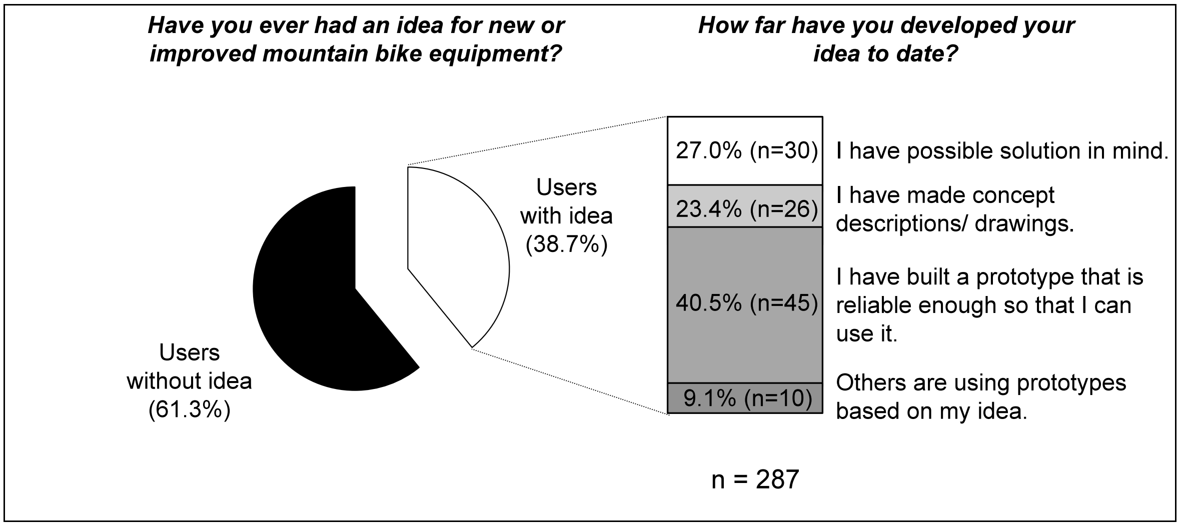
4. Findings

4.1 Nature of innovations reported

Innovation frequency

A significant number of individuals responding to the questionnaire stated having generated ideas for new or improved mountain biking equipment. Thirty eight percent of the 287 respondents reported having developed one or more such idea. Of these, 40.5% reported building and personally using a prototype embodying their idea, and 9.1% of the inventing users reported that their innovative idea had been adopted and put to use by other mountain bikers (figure 1).

Figure 1: Frequency of idea and prototype generation by serious mountain bikers



It is possible that the level of user innovation in our sample overstates the actual level of innovation in our population of mountain bikers: innovators may have been more likely than non-innovators to respond to our questionnaire. However, Franke and Shah 2002 report similar levels among serious practitioners of the four diverse sporting fields they studied: sailplane flying, canyoning, bordercrossing and cycling by individuals with physical disabilities. (Lüthje, 2004 finds a lower level (10%) among recipients of specialized mail-order catalogs for outdoor sporting products.)

General nature and utility of user innovations

Respondents typically characterized their ideas or innovations as relatively moderate improvements utilizing fairly routine solution technologies (table 2). Twenty four percent considered their ideas to be totally new products, and only 13% thought that their solutions incorporated "high technology" or new technology. This type of relatively incremental innovation is characteristic of the mountain biking field. Ever since the introduction of the mountain bike – itself a modification of the general biking equipment then in use - the predominant innovation pattern has involved incremental and minor novelties, with technological progress mainly consisting of accumulated improvements and minor modifications to the same basic design (Buenstorf, 2002).

Table 2: Characteristics of user-developed innovations

Rating dimensions	Mean	% of innovations with high or very high agreement
Newness [a)]	3.49	24.1%
Technical Sophistication [b)]	2.61	12.9%
Personal Benefit [c)]	5.39	66.1 %
Market Potential [d)]	4.32	31.2%

n=109 ; 7-point-rating scales were used
a) 1=small improvement / modification of existing product; 7=totally new product
b) 1=low-tech solution / known technology; 7= high tech solution / new technology
c) 1=personally benefit very little; 7=personally benefit very much
d) 1=few people would adopt if commercially produced; 7=many people would adopt if produced

Users developing innovations reported that they gained a high personal benefit from using their innovations in their own mountain biking activities. On average, they also thought that quite a few people would buy their innovations if they were commercially available (table 3).[4]

Of course, a user's appraisal of the general appeal of his or her own innovation might well involve a significant bias. We tested this possibility by having a random subset of the innovations descriptions provided by the respondents also evaluated by 10 mountain biking experts who had no relationship to the innovators or innovations in our sample.[5] Via an interview, the experts were presented with concept descriptions of the ideas and were asked to rate their market potential and their usefulness for mountain bikers on the same scales that were used in the questionnaire. We then compared the self-rating of the developers of the innovations with those of the independent experts. Due to the small sample, we used a non-parametric test (Wilcoxon-Signed-Rank-Test)

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4 Likely sales volumes of innovations appealing to "many" mountain bikers is not clear. One can get a flavor of likely volumes, however, based upon the following market-related information. Sporting Goods Manufacturers Association (SGMA) estimates that in 2001 there were approximately 8 million people who went off-road mountain biking in the United States. Of these, about 2 million are "frequent riders," riding on at least 25 occasions a year on traditional or modified mountain bikes ("comfort bikes"). A $50 innovation purchased by 10% of frequent riders would thus generate $1 million in sales. Purchase of a $50 item of equipment seems reasonable: According to a survey of USA Cycling Association frequent riders spend an average of $1,212 per year in bikes/cycling equipment.

5 Since the experts were engaged in mountain biking on a semi-professional level they had a good understanding of the purpose and utility of the innovations developed by the innovators in our sample. They also all worked part-time at bike shops, and so had a good understanding general user needs – at least from that vantage point.

and determined that the null hypothesis - that the distribution of user-innovator and user-expert ratings are equal - is not to be rejected. We found that, although user-innovators did evaluate the commercial potential of their innovations slightly more positively than did the independent experts, the level of difference was not statistically significant.

Innovation heterogeneity

Mountain biking, which casual observers might assume to be a single type of athletic activity, in fact has many subspecialties. The specializations of mountain bikers in the sample involved very different mountain biking terrains, and important variations in riding conditions and riding specializations. In order to assess whether the heterogeneous riding activities of the user-innovators in our sample lead to a high level of heterogeneity of their innovations, we assigned the innovations to different areas of specialization: On the basis of the descriptions provided by the users, we determined for each innovation the speciality to which that innovation primarily applied. It was assessed if an innovation was specifically suitable to ease riding in a particular terrain, to better cope with particular outside conditions, and to improve specific riding abilities.[6] As can be seen in table 3, the functions of the innovations covered a wide range of different mountain biking specialities. The findings reflect a high level of innovation heterogeneity.

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[6] Coding of the sub-specialty in mountain biking to which the user innovations primarily applied was carried out by a single coder - the first author. The reliability of this coding was then tested by asking the 10 expert users mentioned before to independently perform the same coding task for a random subsample of 23 of our 111 user innovations. Each expert was asked to associate the users' inventions to the sub fields of mountain biking shown in table 4. An acceptable level of agreement between the authors' and the expert users' coding was achieved. For the ten expert users the Cohen's Kappa coefficients range between 0.77 and 0.86. The overall level of agreement for the random sample of 23 user innovations was 81%.

Table 3: Application fields of user innovations

Applicability of innovations to following <u>terrain</u>	Number of innovations	Applicability of innovations to following <u>outside conditions</u>	Number of innovations	Applicability of innovations to following to following <u>riding abilities</u>	Number of innovations
Fast Downhill Tracks (steep, drops, fast)	49 (44.1%)	darkness, night riding	43 (38.7%)	jumps, drops, stunts, obstacles	31 (27.9%)
Technical Single Tracks (up & down, rocky, jumps)	56 (50.5%)	snow, ice, cold	60 (47.8%)	Technical ability/balance	6 (5.5%)
Smooth Single Tracks (hilly, rolling, speed, sand, hardpack)	19 (17.1%)	rain, muddy conditions	37 (33.3%)	fast descents / downhill	49 (44.1%)
Urban and streets	6 (5.5%)	heat	3 (2.7%)	Endurance	12 (8.1%)
No special terrain preferred	29 (26.1%)	extreme heights / altitude	6 (5.4%)	Climbing	25 (22.5%)
		No extreme outside conditions	52 (46.8%)	Sprint	59 (53.2%)
				No focus on specific riding ability	31 (27.9%)

Notes: This table includes all 111 ideas for improvements to mountain biking equipment. (Fifty five of these ideas have been transferred into a reliable prototype.) Many of the ideas are suitable to improve riding in more than one category of activity, so the sum in each column is higher than 111.

Three examples of needs and solutions drawn from our sample illustrate both the nature of and heterogenity of innovations reported by our respondents:

- Problem encountered by user in “stunt” riding: “When doing tricks that require me to take my feet off the bike pedals in mid-air, the pedals often spin, making it hard to put my feet back onto them accurately before landing.” Solution devised: “I have added a foam ring around the pedal axle near the crank. This adds friction, and prevents the pedals from free-spinning when my feet are off.”
- Problem encountered by user riding in extreme conditions: “When riding on ice, my bike has no traction and I slip and fall.” Solution devised: I increased the traction of my tires by getting some metal studs used by the auto industry for winter tires. Then I selected some mountain biking tires with large blocks of

rubber in the tread pattern, drilled a hole in the center of each block and inserted a stud in each hole."

- Problem encountered by user related to racing: "You need to try out different "lines" on a race course [the precise path that your bike will travel] and compare them to figure out which is the fastest." Solution developed: "I mounted a thumb-activated stopwatch next to my bike's handlebar to be able to conveniently and accurately time each line tested."

4.2 Relying on local need information

We explored whether generating ideas for desirable new bike equipment was correlated with the nature and intensity of a respondent's use experience in mountain biking. We used a logit model to examine the differences between users having no idea for an improvement to mountain biking equipment with those users who have a need and a general type of solution in mind (Agresti & Finlay, 1997, Aldrich & Nelson, 1984).[7]

The results of the logit model presented in table 5 demonstrate the degree to which the amount and type of use experience can explain why users do or do not have an idea for an improvement to mountain biking equipment. A positive logit coefficient indicates that it is more likely that users generate an idea for innovations if the corresponding factor takes high values. The coefficient itself indicates the change of the logit of the dependent variable if the independent variable changes by one unit. All measures indicate a good fit with the estimation model. The rate of correct classification of respondents into the two subgroups (no idea versus idea) is 79.1%. The Proportional Chance Criterion (PCC) is significantly lower at 52.6%.

Users that reported having ideas for improving mountain biking equipment differed significantly from those without such ideas on a number of measures of experience and technical skills. Those with ideas spent more hours per week in mountain biking, had been active in their sport for a longer time, and were active in more different mountain biking specialties such as jumping and endurance riding. They

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[7] The application of the logit model requires the independent variables not to be correlated. To assess the level of multicollinearity we examined the correlation matrix and observed the impact of exclusion of most highly-correlated variables on the model estimation. With respect to use experience, no item had to be excluded.

also participated more frequently in races, rode to a greater extent on challenging terrain and under extreme outside conditions and were more focused on particular riding abilities. They also reported a higher level of technical knowledge with respect to how their mountain biking equipment functions and how to fix it than did those not reporting ideas for improvements (table 4).

Table 4: Logit model to test differences between users having NO idea for an improvement versus those that HAVE an idea and may have developed a prototype

Variables of use experience	logit-coefficient	Standard error	Wald statistic
Hours per week in MTB	**0.06**	0.03	4.39 ($p<0.05$)
Years of MTB	**0.21**	0.04	27.59 ($p<0.001$)
No. of different disciplines of MTB	**0.30**	0.20	2.50 ($p<0.1$)
Participation in MTB races [a)]	**0.27**	0.09	8.31 ($p< 0.001$)
Riding under extreme outside conditions [b)]	**0.26**	0.12	4.41 ($p<0.05$)
Focusing on specific riding ability [b)]	**0.24**	0.12	4.34 ($p<0.05$)

-2 log likelihood= 262.10; Likelihood-Ratio=113.25 (df=6, p<0.001); McFaddens R2= 0.30; n=280.
a)measured on 7-point-rating-scale (1 = never; 7 = very often)
b)measured on 6-point-rating-scale (1 = never; 6 = very often)

Innovators report that their innovative ideas were triggered by direct and repeated *personal experience* with a problem associated with mountain biking (table 5). Repeated experience can be helpful in isolating an item in a continuous flow of events as a problem. It can also be helpful for prototype development: Repeatedly experiencing the same problem creates a laboratory for repeated trial-and-error experimentation in the field.

Table 5: Experience-related triggers of user innovations

	Mean	Median	% of users
"How did you recognize the problem/need solved by your idea? Because of your personal experience or because you learned that other riders experienced it?" [a)]	2.15	2	84.5% rather personal experiences
"How did you recognize the problem/need? As a result of frequently repeated experience or as a result of a single incident?" [b)]	2.07	2	87.3% rather frequently repeated experience

n=110
a) 6-point-rating-scale (1=because of my personal experiences; 6=because other riders experienced it)
b)) 6-point-rating-scale (1=very frequently repeated experience; 6=single incident)

Users' assertions that their innovations are triggered by problems they personally encounter can be indirectly tested by comparing the function of each innovation idea developed by a particular user with that user's declared special biking interests. To make this comparison, we used the categorization of the innovations provided in table 3. The innovations in our sample were categorized according to the type of speciality to which they primarily applied (type of terrain, type of outside condition, type riding ability). Since not all innovations had a clear relationship to a specific terrain, outside condition or riding ability, only a fraction of all 111 innovations could be included to test the correspondence (see first row of table 6). We explored to what extent the application field of a given innovation corresponded to the special biking interest of the user-innovator. The fit between the application field of the innovation and the riding activities of the innovators is expressed by the percentages provided in the second row of table 6.

Table 6: Applicability of innovation to sub field of special interest to innovator

	Dimensions of mountain biking activity			
	Preferred terrain	**Predominant outside conditions**	**Particular riding ability**	**Total**
Number of user innovations associated with the particular dimension of biking activity	82	59	52	**193**
Percentage of these innovations applicable to at least one subfield mountain biking activity of special interest to the innovator.	94,0% (77)	95.0% (56)	88.5% (46)	**92.7% (179)**

A comparison of the functions of user-built prototypes with the special interests of our user-innovator respondents shows that mountain bikers do indeed tend to develop prototypes useful for the specific kind of mountain biking that they personally perform. Very rarely does an innovation lie exclusively in fields of product use where the innovating user has no personal use experience.

To illustrate what we mean by a close link between user experience and innovation content, consider the example of knee-activated brake levers drawn from our sample. Knee-activated braking levers can provide greater braking power than the handbrakes traditionally used in mountain biking. The knee lever developer reported that he rode his bike primarily in very mountainous terrain. On long descents, he found that continuously applying his hand brakes created such a strain on his hands and upper arms that muscle fatigue was seriously affecting his safety. By creating a way to activate his brakes using his knees, he was able to utilize his much-stronger leg muscles for braking and thus avoid fatigue.

4.3. Relying on local solution information

We have seen that generating ideas for desirable new improvements is associated with the nature and intensity of a respondent's use experience. Some of the respondents with ideas went on to actually build prototypes embodying their ideas. Going beyond the idea stage to the actual building of prototypes embodying the idea should – to the extent that a user-innovator relies on local knowledge - be associated with a respondent's general level of technical skill.

To explore this matter we took a closer look on the impact of local technical knowledge on the probability that the users with an innovation idea go on to build the equipment they envisioned. In a second logit analysis we now contrast respondents who had an idea but did not go further in the development process with those who did develop a reliable innovation prototype (table 7).

When we compare the users that only developed an idea/concept with those that developed a reliable prototype we see that none of the variables measuring aspects of use experience can explain why a user decides to actually develop his idea or concept into a working prototype. However, we see that bikers that did develop prototypes had significantly higher general technical knowledge with respect to biking equipment than those who did not. The level of a user's personal technical knowledge explains why some users stop at the idea/concept stage while others go on to build a prototype.

Table 7: Logit model to test differences between users that have only developed innovation ideas versus those who have an idea and also have built a prototype

Variables of user background	Logit-coefficient	Standard error	Wald statistic
Aspects of use experience			
Hours per week in MTB	**-0.04**	0.03	1.60 (n.s.)
Years of MTB	**-0.01**	0.06	0.05 b(n.s.)
No. of different disciplines of MTB	**030**	0.25	1.45 (n.s.)
Participation in MTB races [a)]	**0.05**	0.13	0.17 (n.s.)
Riding under extreme outside conditions [b)]	**0.08**	0.17	0,22 (n.s.)
Focusing on specific riding ability [b)]	**0.08**	0.16	0.29 (n.s.)
Aspects of technical knowledge			
Know-how about equipment functionality [c)]	**0.54**	0.27	2.94 ($p<0.1$)
Relation to others with repair abilities [c)]	**0.34**	0.17	4.19 ($p<0.05$)
Knowledge about tools and repair facilities [c)]	**0.94**	0.49	3.81 ($p<0.05$)
Constant	**-6.63**	2.44	7.34 ($p<0.01$)

-2 log likelihood= 111.76; Likelihood-Ratio=37.92 (df=9, p<0.001); McFaddens R2= 0.25; n=108.
The proportion of correct classifications is 72.7% which is a higher than the PCC of 49.9%.
a)measured on 7-point-rating-scale (1 = never; 7 = very often)
b)measured on 6-point-rating-scale (1 = never; 6 = very often)
c)measured on 7-point-rating-scale (1 = not at all; 6 = very much)

We asked the users to indicate whether they had their general technical knowledge prior to building a prototype or acquired it in order to build their prototype. Innovators in our sample indicated that they already had the knowledge they needed to develop the type of technical solution embodied in their innovation, either from their profession or from mountain biking or other hobbies. Only 15.6% of our innovators strongly agreed that they had acquired new knowledge to develop the solution to their problem (table 8).

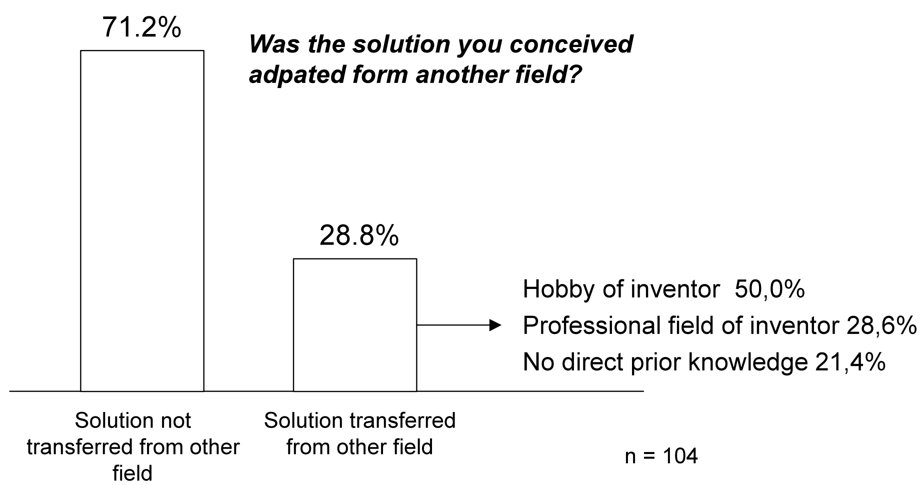
Table 8: How did you obtain the information needed to develop your solution?

	Mean	Median	Very high or high agreement
"I had it due to my professional background." [a)]	4.22	4	47.5%
"I had it from mountain biking or another hobby." [b)]	4.56	5	52.4%
"I learned it to develop this idea."	2.11	2	15.6%

n=61; all responses were measured on a 7-point-rating-scale (1=not at all true; 7=very true)

This general finding is supported by responses to another question we posed to our sample of user-innovators. We asked whether the innovation was adapted from a field *outside* of mountain biking (for example, the automotive field) – and, if so, whether the users had professional or hobby-related direct experience in that field (figure 2). Similarly to the findings regarding acquisition of need-related information, direct personal experience was reported to be involved in 78,6% of the instances where a user drew a solution from a field outside of mountain biking. In 50,0% of the cases the other field involved another hobby of the innovator (e.g. motocross). In 28,6% of the cases, the other field was related to the innovators' profession (e.g. medicine).

Figure 2: Was solution transferred from a field outside of mountain biking?



In only 21,4% of the cases did user-innovators *not* have direct prior experience with the solution-related technology used. In almost all of these, the innovators knew about the solution through friends active in the external field. Only one respondent indicated that information was obtained from an external field by a systematic scanning of different information sources. Again, the findings show that inventors primarily develop solutions that are related to their personal experience, knowledge and skills.

5. Discussion

In sum, our empirical study has shown that in mountain biking, a user's personal patterns of product usage and needs directly encountered – his or her "local" information – strongly affects the functionality of the innovation ideas he or she develops. That user's pre-existing local stocks of technical knowledge and skills will then determine the type of solution that will be developed. We next discuss the likely generality of this pattern, and finally we consider the practical implications of this pattern where it is present.

Generality of reliance on local information

When can we expect users to draw primarily or exclusively on local need and solution information to develop their innovations? Consider first the case of need-related information. If users expect rewards from in-house use only and build their own innovations, then we can expect them to always rely on their own, local need information. If, in contrast, they expect to employ or persuade a manufacturer to build a solution for them, then the stickiness of their need information becomes relevant. In such cases users will be more likely to find it cost-effective to transfer their need information to a manufacturer if the stickiness of that information is low. Support for this proposition can be seen in Ogawa (1998). As was noted earlier, controlling for profit expectations, he found that increases in the stickiness of user need information were associated with a significant increase in the amount of need-related design undertaken by the user in joint user-manufacturer development projects. In the specific case of mountain biking, need information is likely to be very sticky, because it involves human skills information that is tacit and therefore sticky (Polanyi, 1958). We therefore speculate that mountain bike users would have a difficult time transferring critical need information to bike manufacturers even if they wanted to do this.

In the case of solution information, users have no inherent reason to prefer local information apart from the matter of acquisition costs. We can therefore reason that user-innovators will rely increasingly on solution information that they already have in hand as the resources they are willing to devote to innovation decrease. Thus, suppose IBM, a company with major resources, were to develop a new production process for its own use, anticipating that it will yield great profit. Under these conditions, it would be economically reasonable for that firm to invest heavily in a search for new, non-local solution technologies. Our mountain-biking case represents the other end of the scale with respect to user-innovator resources. Individual user-innovators in mountain biking presumably do not have major resources to devote to the acquisition of non-local solution information. If this is indeed the case, our finding that mountain bikers do rely primarily on local solution information fits into the more general framework.

When user-innovators are developing innovations that require only their local need and solution information they are operating in a low-cost innovation niche relative to others who must import sticky information to develop those same innovations. To the extent that users have heterogeneous and sticky need and solution information, they will have heterogeneous low-cost innovation niches. Users can be sophisticated developers within those niches, despite their reliance on their own need information and solution information that they already have in stock. On the need side, a number of studies have shown that user-innovators generally are lead users and generally are expert in the field or activity giving rise to their needs (von Hippel 2005). With respect to solution information, user firms have specialties that may be at a world-class level. Individual users can also have high levels of solution expertise. After all, they are students or employees during the day, with training and jobs ranging from aerospace engineering to orthopedic surgery. Thus, mountain bikers might not want to *learn* orthopedic surgery to improve their biking equipment, but if they already *are* expert in that field they could easily draw on what they know for relevant solution information. Consider the following example drawn from our mountain biking study:

> I'm a human movement scientist working in ergonomics and biomechanics. I used my medical experience for my design. I calculated a frame design suitable for different riding conditions (downhill, climb). I did a CAD frame design on Catia and conceived a spring or air coil that can be set to two different heights. I plan to build the bike next year.

Users' low-cost innovation niches can be narrow because their development "labs" for such experimentation often consist largely of their individual use environment and customary activities. Consider, for example, the low-cost innovation niches of individual mountain bikers. As we have seen, mountain bikers generally specialize in a particular type of mountain biking activity. Repeated specialized play and practice leads to improvement in related specialized skills. This, in turn, may lead to a discovery of a problem in existing mountain biking equipment and a responsive innovation. Once the problem has been encountered and recognized, the skilled specialist user can re-evoke the same problematic conditions at will during ordinary practice. The result is the creation of a low-cost laboratory for testing and comparing different solutions to that problem. The user is benefiting from enjoyment of his chosen activity and is developing something new via learning by doing at the same time.

In sharp contrast, if that same user decides to stray outside his chosen activity in order to develop innovations of interest to others with needs that are different from his own, the cost properly assignable to innovation will rise. To gain an equivalent-quality context for innovation, such a user must invest in developing personal skill related to the new innovation topic. Only in this way will he gain an equivalently deep understanding of the problems relevant to practitioners of that skill, and acquire a "field laboratory" appropriate to developing and testing possible solutions to those new problems.

Predicting the nature of user-innovations ex ante

Research on user innovation to date has not explored the possibility of identifying the general nature of innovations users might develop *ex ante*. Thus, lead user idea generation methods involve searching among user innovations that already exist, in order to find attractive new solutions to a given problem (von Hippel, 1988). However, the findings in this paper suggest that a fundamentally different approach might be possible.

In this case study, we documented a setting where about 20% of the users in our sample were developing modifications to their mountain biking equipment to better serve their personal needs. We also saw that these users relied primarily on the local need and solution information that they already had "in stock" to develop those innovations. This suggests that it might be possible to pre-identify users likely to develop a *specific type* of innovation. For example, if firms or others wanted to identify users likely to develop safer mountain bikes, they might choose to focus on mountain bikers who have a high need for safety – for example, because the users specialize in relatively dangerous activities – *and* who have a relevant type of solution expertise – for example, they are medical doctors. From the perspective of Fleming (2001), who has studied innovations as consisting of novel combinations of pre-existing elements, such innovators can be anticipated to use their membership in two distinct communities to combine previously disparate elements.

Once such a subset of users is identified, product manufacturers or others with an interest can invest in activities to affect the rate and direction of those users' innovation-related activities. Firms could, for example, offer those potential innovators resources to support innovation-related efforts. They could give them challenges in line with their interests, such as a prize for safety-related innovations and so on. Via such *ex ante* strategies, firms could gain advantage over competitors by investing in *likely-to-innovate* users in exchange for access to their innovations on favorable terms.

The potential value of this possibility is illustrated in an industrial field by practices used at General Electric Company (GE). Managers in the medical imaging business at GE have understood the strategy mentioned above and have learned to exploit it to commercial advantage. They realized that nearly all the major, commercially important improvements to the clinical software used on MRI machines are developed by leading-edge users rather than by GE researchers. In response, they developed a policy of selectively supplying machines at a very low price to scientist-users that GE managers thought most *likely* to develop commercially-important improvements *in advance of innovation*. In exchange for this research support, the medical researchers contract to give GE preferred access to innovations they develop. Over the years, supported researchers have provided a steady flow of significant improvements that have been first commercialized by GE (von Hippel, 2005).

To conclude, we have seen a strong reliance on local information among innovating users in a single field. We have discussed the conditions under which this pattern is likely to occur and some consequences that flow from it. The frequency with which the pattern will hold for user innovation is yet to be determined.

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