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Finding Commercially Attractive User Innovations: A Test of Lead-User Theory*

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Firms and governments are increasingly interested in learning to exploit the value of lead-user innovations for commercial advantage. Improvements to lead-user theory are needed to inform and to guide these efforts. The present study empirically tests and confirms the basic tenets of lead-user theory. It also uncovers some new refinements and related practical applications. Using a sample of users and user–innovators drawn from the extreme sport of kite surfing, an analysis was made of the relationship between the commercial attractiveness of innovations developed by users and the intensity of the lead-user characteristics those users display. A first empirical analysis is provided of the independent effects of its two key component variables. In the empirical study of user modifications to kite-surfing equipment, it was found that both components independently contribute to identifying commercially attractive user innovations. Component 1, the high expected-benefits dimension, predicts innovation likelihood, and component 2, the ahead of the trend dimension, predicts both the commercial attractiveness of a given set of user-developed innovations and innovation likelihood due to a newly proposed innovation supply side effect. It was concluded that the component variables in the lead-user definition are indeed independent dimensions, so neither can be dropped without loss of information—an important matter for lead-user theory. It also was found that adding measures of users' local resources can improve the ability of the lead-user construct to identify commercially attractive innovations under some conditions. The findings reported here have practical as well as theoretical import. Product modification and development has been found to be a relatively common user behavior in many fields. Thus, from 10 to nearly 40 percent of users report having modified or developed a product for in-house use in the case of industrial products or for personal use in the case of consumer products in fields sampled to date. As a practical matter, therefore, it is important to find ways to selectively identify the user innovations that manufacturers will find to be the basis for commercially attractive products in the collectivity of user-developed innovations. The implications of these findings for theory as well as for practical applications of the lead-user construct are discussed—that is, how variables used in lead-user studies can profitably be adapted to fit specific study contexts and purposes.

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Introduction and Overview

There is a growing interest in applying lead-user methods to the development of new products and services. This interest has been fueled by practical demonstrations that such methods can effectively and systematically generate ideas for commercially attractive new products (Herstatt and von Hippel, 1992; Lilien et al., 2002; Olson and Bakke, 2001; Urban and von Hippel, 1988). In tandem and for the same reason, governmental policymakers are increasingly interested in learning how to support user-centered innovation practices to improve national competitive advantage (National Innovation Initiative Final Report, 2004; Nye Mal Regerings Grundlag, 2005). Given this growing interest by practitioners and policymakers, it is important to further develop and to test lead-user theory. Improvements will provide a deeper understanding of present practices and also will provide new insights for further improvements.

The present study tests some basic tenants of lead-user theory. An analysis is conducted of the relationship between the commercial attractiveness of innovations developed by users and the intensity of the lead-user characteristics embodied in those users. The independent explanatory value of each of the two components in the lead-user construct is tested with respect to innovation likelihood and innovation attractiveness.

The present article is organized as follows. First a development of the hypotheses is provided via a review of the literature on lead-user theory, research, and practice. Then a description of the research setting for the empirical study and the research methods used are outlined, followed by presentation of the research findings. Finally, a discussion of these findings and related deepened insights regarding the relationship between innovation and lead user characteristics is given.

BIOGRAPHICAL SKETCHES

Dr. Nikolaus Franke is professor and head of the Institute for Entrepreneurship and Innovation at Vienna University of Economics and Business Administration. He is interested how companies can harness the innovative and creative potential of users. His research therefore focuses on toolkits for user innovation and design, horizontal innovation networks, and lead-user method.

Dr. Eric von Hippel is professor and head of the Management of Innovation and Entrepreneurship Group at the Massachusetts Institute of Technology Sloan School of Management. His research examines the sources of and economics of innovation, with a particular focus on the significant role played by lead users in the development of new products.

Dr. Martin Schreier is assistant professor in the Institute for Entrepreneurship and Innovation at Vienna University of Economics and Business Administration. In general, he is working on customer integration and new product development. In particular, he is interested in the phenomenon of user innovation, lead-user research, and toolkits for user innovation and design.

Lead-User Theory

Lead users are defined as members of a user population who (1) anticipate obtaining relatively high benefits from obtaining a solution to their needs and so may innovate and (2) are at the leading edge of important trends in a marketplace under study and so are currently experiencing needs that will later be experienced by many users in that marketplace (von Hippel, 1986). The original theoretical thinking that led to defining lead users in this way was built on findings from von Hippel (1986, 2005).

The *high expected benefits* component of the lead-user definition was derived from research on the economics of innovation. Studies of industrial product and process innovations have shown that the greater the benefit an entity expects to obtain from a needed innovation, the greater will be that entity's investment in obtaining a solution (e.g., Mansfield, 1968; Schmookler, 1966). Component 1 of the lead-user definition was therefore intended to serve as an indicator of innovation likelihood.

The *ahead on an important marketplace trend* component of the lead-user definition was included because of its expected impact on the commercial attractiveness of innovations developed by users residing at that location in a marketplace (von Hippel, 1986). Studies of innovation diffusion regularly show that some adopt innovations before others (Rogers, 1994). Further, classical research on problem solving shows that subjects are strongly constrained by their real-world experience via an effect called *functional fixedness:* For example, those who use an object or see it used in a familiar way find it difficult to conceive of novel uses (Adamson, 1952; Adamson and Taylor, 1954; Allen and Marquis, 1964; Birch and Rabinowitz, 1951; Duncker, 1945). Taken in combination, these findings led to the hypothesis that users at the leading edge would be best positioned to understand what will be needed later by many. After all, their present-day reality represents aspects of the future from the viewpoint of those with mainstream market needs.

Note that these two components of the lead-user definition are conceptually independent. They stem from different literatures, and they serve different functions in lead-user theory. Although they may be related in some cases and to some degree, this is not necessarily the case. Consider, for example, that an animated film studio such as Pixar and a hobbyist maker of animated films may both be at the leading edge of needs for video editing capabilities. However, it is likely that Pixar would anticipate far higher benefits from obtaining a solution to those leading-edge needs.

Review of Related Literature

Lead-user theory was originally proposed as a way to selectively identify commercially attractive innovations developed by users (von Hippel, 1986). Empirical studies to date support the likelihood that the theory can offer this functionality. Some studies have explored the effectiveness of the theory with regard to identifying any user innovations. Thus, Franke and Shah (2003), Lüthje (2003), Lüthje, Herstatt, and von Hippel (2002), and Morrison, Roberts, and von Hippel (2000) divided their samples into innovators and noninnovators as a dependent variable and showed that lead-user characteristics are systematically different in these two groups by using t-tests and logit analyses. The effect sizes found in these studies tend to be very large. For example, Urban and von Hippel (1988) found that 82 percent of the lead-user cluster in their sample had developed their own version of or had modified the specific type of industrial product they studied, whereas only 1 percent of the nonlead users had done this.

Empirical studies have also found that many of the innovations developed by users do have commercial attractiveness. Thus, Urban and von Hippel (1988) found that an industrial software product concept developed by lead users had greater marketplace appeal than did concepts developed by conventional marketing research methods. Morrison, Roberts, and von Hippel (2000) showed that manufacturers of information technology (IT) systems for libraries judged that many of the IT innovations developed by libraries had potential value as commercial products sold in the marketplace. Lüthje (2003) found that 48 percent of surgical innovations developed by surgeons in university clinics in Germany had been or would be produced as commercial products. Evaluators of the commercial potential of innovations developed by a sample of mountain bikers judged that 31 percent of the innovations would be adopted by many users if produced (Lüthje, Herstatt, and von Hippel, 2002).

Several published studies have reported successful experiments with a lead-user-centered approach to new product idea generation. Two such studies have quantitatively compared the outputs of lead-user idea-generation studies with the outputs of traditional voice of the customer studies that focus on target market customers (Griffin, 1997). Both studies found that the ideas generated by a process using inputs from lead users have much higher commercial attractiveness (Urban and von Hippel, 1988; Lilien et al., 2002). Lilien et al. (2002) also found lead-user studies capable of systematically generating ideas for breakthrough innovations, where breakthroughs were defined as new product lines providing new sales representing over 20 percent of total existing sales of the entity, a corporate division, developing them.

With respect to development of lead-user theory, Morrison, Roberts, and Midgley (2004) showed that the lead-user construct and a closely related construct developed by these authors called *leading-edge status* is distributed in a continuous, unimodal manner in a sample of innovating and noninnovating users. These authors also found that the three component variables in their construct—being ahead of the trend, having high levels of need, and actual development of innovations—were significantly correlated throughout their sample. On the basis of this finding, they reasoned that the lead-user components are reflective rather than formative indicators. The present study hypothesizes and empirically finds that this is not the case: The lead-user components are in fact independent dimensions.

This distinction is an important one for lead-user theory. Reflective indicators are highly correlated and interchangeable and do not have an independent meaning. As they all attempt to measure the same thing, they usually are merged to an index without loss, and consequently their independent contribution to an explanation is not analyzed. In contrast, dimensions of a construct usually have a formative nature: They do have an independent meaning, are not interchangeable, and cannot be merged into an index variable without loss of information. As an illustration of the use of reflective variables within a larger construct, consider the construct creativity. This may be reflected, for example, in the number and quality of ideas in a test or in the preference for particular careers and hobbies (Spector, 1992). Dimensions of a construct

and formative indicators, in contrast, are not interchangeable and are not necessarily correlated. Diamantopoulos and Winklhofer (2001) used the construct of socioeconomic status (SES) and its components—education, income, occupation, and residence—to illustrate. If one of the construct com ponents increases, SES would also increase, but an increase in SES does not necessarily indicate an expected increase in all four components.

Development of Hypotheses

As was discussed earlier, the general assertion of the lead-user theory is that users who have a high personal need for innovations (component 1) and are in a position ahead of an important trend (component 2) are more likely to develop innovations of high value to others. Following Morrison, Roberts, and Midgley (2004) the lead-user construct is assumed to be continuous. Thus,

H1: The higher the intensity of lead-user characteristics displayed by a user the greater the likelihood that the respective user yields commercially attractive innovations.

Next, it is useful and necessary to differentiate the function of the components, especially if the components are formative dimensions rather than reflective indicators. If both have different explanatory functions, this is a clear argument for the components being independent dimensions: They would not be interchangeable.

Finding attractive innovations can be thought of as consisting of two steps: (1) innovations must be found; and (2) the most attractive must be identified. As indicated previously, lead-user theory argues that the first function is carried out by the high benefit expected component and the second by the ahead on an important marketplace trend component. Therefore,

H2: The expectation of high benefits component of the lead-user construct has a positive impact on user-innovation likelihood.

H3: The ahead on an important marketplace trend component of the lead-user construct has a positive impact on innovation attractiveness.

As was discussed earlier, initial lead-user theory development focused on two components only. However, there is a strong case for expecting that innovators' own resources and also their links to communities, which can provide innovation-related assistance, will also affect innovation likelihood and attractiveness. Why should this be so? Given perfect information and given that innovations under study were being developed for financial gain, expected benefit would be both a reasonable and sufficient indicator of the probability that an innovation would be funded. The presence or absence of internal resources would then be irrelevant because, given perfect information, external investors will be willing to fund an innovation on nearly the same terms as would the innovator. However, ample argumentation and evidence exists that innovation-related information is far from perfectly distributed (Hayek, 1945; Ogawa, 1998; von Hippel, 1994, 2005; Winter and Szulanski, 2001). When potential innovators—and their intimate innovation communities—have better information regarding an innovation opportunity than can be conveyed to outside investors, internal resources and help from community members can be obtained on better terms than can resources from outside investors. Under these conditions, the availability of local resources will matter and will have an effect on innovation likelihood. If the innovation is being developed for consumption rather than investment, in-house resources will again matter. An outside investor will require that the innovator have some other source of income or other assets to assure that its investment will be paid back. Morrison, Roberts, von Hippel (2000) found that in-house resource variables did have a strong impact on the likelihood of innovation. Lüthje, Herstatt, and von Hippel (2002) found that user–innovators tended to rely on in-house resources with respect to information employed in their innovation-related activities. Franke and Shah (2003) found that users did get significant help with their innovation development efforts from members of their user communities for free.

The present study also expected a user innovator's internal resources to have an impact on the commercial attractiveness of the innovation developed. To the extent that an innovator must rely on internal resources, having better resources—such as higher technical capabilities, more support from the top management or from a community of peers, lower time constraints in the process, or more funds for testing and refining the innovation—should have a positive impact on the value of the innovative outcome (see, e.g., Hadjimanolis, 2000). Therefore,

H4: A user's local, innovation-relevant resources have a positive impact on (a) the likelihood that the user

innovates and (b) the commercial attractiveness of the innovations that user develops.

Study Methods

This section reports on the context of the research field being studied, on the data collection procedures and the characteristics of the study's samples, and on the operationalization of the dependent and independent variables.

Context for Empirical Research

To test the study's hypotheses empirically a field research context was needed that met three criteria: (1) user innovations are likely to occur; (2) users seek to make advances with respect to a clearly definable major trend; and (3) users can objectively be ranked metrically on this trend. Discussions with innovation researchers familiar with a wide variety of fields led to the decision that the relatively young field of kite surfing would meet these criteria. Kite surfing is a water sport in which the user stands on a special board, somewhat like a surfboard, and is pulled along by holding onto a large, steerable kite. Equipment and technique have evolved to the point that kites can be guided both with and against the wind by a skilled kite surfer and can lift rider and board many meters into the air for tens of seconds at a time. Today there are between 100,000 and 250,000 kite surfers worldwide.

Tietz et al. (2004) studied kite surfing and found users to be quite active as innovators. By studying literature on the sport of kite surfing and by interviewing professional kiters it was found that the major trend in the sport is an increase in the radical nature of performances over time. More specifically, the worldwide elite competes primarily in two categories: freestyle and hang-time. Freestyle is scored by measures of the level of challenge of tricks performed in the air; hang-time is measured by the time a kiter stays suspended in the air without touching water. (For more information on the world pro tour, see the Professional Kiteboard Riders Association's website, http://www.pkra.info/.)

Data Collection and Sample Characteristics

Data were collected in two major waves. First, kite surfers were surveyed to determine whether they innovated or not. Second, user innovations were then evaluated in terms of attractiveness by six external experts in the field.

As kite surfing is a very young and trendy sport, essentially all serious participants are members of some online community. Therefore data were collected from the memberships of several important European kite-surfing communities via a multisample method. The questionnaire was either posted directly on the community's website or, if possible, was sent by the Web or community master to its members by newsletter via e-mail. Whenever it was possible, at least one reminder was sent out.

Table 1 reports on population sizes and response rates of the study's 15 samples. In sum, 456 questionnaires were returned. Response rates for samples surveyed via e-mail (mean = 14.6 percent) are based on the actual number of delivered e-mails. For two major reasons, it is likely that this calculated response rate is a serious underestimate and that the actual response rate is 30 percent or greater. First, based on conducting previous online surveys, it is known that many delivered e-mails are not read by recipients due to causes ranging from spam filters to e-mail accounts that, though functional, are no longer actually accessed by their owners. Second, due to the decision to contact several kite-surfing websites, multiple surveys often were sent to single individuals, because many individuals have membership to more than one site. For example, site webmasters reported that 75 percent of members of the community DWSV also belong to Kiteforum or Oase and that at least 30 percent were also members of additional sites sampled in this study. A conservative estimation of membership overlap in the study's 15 samples is roughly 50 percent. If it is assumed, as is likely, that individuals contacted multiple times would only answer the survey once, the response rates would double based on this factor alone.

T-tests of early and late respondent revealed no systematic differences. Respondents were predominantly male (91.5 percent) and are on average 30 years old (s.d. = 8.8), started kite surfing in 2002 (the range was from 1988 to 2005), and practice the sport 64 days per year (s.d. = 67.6). This latter figure suggests that the study's sample is biased toward active kiters.

Operationalization of Independent Variables

In general, all items were generated by means of literature review as well as interviews with experts in the

Table 1. Population and Response Rates

#	Sample	Country	Size *n*	Response *n* (Percent)	Innovations *n* (Percent)	Sample Response from Total Response (Sample Innovations from Total Innovations) Percent
1	Professional Kiteboard Riders Association (PKRA)[a]	International	128	11 (8.6)	7 (5.5)	2.4 (5.0)
2	*Deutscher Windsegelverein* (DWSV)[a]	Germany	519	57 (11.0)	15 (2.9)	12.5 (10.7)
3	Greek Wakeboard Association[a]	Greece	96	9 (9.4)	3 (3.1)	2.0 (2.1)
4	Irish Kite Association[b]	Ireland	495	13 (2.6)	1 (0.2)	2.9 (0.7)
5	Kiteforum.com[d]	Germany	3000	60 (2.0)	27 (0.9)	13.2 (19.3)
6	Kitegenossen[a]	Switzerland	105	5 (4.8)	2 (1.9)	1.1 (1.4)
7	Kitesailing[a]	Switzerland	250	66 (26.4)	15 (6.0)	14.5 (10.7)
8	Kitesurfing.gr[b]	Greece[c]	32	2 (6.3)	0 (0.0)	0.4 (0.0)
9	Kitesurfvereinigung.nl[c]	Netherlands	200	27 (13.5)	12 (6.0)	5.9 (8.7)
10	Kitetour.dk[c]	Denmark	240	12 (5.0)	3 (1.3)	2.6 (2.1)
11	Kudernatsch Kite Surfing[a]	Austria	40	16 (40.0)	7 (17.5)	3.5 (5.0)
12	Kite Community Mondsee[a]	Austria	214	41 (19.2)	8 (3.7)	9.0 (5.7)
13	Oase.com[d]	Germany	2000	81 (4.1)	17 (0.9)	17.8 (12.1)
14	Verein Deutscher Wassersportschulen (VDWS)[a]	Germany	208	23 (11.1)	11 (5.3)	5.0 (7.9)
15	Xtremebigair.com[b]	International	570	33 (5.8)	12 (2.1)	7.2 (8.6)
	Total		8097	456 (5.6)	140 (1.7)	100 (100)
	E-Mail		1560	228 (14.6)	68	50.0 (48.6)
	Online		6537	228 (3.5)	72	50.0 (51.4)

[a] Survey sent via e-mail (sample population based on delivered mails).
[b] Survey posted on website (sample population based on views of questionnaire posting—not unique, i.e., including multiple views per person).
[c] Survey posted on website (sample population based on unique website views—i.e., total number of distinct visitors).
[d] Survey posted on website (sample population based on estimation of webmaster regarding number of active users).

field under study. All independent variables in the study's hypotheses—ahead of a trend, high benefit expected, and resources at hand—were measured by reflective complex construct measurement (e.g., Churchill, 1979).

Ahead of a trend. As noted already, kite surfing is dominated by the trend to perform more radical jumps in terms of height above water achieved, length of time in air, and the degree of difficulty of tricks performed. Therefore, being ahead of a trend was measured by the user's ability to achieve in terms of these measures. Following the Professional Kiteboard Riders Association, it was operationalized according to the two categories of competition used in the sport. Freestyle scores the difficulty of tricks performed, such as technical difficulty, height, smoothness, power, and style of jumps. Hang-time simply measures the elapsed time between a kite sufer's lift-off from the water into flight and touching back down.

For the freestyle mastery a scale was developed following the idea of Thurstone (Thurstone and Chave, 1929; see also Likert, Roslow, and Gardner, 1993; Wrenn, 1997). The most popular tricks were collected that reflect the whole range of freestyle jumps. Then, in pilot study 1, 12 experts were asked to rate the selected tricks on a metric scale from 0 to 10. The highest and lowest judgments were eliminated, and means were used to denominate the scale for the questionnaire (see Appendix 1). In addition to evaluating the tricks, experts in pilot study 1 were asked to rate the skill level of a kiter who would perform such tricks, ranging from beginner to professional level with scores again from 0 to 10. These additional anchors facilitated orientation for self-evaluation and thus increased validity of measurement. In the course of the main study, kiters could use a scroll bar to precisely indicate their freestyle mastery.

Hang-time was measured, via self-assessment, as the maximum time a kiter managed to be off the water when jumping. Additionally, kiters were asked for the maximum height they reached when jumping. For both measures kiters were provided with reference points for orientation purposes. For reliability and validity concerns see Tables 2 and 3.

High benefit expected and resources at hand. In the absence of satisfactory scales in existing literature, appropriate scales were developed for these two variables. First, items were generated to reflect all

Table 2. Tests of Latent Construct Measurement[a]

Construct	Items	Squared Multiple Correlation	Factor Loading (*t*-Value)	Item-to-Total Correlation	Cronbach's Alpha	Explained Variance of First Extracted Factor (%)
Ahead of a Trend (AT)	Hang-Time	0.82	0.90 (–)	0.85	0.91	88.21
	Height	0.81	0.90 (27.44)	0.86		
	Tricks	0.84	0.92 (27.90)	0.87		
High Benefit Expected(HBE)	HBE 1	0.40	0.63 (–)	0.58	0.84	55.89
	HBE 3	0.45	0.67 (10.75)	0.60		
	HBE 4	0.41	0.64 (10.60)	0.58		
	HBE 5	0.53	0.73 (11.57)	0.65		
	HBE 7	0.58	0.76 (11.86)	0.67		
	HBE 8	0.56	0.68 (10.93)	0.62		
Technical Expertise (TE)	TE 1	0.49	0.70 (–)	0.61	0.82	64.73
	TE 3	0.67	0.82 (13.51)	0.54		
	TE 4	0.36	0.60 (10.64)	0.58		
	TE 5	0.58	0.76 (13.35)	0.72		
Community-Based Resources (CR)	CR 1	0.43	0.66 (–)	0.60	0.88	62.90
	CR 2	0.69	0.83 (14.06)	0.78		
	CR 3	0.46	0.68 (11.70)	0.62		
	CR 4	0.59	0.77 (12.96)	0.72		
	CR 5	0.58	0.76 (12.77)	0.70		
	CR 6	0.59	0.77 (12.93)	0.72		

[a] Global fit measures of confirmatory factor analysis ($n = 399$; missing values deleted): $\chi^2/df = 2.15$ ($\chi^2 = 314.30$; $df = 146$); GFI = 0.92; AGFI = 0.90; CFI = 0.96; IFI = 0.95; TLI = 0.95; RMSEA = 0.05.

construct properties. After testing content-related validity by expert discussions (e.g., Bearden and Netemeyer, 1989) remaining items were tested in pilot study 2 ($n = 30$; Swiss community *Kitegenossen*; population = 117 users; response rate = 25.6 percent). High benefit expected was measured by 12 items. Resources at hand was divided into two constructs, which seemed to be conceptually independent. Technical expertise, the ability of a user to actually accomplish modifications or changes to existing kite-surfing equipment (e.g., Lüthje, Herstatt, and von Hippel, 2002), was measured by ten items; community-based resources, the potential contacts on which a user can draw at low or no cost when facing a problem with existing kite-surfing equipment (e.g., Franke and Shah, 2003), was measured by eight items. Both resource-based constructs might add independently when explaining innovation likelihood and innovation attractiveness; thus, they were not further aggregated.

Exploratory factor analyses led to a drop of four, three, and two items, respectively, due to low factor loadings and low item-to-total correlations (Churchill, 1979). All item-to-total correlations of the remaining items, Cronbach's alphas, and explained variances showed satisfactory results for all three constructs (see Appendix 2).

In the course of the study both exploratory and confirmatory factor analyses indicate reliable and valid measurements (see Table 2). For each latent variable, the first factor extracted explained close to or more than 50 percent of the variance in an exploratory factor analysis. Furthermore, Cronbach's alpha clearly surpassed the 0.7 threshold. One item of

Table 3. χ^2 Difference Test and Fornell-Larcker Criteria

		Ahead of a Trend	High Benefit Expected	Technical Expertise	Community-Based Resources
Average Variance Explained		0.82	0.49	0.53	0.56
				Squared Correlations (χ^2 Differences)	
Ahead of a Trend	0.82				
High Benefit Expected	0.49	0.02 (104.00)			
Technical Expertise	0.53	0.48 (351.49)	0.11 (118.90)		
Community-Based Resources	0.56	0.14 (213.19)	0.00 (223.26)	0.15 (132.68)	

technical expertise (TE7) was dropped due to low item-to-total correlation of 0.36. Next, overall measurement quality was assessed by employing confirmatory factor analysis (e.g., Anderson and Gerbing, 1988, 1992) where maximum likelihood estimation was used to fit the model. Initial analysis led to the dismissal of four items—HBE2, HBE6, TE2, and TE6—due to low squared multiple correlations (<0.4) and low factor loadings (<0.5) (e.g., Babin and Boles, 1998; Bagozzi, 1994).

Table 2 reports the final quality assessment of latent construct measurement (in both exploratory and confirmatory factor analysis). All factor loading surpass 0.5 (t-values >10; $p<.001$). Global fit measures consistently support the study's measurement model (χ^2 / df = 2.15; AGFI = 0.90; CFI = 0.96; RMSEA = 0.05). This indicates a reliable and valid measurement of the independent variables.

Table 3 reports results of the χ^2 difference test and Fornell-Larcker criterion (Fornell and Larcker, 1981; Jöreskog and Sörbom, 1982) to assess discriminant validity. Both tests show a high measurement validity. This is a first empirical confirmation of the independence of the two lead-user components. The correlation between the two lead-user components is only relatively moderate, albeit significant ($r = 0.14$; $p<.05$).

Operationalization of Dependent Variables

Following previous research (e.g., Franke and Shah, 2003; Franke and von Hippel, 2003; Lüthje, 2004; Lüthje, Herstatt, and von Hippel, 2002; Morrison, Roberts, and von Hippel, 2000), innovative activities were measured as a dummy variable, asking respondents, "Have you ever had specific suggestions for improvement for existing products or had ideas for new pieces of equipment which were not yet available on the market?" Users who had an idea were then asked to describe the most innovative one by stating the problem and its solution: "Please describe your most innovative idea as specifically as possible so that we can understand it fully—what was the problem, and what was the solution?"

Out of 452 respondents who answered this question 140 indicated having an idea to improve kite-surfing equipment (30.9 percent). Table 4 provides some examples. Asking about innovative activities bears the risk of social desirability. Therefore, respondents were only coded as innovators if they both provided descriptions of their respective innovation and when experts agreed that, based on the information provided, they were confident that the users' ideas were indeed meaningful innovations. The expert evaluation was performed by six individuals who rated all user ideas in a one-day workshop held at the first author's university. All six experts dealt with kite equipment in their jobs; for example, they were employed as product developers or salespersons by significant kite-manufacturing companies. They also had a very good overview of the sport's history and the technical aspects of equipment, and all of them have been practicing the sport themselves for several years. A number of descriptions lacked a fully satisfactory description; thus, 88 innovators were found (19.5 percent). The present study's conservative classification did not affect the pattern of results reported later; however, results are robust for different classification schemes.

Innovation attractiveness. Two measures of innovation attractiveness were used. First, a continuous attractiveness index was constructed based on the averaged ratings along the variables originality of problem ($\alpha = 0.70$), newness of idea ($\alpha = 0.66$), short-run ($\alpha = 0.63$) and long-run benefit ($\alpha = 0.56$), and short-run ($\alpha = 0.63$) and long-run sales potential ($\alpha = 0.56$). Second, the expert was asked to nominate the most outstanding innovations, and a dummy variable was constructed from their judgments (average pairwise intercoder reliability: Cohen-Kappa = 0.12). This procedure was carried out since experts seemed to have difficulty differentiating between an average idea and a somewhat-below-average idea. Given the moderate agreement, an innovation was treated as highly attractive if at least four of the six experts considered it outstanding, leading to 26 innovations that fall into this category. Again, variations of this classification scheme did not affect the patterns of results reported following.

In conclusion, reliability of measurement seems to be reasonable for such evaluations (see similar studies such as Kristensson, Gustafsson, and Archer, 2004). For further analysis, validation of overall attractiveness judgment ratings were averaged (Amabile, 1996; Blackman and Funder, 1998). All measures are positively and highly intercorrelated and are also correlated with innovators' self-assessment of their ideas (see Table 5).

Findings

Before turning to statistical analyses, Figure 1 presents a graphic illustration of the findings with regard

Table 4. Example of User Innovations

Examples of User Innovations	
Problem	Solution[a]
Standard release systems offered by certain brands using a loop of rope and pin on the chicken loop are near on impossible to release under loads such as kiteloops from such things as broken lines. Needed to do something about it to help my safety on the water after a few close calls ending in being knocked out.	An all-metal release solution, with steel loop and support and hardened steel pin, which eliminates the problems a rope loop causes and makes the release a lot more reliable and as a byproduct easier to reset on the water. Many galvanization and coating processes had to be used, and the hardened steel had to be used to stop it from bending and making release more difficult.
Suicide leashes are horrible, but they are the only option for advanced riders; any other type of leash other than a fifth-line system there is no way to ride again after they are deployed. They are so bad some riders try them but don't use leashes at all instead. If you mess up badly the only way to stop getting dragged is to release your kite and watch it fly away, plus spinning leashes are very expensive or very complicated or both (fifth line).	I created a tiny cylindrical system that fits on the chicken loop between the bar and the harness loop. It works because on the outside of the system there are two spinning attachments: One attachment is where you would attach a line from your harness, and the other attachment goes to the sliding ring on a rear line (the ring is the traditional safety system supplied with all bars). When the rider spins the bar the attachment that connects to the ring swivels and doesn't tangle. If a rider misses a pass he can get to the bar and continue riding without having to swim in. If the rider misses a pass and gets out of control or starts heading for something hard he pulls the quick release on his chicken loop and is left attached to the kite but on the safety line so there is no power. At that point he's going to have to swim in. Also unlike other systems it works for beginners and pros. In addition it is super cheap and simple; I made the prototype out of $5 worth of copper pipes and a hacksaw in 10 minutes.
Couldn't find a production or custom kite board to meet the performance requirements to meet the needs of a 100 kg rider in light wind, gusty, and wave surfing conditions of my location.	Designed a light wind kiteboard that compresses air at the concave tip scoop and automatically lifts the nose of the board over chop and wave soup (foam that is formed after the wave breaks). The combination of bottom contour, rail geometry, and overall dimensions allow me to achieve early planning but to still hold more than enough power to control the kite's speed and position when conditions increase in strength. The design is efficient enough that I don't need to use fins. Fins can be added to help riders of a lower skill level, however.

[a] 31.7 percent imagined a possible solution; 14.6 percent developed a plan with descriptions or drawings or both; 27.6 percent built a prototype so reliable that it can be used; 13.0 percent of the innovations are already used by others; 13.0 percent indicated that their idea was already being marketed. Ideas per user ranged from 1 to 25 (only 15 percent indicated that they had had only one idea so far).

to the effects of the lead-user components. It is first evident that both components are indeed relatively independent. Users (displayed as dots or bubbles) are seen in all four quadrants of the diagram. This indicates that beyond users whose trend position and expected benefit positively correlate, there is also a considerable number of users who are far ahead of the trend but have hardly any benefit from innovating and also many users who would reap high benefits from an innovation but are not ahead of the trend at all. Second, moving from left to right in Figure 1—from low to high benefit—the proportion of innovators rises, just as lead-user theory proposes. Third, moving upward, from a position behind the trend to a position ahead of the trend, the attractiveness of innovations rises, which is also in line with the theory. In the lead-user region of Figure 1, the top right, both the proportion of users with innovative ideas and the commercial attractiveness of the innovations they develop is highest, again in clear agreement with lead-user theory.

The following analyzes these effects statistically. In the analyses are included the two local resource variables in addition to the two originally proposed components of lead-user theory. Results of the study's tests are presented in Table 6. Overall, results clearly confirm all the study's hypotheses, and model performance generally is very good. The findings are described along the different models.

In model 1, the overall test was conducted of the lead-user theory, which states that the two lead-user components serve to identify commercially attractive innovations (H1). For this, the 26 subjects who provided highly attractive innovations—ranked as high potential by at least four out of six experts—were coded as 1; users with less attractive innovations as

Table 5. Correlations among Attractiveness Measures

	Originality of Problem[a]	Newness of Idea[b]	Benefit to Kite Surfing		Sales Potential		Self-Assessed Quality of Idea (by User)[g]
			Short Term[c]	Long Term[d]	Short Term[e]	Long Term[f]	
Overall Attractiveness[h]	0.78***	0.79***	0.91***	0.87***	0.91***	0.88***	0.35**
Originality of Problem		0.94***	0.54***	0.45***	0.53***	0.46***	0.28**
Newness of Idea			0.55***	0.46***	0.55***	0.48***	0.30**
Benefit to Kite Surfing							
Short Term				0.93***	0.88***	0.85***	0.29**
Long Term					0.89***	0.90***	0.31**
Sales Potential							
Short Term						0.95***	0.32**
Long Term							0.31**

[a] "Please rate the problem's originality" (five-point rating scale: 1 = not original at all; 5 = very original); averaged index of six experts.
[b] "Please rate the idea's newness" (five-point rating scale: 1 = not new at all; 5 = very new); averaged index of six experts.
[c] "Please rate the benefit of the idea to kite surfing today (assuming that a commercial product is developed)" (five-point rating scale: 1 = very low; 5 = very high); averaged index of six experts.
[d] "Please rate the benefit of the idea to kite surfing in the future (assuming that a commercial product is developed)" (five-point rating scale: 1 = very low; 5 = very high); averaged index of six experts.
[e] "Please estimate how many kiters would buy the idea today (assuming that a commercial product is developed and offered for sale)" (five-point rating scale: 1 = a few; 5 = many); averaged index of six experts.
[f] "Please estimate how many kiters would buy the idea in the future (assuming that a commercial product is developed and offered for sale)" (five-point rating scale: 1 = a few; 5 = many); averaged index of six experts.
[g] Innovators' self-assessment of their idea; averaged index of idea's newness, benefit to others, and overall potential.
[h] Overall attractiveness index; averaged index of the six items.
† $p < .10$ (two-tailed test).
* $p < .05$ (two-tailed test).
** $p < .01$ (two-tailed test).
*** $p < .001$ (two-tailed test).

well as noninnovators were coded as 0. This setting is a realistic equivalence to a lead-user study for which only attractive innovations are searched.

As predicted by H1, both components were found to have an independent explanatory contribution to the likelihood of an attractive innovation, with effect and significance level of component 2, being ahead of the trend, being somewhat stronger. Local resources —technical expertise as well as the availability of community-based resources—were seen as having a clear contribution; thus, H4 also was confirmed.

In models 2, 3, and 4 the lead-user theory was split into in the particular functions associated with the two components. Component 1, expected benefit, is hypothesized (H2) to separate innovators from noninnovators irrespective of the commercial attractiveness of their innovations, and component 2, being ahead of the trend, is hypothesized (H3) to filter out attractive from less attractive innovations.

Model 2 analyzes H2 and H4a. A clear association was found between the independent variables of high benefit expected (H2) and both innovation-related resources, technical expertise and community-based resources (H4) and the likelihood of an innovation. Additionally, a positive association was found between component 2, being ahead of the trend, and the likelihood of innovation. An interpretation of this finding is provided in the discussion section.

Model 3 tested H3 and H4b. For this test, noninnovator data was ignored, using only data from the 88 innovations in the sample that could be evaluated by experts. As predicted in the hypotheses, component 2, being ahead of the trend, as well as resources at hand, were found to significantly impact the likelihood of yielding a commercially attractive innovation. Regarding technical expertise, the effect was only relatively weak. Lead-user component 1, expected benefit, has no independent impact.

Model 4 tested the robustness of model 3's findings by treating the attractiveness of the innovation as a continuous variable. As can be seen from the fourth column, results of the ordinary least squares regressions show very similar significance patterns as in model 3. Again, H3 can be confirmed. H4b gains only partial confirmation, as a user's technical expertise had no significant impact.

Discussion

The present study formulated lead-user theory as a set of four interrelated hypotheses and tested these

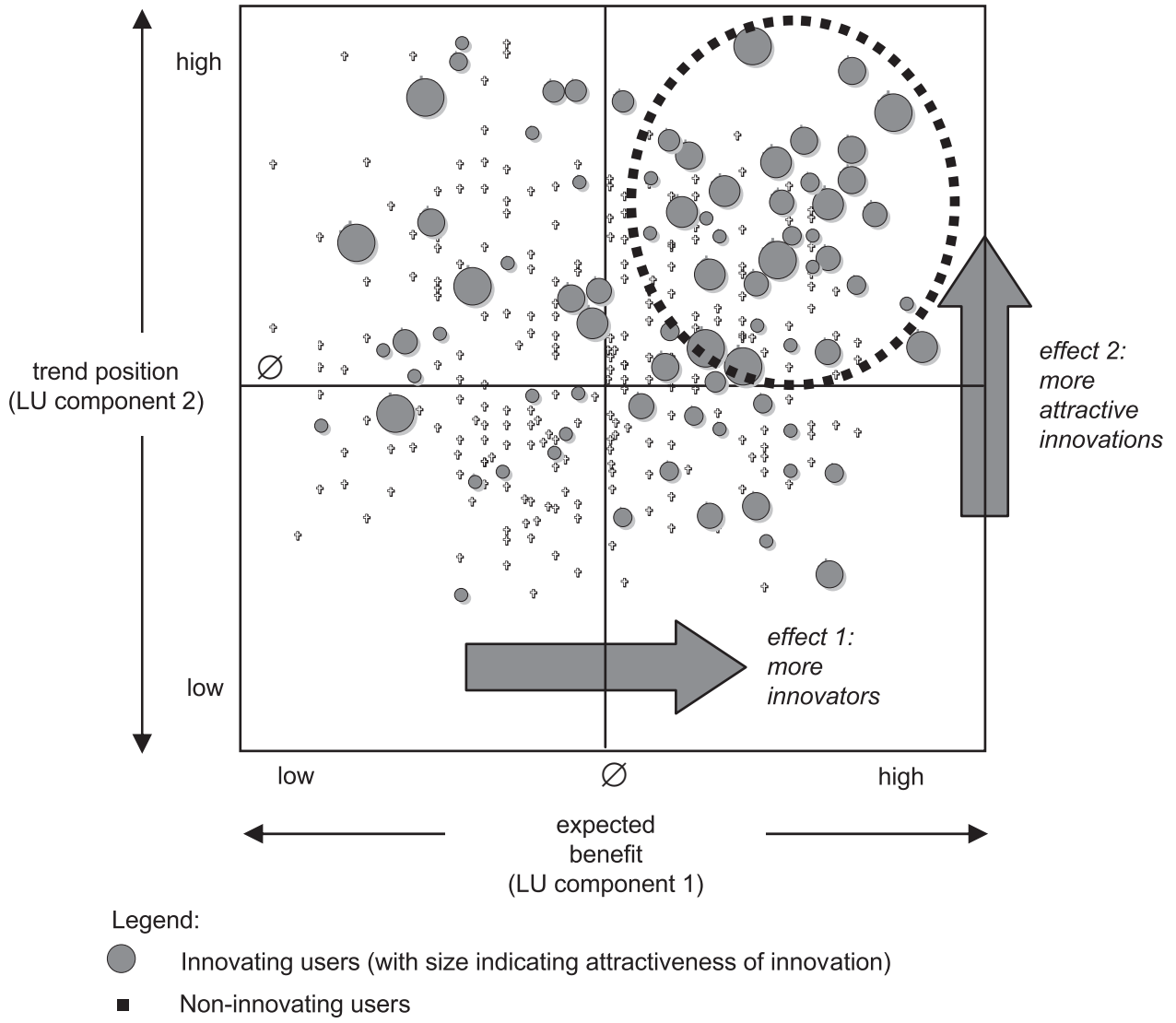

Figure 1. Effects of Lead-User Components (Users with a higher expectation of innovation-related benefit are more likely to innovate—as users move increasingly ahead of the trend, there is an increase in both innovation attractiveness and innovation likelihood; in accordance with lead-user theory, when both lead-user components are high, the largest fraction of users innovate, and average innovation attractiveness is high—see area highlighted in segmented circle)

hypotheses for the first time. Overall, the study confirmed that a high intensity of lead-user characteristics displayed by a user has a positive impact on the likelihood that the respective user yields a commercially attractive innovation. More specifically, it was found that the two components of the lead-user construct—being ahead of the trend and obtaining benefit from the innovation—work as theoretically postulated: High benefits expected are associated with innovation likelihood, and a position ahead of the trend is associated with innovation attractiveness. Thus, it appears appropriate to treat the two components as conceptually independent dimensions rather than reflective items. This finding suggests that neither of the two dimensions can be omitted without loss in a lead-user search.

Unexpectedly, it also was found that a single component of the lead-user definition—being at the leading edge of a marketplace trend—predicts both user innovation likelihood and innovation attractiveness. Extant lead-user theory had proposed that the ahead of the trend variable would predict innovation attractiveness only. The present study speculated that the ahead of trend component of the lead-user construct also predicts the likelihood of user innovation because it addresses the supply side of the innovations desired by lead users. Lead users experience needs for products ahead of others in the marketplace, and

Table 6. Results

	Model (1)	(2)	(3)	(4)
Independent Variable	• DV = Highly Attractive Innovation Y/N[a]	• DV = Innovation Y/N[b]	• DV = Highly Attractive Innovation Y/N[c]	• DV = Attractiveness of Innovation[d]
Lead-User Components				
High Benefit Expected	**0.557 (0.279)***	**0.387 (0.147)****	−0.007 (0.330)	0.089 (0.082)
Ahead of Trend	**1.190 (0.298)*****	**0.602 (0.164)*****	**1.370 (0.415)*****	**0.304 (0.084)*****
Resources at Hand				
Technical Expertise	**1.103 (0.429)****	**1.137 (0.209)*****	0.910 (0.541)†	0.084 (0.127)
Community-Based Resources	**0.835 (0.314)****	**0.331 (0.173)***	**1.363 (0.502)****	**0.217 (0.108)****
McFadden R^2	0.269	0.216	0.219	
R^2				0.213
R^2 adjusted				0.170
−2 Log Likelihood	134.021	378.990	75.789	
χ^2	49.255	104.386	21.231	
Df	4	4	4	4
F-Value				5.003
p-Value	<0.0001	<0.0001	<0.0001	<0.001
Model Classification Rate (Hit Ratio)	94.2%	78.3%	69.6%	
N[e]	414 (total sample)	414 (total sample)	79 (innovators only)	79 (innovators only)

[a] Highly attractive innovation (ranked so by four out of six experts); 0 = less attractive idea and no idea; logit analysis; total sample; test of H1, H4.
[b] 1 = innovation (user innovated); 0 = no innovation (user did not innovate); logit analysis; total sample; test of H2, H4a.
[c] 1 = Highly attractive idea (ranked so by four out of six experts); 0 = less attractive idea; logit analysis; innovators only; test of H3, H4b.
[d] Overall attractiveness index (continuous); ordinary least squares regression; innovators only; test of H3, H4b.
[e] Deviations from total sample size (e.g., model 1 $n = 456$) due to missing values, which were pairwise deleted.
† $p < .10$ (one-tailed test).
* $p < .05$ (one-tailed test).
** $p < .01$ (one-tailed test).
*** $p < .001$ (one-tailed test).

the leading edge of markets are by definition small and in addition may be uncertain. As a consequence, manufacturers are unlikely to have a product on offer when lead users encounter a need for it; those that do want the product early are likely to have to innovate rather than to buy. The further ahead of a trend a user is, the lower the likelihood of an existing solution and so the greater the likelihood this supply-side motivator will contribute to inducing innovation.

In addition it was found that innovation-related local resources contribute to explaining both user-innovation likelihood and innovation attractiveness. Due to reasoning discussed earlier this study proposes that innovators' resources at hand will be important predictors of innovation attractiveness when either or both of two conditions hold: (1) information about the potential returns of an innovation held by a potential user–innovator is better than the information on that opportunity obtained by outside investors; or (2) investment in an innovation is not expected to create an innovation-related profit stream that could be used to repay an outside investor. In contrast, local resource measures will not predict innovation attractiveness under conditions of perfect distribution of information and profit-making innovations.

The relatively large effect sizes found in this study bode well for practical applications of lead-user theory. In addition, the findings suggest that the variables that will be most effective for identifying commercially attractive user innovations will differ depending on study conditions and goals. The goal of identifying as many user-developed innovations as possible independent of commercial promise can be achieved by adding resource-related variables with regard to users' technical expertise and availability of support from a user–community to the two lead-user components. If, in contrast, one aims at finding the most attractive user innovations only from a given field of innovative users (i.e., a certain community), a good strategy will be to search for users leading an important market trend. Third, if the aim is to efficiently identify attractive user ideas from an unknown population, all four search criteria might be employed

at once: the two lead-user components as well as both resource-related variables technical expertise and community-based resources.

This article concludes with two suggestions for further research. First, the lead-user theory so far contains merely situation-specific variables. It would be interesting to analyze how far a high intensity of lead-user characteristics correlate with individual factors like personality traits (e.g. Burroughs and Mick, 2004; Higgins, 1990). If lead users are found to be distinct from others in dimensions that are easier to observe than the relative abstract variables of trend position and expected benefit from innovation, this might facilitate identification of this valuable user group.

Finally, this study focused on how the most promising innovations might be selectively identified among lead users within a target market. However, Lilien et al. (2002) found that innovations by users offering breakthrough potential for a target market will often be found among lead users entirely outside of a target market population facing needs more intense than or ahead of all members of the target market. Those seeking breakthrough innovations developed by lead users will therefore find it very important to explore how to incorporate promising groups of outside lead users into empirical research on innovations developed by lead users.

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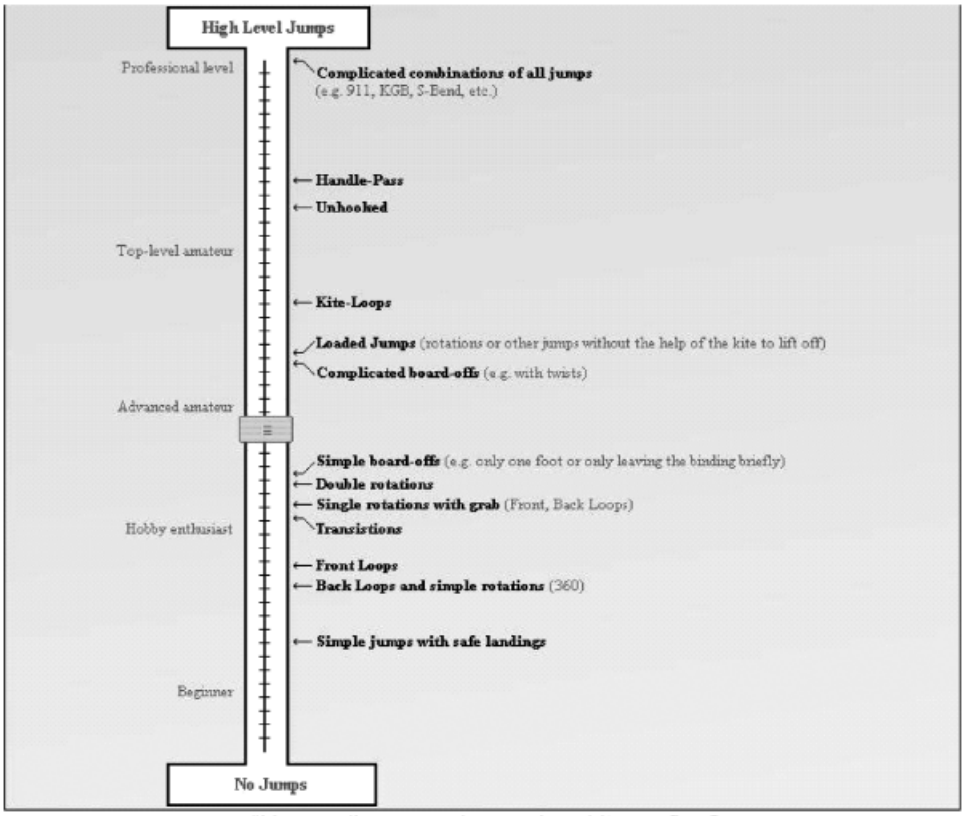
Appendix 1. Freestyle scale (ahead of a trend 1)



"How well can you jump when kite surfing?
Please rate your ability according to the scale below.
Move the cursor to the level which reflects your ability"

Appendix 2. Measurement Results of Latent Constructs (Pilot Study 2)

Construct	Items[a]	Item-to-Total Correlation	Cronbach's Alpha	Explained Variance of First Extracted Factor (%)
High Benefit Expected (HBE) ($n = 30$)	HBE 1: While kite surfing, I am often confronted with problems that cannot be solved by kite-surfing equipment available on the market.	0.71	0.88	54.55
	HBE 2: The equipment available in kite-surfing stores is sufficient for my needs.[b]	0.51		
	HBE 3: I am dissatisfied with some pieces of commercially available equipment.	0.78		
	HBE 4: I have already had problems with my equipment that could not be solved with the manufacturer's conventional offerings.	0.81		
	HBE 5: In my opinion, there are still unresolved problems with kite-surfing equipment.	0.68		
	HBE 6: I am constantly searching for improved kite-surfing equipment.[b]	0.45		
	HBE 7: I have needs related to kite surfing that are not covered by the products currently offered on the market.	0.64		
	HBE 8: I often get irritated about the lack of sophistication in certain pieces of kite-surfing equipment.	0.55		
Technical Expertise (TE) ($n = 30$)	TE 1: I can repair my own equipment.	0.61	0.88	55.55
	TE 2: I always try to keep up to date with regard to the materials, innovations, and possibilities with regard to my equipment.[b]	0.53		
	TE 3: I can help other kite surfers solve problems with their equipment.	0.74		
	TE 4: I am handy and enjoy tinkering.	0.73		
	TE 5: I can make technical changes to my kite-surfing equipment on my own.	0.82		
	TE 6: I am a huge fan of the technical aspects of this area.[b]	0.76		
	TE 7: I come from a technical background in my profession or education (e.g., engineering).[b]	0.50		
Community-Based Resources (CR) ($n = 28$)	CR 1: If I wanted to make changes to my equipment, I would know enough people who could help me do so.	0.71	0.90	68.35
	CR 2: When I encounter technical problems, I know exactly who to ask for advice.	0.63		
	CR 3: I know kite surfers who are capable of repairing their own equipment.	0.83		
	CR 4: I know many kite surfers who have a thorough knowledge of kite-surfing equipment.	0.85		
	CR 5: In my surroundings, I can find people who possess all of the abilities I would require to make improvements to kite-surfing equipment.	0.64		
	CR 6: If I were to make changes to my kite-surfing equipment, I could count on getting positive feedback about the changes from my fellow kite surfers.	0.76		

[a] All items are measured on five-point scales (1 = strongly disagree; 5 = strongly agree).
[b] Eliminated after validity tests.