Finding commercially attractive user innovations: A test of lead user theory

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Abstract

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 guide these efforts. In this paper we empirically test and confirm the basic tenants of lead user theory. We also discover some new refinements and related practical applications.

Using a sample of users and user-innovators drawn from the extreme sport of kite surfing, we analyze the relationship between the commercial attractiveness of innovations developed by users and the intensity of the lead user characteristics those users display. We provide a first empirical analysis of the independent effects of its two key component variables. In our empirical study of user modifications to kite surfing equipment, we find 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. We conclude that the component variables in the lead user definition are indeed independent dimensions and so neither can be dropped without loss of information - an important matter for lead user theory. We also find 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 we report 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% 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. We discuss the implications of these findings for theory and also for practical applications of the lead user construct, i.e. how variables used in lead user studies can profitably be adapted to fit specific study contexts and purposes.

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 (Urban and von Hippel 1988, Herstatt and von Hippel 1992, Olson and Bakke 2001, Lilien et al. 2002). In tandem and for the same reason, governmental policymakers are increasingly interested in learning how to support user-centered innovation practices in order 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 test lead user theory. Improvements will provide a deeper understanding of present practices, and also will provide new insights for further improvements.

In this paper we test some basic tenants of lead user theory. We analyze the relationship between the *commercial attractiveness* of innovations developed by users and the intensity of the lead user characteristics embodied in those users. We test the independent explanatory value of each of the two components in the lead user construct with respect to innovation likelihood and innovation attractiveness.

Our article is organized as follows. We next develop our hypotheses via a review of the literature on lead user theory, research and practice. Then we describe the research setting for our empirical study and the research methods used. Next, we present our research findings. Finally, we discuss these findings and related deepened insights regarding the relationship between innovation and lead user characteristics.

Lead user theory

Lead users are defined as members of a user population having two characteristics. First, they anticipate obtaining relatively high benefits from obtaining a solution to their needs - and so may innovate. Second, they 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 upon findings from two different literatures (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., Schmookler 1966, Mansfield 1968). 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, Birch and Rabinowitz 1951, Duncker 1945, Adamson and Taylor 1954, Allen and Marquis 1964). 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 both 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 (2004), Lüthje et al. (2002) and Morrison et al. (2000) divided their samples into innovators and non-innovators as a dependent variable, and showed that lead user characteristics are systematically different in these two groups via 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% 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, while only 1% of the non-lead 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 et al (2000) showed that manufacturers of 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% 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% of the innovations would be "adopted by many users if produced" (Lüthje et al 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). These 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% of total existing sales of the entity (a corporate division) developing them.

With respect to development of lead user theory, Morrison et al. (2004) showed that the lead user construct, and a closely-related construct developed by Morrison called Leading Edge Status, is distributed in a continuous, unimodal manner in a sample of innovating and non-innovating 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. As will be seen below, we hypothesize and empirically find 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, 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 e.g. in the number and quality of ideas in a test, in the preference for particular careers and hobbies etc. (Spector 1992). *Dimensions* of a construct and formative indicators, in contrast, are *not* interchangeable, and are not necessarily correlated. Diamantopoulos and Winklhofer (2001) use the construct of "socioeconomic status" (SES) and its components education, income, occupation, and residence to illustrate. If one of the construct components increases, SES would also increase c.p. but if SES increases, we would not necessarily expect an 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 et al (2004) we assume the lead user construct to be continuous and state as our first hypothesis:

> *Hypothesis 1. 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, we differentiate the functions of the components. This step is useful and necessary 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: first innovations must be found and, second, the most attractive must be identified. As indicated

above, lead user theory argues that the first function is carried out by the "high benefit expected" component, the second by the "ahead on an important marketplace trend" component. Therefore:

Hypothesis 2. The "expectation of high benefits" component of the lead user construct has a positive impact on user innovation likelihood.

Hypothesis 3. 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 that 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 itself. However, ample argumentation and evidence exists that innovation-related information is far from perfectly distributed (Hayak 1945, von Hippel 1994, 2005, Ogawa 1998, 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 et al. (2000) found in-house resource variables did have a strong impact on the likelihood of innovation. Lüthje 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.

We also expect 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, 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:

Hypothesis 4. 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

In this section we report on the context of the research field being studied, on our data collection procedures and the characteristics of our samples, and finally on the operationalization of our dependent and independent variables.

Context for empirical research

In order to test our hypotheses empirically we needed a field research context meeting 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 us to decide 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 (Plastic 2004).

Tietz et al. (2004) have studied kite surfing and have found users to be quite active as innovators. By studying literature on the sport of kite surfing and by interviewing professional kiters we 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 the two categories "Freestyle" and "Hang-Time" (see "PKRA - Professional Kiteboard Riders

Association" - www.pkra.info, organizer of the world tour). "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.

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. We therefore chose to collect data from the memberships of several important European kite surfing communities (multi-sample method). The questionnaire was either posted directly on the community's website or, if possible, sent by the web- or community-master to its members by newsletter via email. Whenever it was possible, at least one reminder was sent out.

Table 1 reports on population sizes and response rates of our 15 samples. In sum, 456 questionnaires were returned. Response rates for samples surveyed via e-mail (mean: 14.6%) are based on the actual number of *delivered* emails. For two major reasons, it is likely that this calculated response rate is a serious underestimate, and that the actual response rate is 30% or greater. First, we have learned from previous on-line surveys that many delivered e-mails are not *read* by recipients due to causes ranging from spam filters to e-mail accounts that, while functional, are no longer actually accessed by their owners. Second, due to our decision to contact several kite surfing websites, we often sent multiple surveys to single individuals - because many individuals have membership in more than one site. For example, site webmasters reported to us that 75% of members of the community DWSV also belong to Kiteforum or Oase, and that at least 30% were also members of additional sites that we sampled. A conservative estimation of membership overlap in our 15 samples is roughly 50%. If we assume, as is likely, that individuals contacted multiple times would only answer our survey once, our 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%) and are on average 30 years old (SD: 8.8), started kite surfing in 2002 (the range was from 1988 to 2005), and practiced the sport 64 days per year (SD: 67.6). This last figure suggests that our sample is biased towards active kiters.

TABLE 1

Population and response rates of our main study

#	Sample	Country	Size	Response	Innovations	Sample response from total response (sample innovations from total innovations)
			N	*n* (%)	*n* (%)	%
1	PKRA[a] Professional Kiteboard Riders Ass.	International	128	11 (8.6%)	7 (5.5%)	2.4% (5.0%)
2	DWSV[a] "Deutscher Windsegelverein"	Germany	519	57 (11.0%)	15 (2.9%)	12.5% (10.7%)
3	Greek Wakeboard Ass.[a]	Greece	96	9 (9.4%)	3 (3.1%)	2.0% (2.1%)
4	Irish Kite Ass.[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	Kite surfing.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	VDWS[a] "Verein Deutscher Wassersportschulen"	Germany	208	23 (11.1%)	11 (5.3%)	5.0% (7.9%)
15	Xtremebigair.com[b]	International	570 [e]	33 (5.8%)	12 (2.1%)	7.2% (8.6%)
	Total		8097	456 (5.6%)	140 (1.7%)	100% (100%)
	Email		*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")

Operationalization of independent variables

In general, all items were generated by means of literature review as well as interviews with experts in the field under study. All independent variables in our hypotheses ("ahead of a trend", "high benefit expected", "resources at hand") are measured by reflective complex construct measurement (e.g., Churchill, 1979).

"Ahead of a trend". As noted above, 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. We therefore measure "being ahead of a trend" by the

user's ability to achieve in terms of these measures. Following the PKRA, we operationalize it 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* we developed a scale following the idea of Thurstone (Thurstone and Chave, 1929, see also Likert, Roslow, and Gardner, 1993, Wrenn, 1997). We collected the most popular tricks that reflect the whole range of freestyle jumps. Then, in course of pilot study 1, twelve experts were asked to rate the selected tricks on a metric scale from zero to ten. The highest and the 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 zero to ten. These additional anchors facilitated orientation for self-evaluation and thus increased validity of measurement. In course of our main study, kiters could use a scroll bar to precisely indicate their freestyle mastery.

Hang-Time was measured as the maximum time a kiter managed to be off the water when jumping (self-assessment). Additionally, we 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, we developed appropriate scales for these two variables. First, items were generated to reflect all construct properties. After testing content-related validity by expert discussions (e.g., Bearden and Netemeyer 1989) we tested remaining items in course of pilot study 2 (n=30; Swiss community "Kitegenossen"; population: 117 users; response rate: 25.6%). "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/changes to existing kite surfing equipment (e.g. Lüthje et al. 2002), is measured by ten items, "community-based resources" – the potential contacts a user can draw on at low or no cost when facing a problem with existing kite surfing equipment (e.g. Franke and Shah 2003), is 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 lead 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 show satisfactory results for all three constructs (see appendix 2).

In the course of our main 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% of the variance in an exploratory factor analysis. Furthermore, Cronbach's alpha clearly surpassed the 0.7 threshold. (One item of "technical expertise" (TE7) was dropped due to low item-to-total correlation of 0.36). Next, we assessed overall measurement quality by employing confirmatory factor analysis (e.g., Anderson and Gerbing, 1988/1992) where maximum likelihood estimation was used to fit the model. Initial analysis lead to a drop 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; $p<0.001$). Global fit measures consistently support our measurement model (e.g. $\chi^2/df=2.15$; AGFI=0.90; CFI=0.96; RMSEA=0.05). This indicates a reliable and valid measurement of our independent variables.

Table 3 reports results of 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 ($r=0.14$; $p<0.05$).

TABLE 2

Tests of latent construct measurement (main study)

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		

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

TABLE 3

χ^2 difference test and Fornell-Larcker criteria (main study)

Average variance explained		Ahead of a Trend	High benefit expected	Technical expertise	Com.-based resources
		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)		
Com.-based resources	0.56	0.14 (213.19)	0.00 (223.26)	0.15 (132.68)	

Operationalization of dependent variables

Following previous research (e.g., Franke and Shah 2003, Franke and von Hippel 2003, Lüthje 2004, Lüthje et al. 2002, Morrison et al. 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?" (Yes/No). Those users who had had an idea where 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, what was the solution?").

Of 452 respondents who answered this question, 140 indicated they had an idea to improve kite surfing equipment (30.9%). Table 4 provides some examples. Asking about innovative activities bears the risk of a social desirability bias. We therefore coded only those respondents as innovators who provided descriptions of their respective innovation *and* where 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 course of a one-day workshop held at the author's university. All six experts dealt with kite equipment in their jobs, for example they were employed as product developers or salesmen 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 we ended with 88 innovators (19.5%). Our conservative classification did not affect the pattern of results reported later, however, i.e. results are robust for different classification schemes.

TABLE 4

Examples 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 broken lines etc, 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 eliminated the problems a rope loop causes and makes the release a lot more reliable and as a by product easier to reset on the water, Many galvanisation and coating processes had to be used and the hardened steel had to be used to stop it 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 5th line system there is no way to ride again afterthey are deployed, They are so bad some riders try them but dont 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(5th 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 atachment is where you would attach a line from your harness, the other attachment goes to the sliding ring on a rear line(the ring is the traditional saftey system supplied with all bars), when the rider spins the bar the attachment that conects 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 quickrelease on his chicken loop and he is left attached to the kite but on the saftey line so there is no power, at that piont he's gona have to swim in, Also unlike other systems it works for beginers and pros, In addition it is super cheap and simple, i made the proto type out of $5 worth of copper pipes and a hacksaw in 10minutes
Couldn't find a production or custom kite board to meet the perfomance requirements to meet the needs of a 100kg rider in lightwind, gusty and wave surfing conditions of my location	Designed a lightwind 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 dementions allow me to achieve early planing, but still hold more than enough power to control the kites 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% imagined a possible solution, 14.6% developed a plan with descriptions and/or drawings, 27.6% built a prototype which is so reliable that it can be used, 13.0% of the innovations are already used by others, 13.0% indicated that their idea was already being marketed. Ideas per user ranged from one to 25 (only 15% indicated that they had had "only" one idea so far).

"Innovation attractiveness". We used two measures of innovation attractiveness. First, we constructed a continuous attractiveness index based on the averaged ratings along the variables originality of problem (α=0.70), newness of idea (α=0.66), short-run (α=0.63) and long-run benefit (α=0.56), and short-run (α=0.63) and long-run sales potential (α=0.56). Second, we asked the expert to nominate the most outstanding innovations and constructed a dummy variable from their judgments (average pairwise intercoder reliability: Cohen-Kappa = 0.12). This procedure we carried out as it appeared difficult for the experts to differentiate e.g. 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 below.

Concluding, reliability of measurement seems to be reasonable for such evaluations (e.g. similar studies like the one conducted by Kristensson et al. (2004). For further analysis, validation of overall attractiveness judgement ratings were averaged (Amabile, 1996, Blackman and Funder, 1998). All measures are positively and highly inter-correlated and are also correlated with innovators' self-assessment of their ideas (see table 5).

TABLE 5

Correlations between attractiveness measures

	Originality of problem [a]	Newness of idea [b]	Benefit to kite surfing short-term [c]	Benefit to kite surfing long-term [d]	Sales potential short-term [e]	Sales potential long-term [f]	Self-assessed quality of idea (by user) [g]	
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**	0.31**
Benefit to kite surfing long-term						0.90***		
Sales potential short-term					0.83***	0.89***	0.32**	
Sales potential long-term						0.95***	0.31**	

[a] "Please rate the problem's originality" (5-point rating scale; 1=not original at all; 5=very original); averaged index of six experts

[b] "Please rate the idea's newness" (5-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)" (5-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)" (5-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)" (5-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)" (5-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

† $p<0.10$ (two-tailed test)

* $p<0.05$ (two-tailed test)

** $p<0.01$ (two-tailed test)

*** $p<0.001$ (two-tailed test)

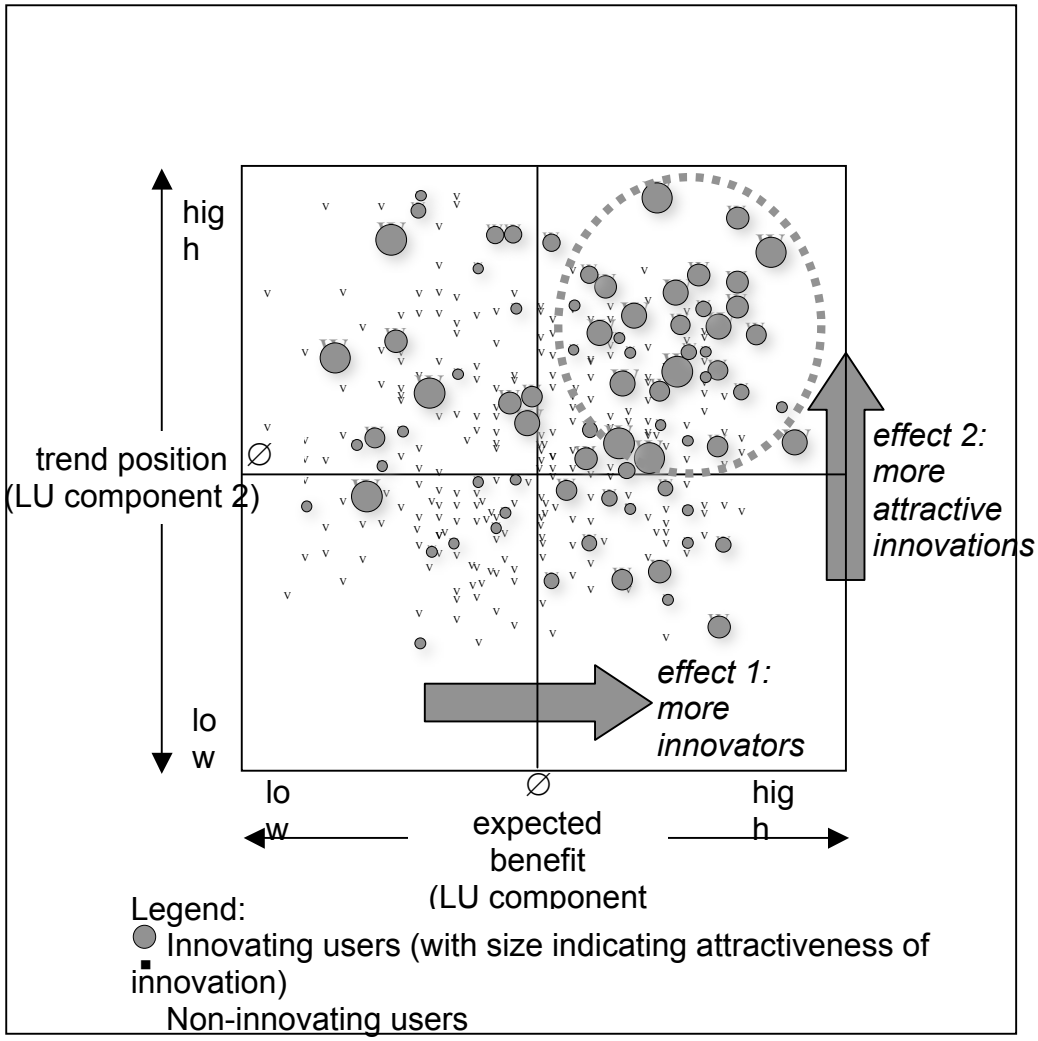
Findings

Before turning to statistical analyses, we give a graphical illustration of the findings with regard to the effects of the lead user components (see figure 1, next page). First of all, we see that both components are indeed relatively independent. Users are broadly distributed and there is 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, we see that moving from left to right on figure 1 (from low to high benefit), the proportion of innovators is rising – just as lead user theory proposes. Third, we see that moving upwards, from a position behind the trend to a position ahead of the trend, that the attractiveness of innovations is rising which also is in line with theory. Interestingly, the proportion of innovations is also increasing in that direction. Hence, in the "lead user region" of figure 1 (top right) both the proportion of users with innovative ideas and the commercial attractiveness of the innovations they develop is highest. This pattern is in clear agreement with lead user theory.

Figure 1

Caption: 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 LU components are high, the largest fraction of users innovate, and average innovation attractiveness is high (see area highlighted in segmented circle).


hig
h
trend position
(LU component 2)
lo
w
∅
effect 2:
more
attractive
innovations
effect 1:
more
innovators
lo
w
∅
hig
h
expected
benefit
(LU component
Legend:
Innovating users (with size indicating attractiveness of
innovation)
Non-innovating users

In the following, we analyze these effects statistically. In our analyses, we include our two "local resource" variables in addition to the two originally-proposed components of lead user theory. Results of our tests are presented in table 6. Overall, results clearly confirm all our hypotheses and model performance generally is very good. We describe the findings along the different models.

TABLE 6

Results

	Model			
	(1)	(2)	(3)	(4)
Independent variable	• DV = highly attractive innovation y/n [a] • logit analysis • total sample • Test of H1, H4	• DV = innovation y/n [b] • logit analysis • total sample • Test of H2, H4a	• DV = highly attractive innovation y/n [c] • logit analysis • innovators only • Test of H3, H4b	• DV = attractiveness of innovation [d] • OLS regression • innovators only • Test of H3, H4b
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)****
Mc Fadden 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 idea – ranked so by four out of six experts (1); less attractive idea and no idea (0)
[b] user innovated (1) or not (0)
[c] highly attractive idea – ranked so by four out of six experts (1); less attractive idea (0)
[d] overall attractiveness index (continuous)
[e] deviations from total sample size (e.g., model 1 n=456) due to missing values which were pairwise deleted
† p<0.10 (one-tailed test)
* p<0.05 (one-tailed test)
** p<0.01 (one-tailed test)
*** p<0.001 (one-tailed test)

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

0. This setting is a realistic equivalence to a lead user study in which only attractive innovations are searched for.

As predicted by H1, we find both components 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. We also see that local resources (technical expertise as well as the availability of community-based resources) have a clear contribution, thus also H4 is confirmed.

In the following models 2, 3, and 4 we split up the lead user theory in the particular functions that are associated with the two components. Component 1 (expected benefit) is hypothesized (H2) to separate innovators from non-innovators 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.

In model 2 we analyze H2 and H4a. We find a clear association 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, we found a positive association between component 2, being ahead of the trend, and the likelihood of innovation. We will provide an interpretation of this finding in the discussion section.

In model 3 we test H3 and H4b. For this test, we drop non-innovator data and use only data from the 88 innovations in our sample that could be evaluated by experts. As predicted in our hypotheses, we find that component 2, being ahead of the trend, as well as resources at hand significantly impact the likelihood of yielding a commercially attractive innovation. Regarding technical expertise, the effect is only relatively weak. Lead user component 1, expected benefit, has no independent impact.

In model 4 we test the robustness of the latter finding (model 3) by treating the attractiveness of the innovation as a continuous variable. As can be seen from the fourth column, results of the OLS regressions show very similar significance patterns as in model 3. Again, hypotheses 3 can be confirmed. Hypothesis 4b gains only partial confirmation as a user's technical expertise had no significant impact.

Discussion

In this study we have formulated lead user theory as a set of four interrelated hypotheses and have tested these hypotheses for the first time. Overall, we 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, we 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, we also 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. We speculate 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 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 – and those that do want the product early are likely to have to innovate rather than 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 we found that innovation-related local resources contribute to explaining both user innovation likelihood and innovation attractiveness. Due to reasoning discussed earlier (section 2) we propose that innovators' resources at hand will be found to 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 and; (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 we have found bode well for practical applications of lead user theory. In addition, our findings suggest that the variables that will be *most* effective for identification commercially-attractive user innovations will differ depending upon study conditions and goals. When the goal is to identify as many user-developed innovations as possible independent of commercial promise, then this can be achieved by adding resource-related variables with regard to user's 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 one aims at efficiently identifying attractive user ideas from an unknown population, he might employ all four search criteria at once – the two lead user components as well as both resource-related variables technical expertise and community-based resources.

We conclude with two suggestions for further research. First, the lead user theory so far contains merely situation-specific variables. It would be interesting to analyze in 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 we find that lead users are distinct from others with regard to personality, we might gain an alternative way for identification.

Finally, we note that in this study we focused on how one might selectively identify the most promising innovations among lead users within a *target* market. However, Lilien et al. (2002) have 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 that are more intense than and/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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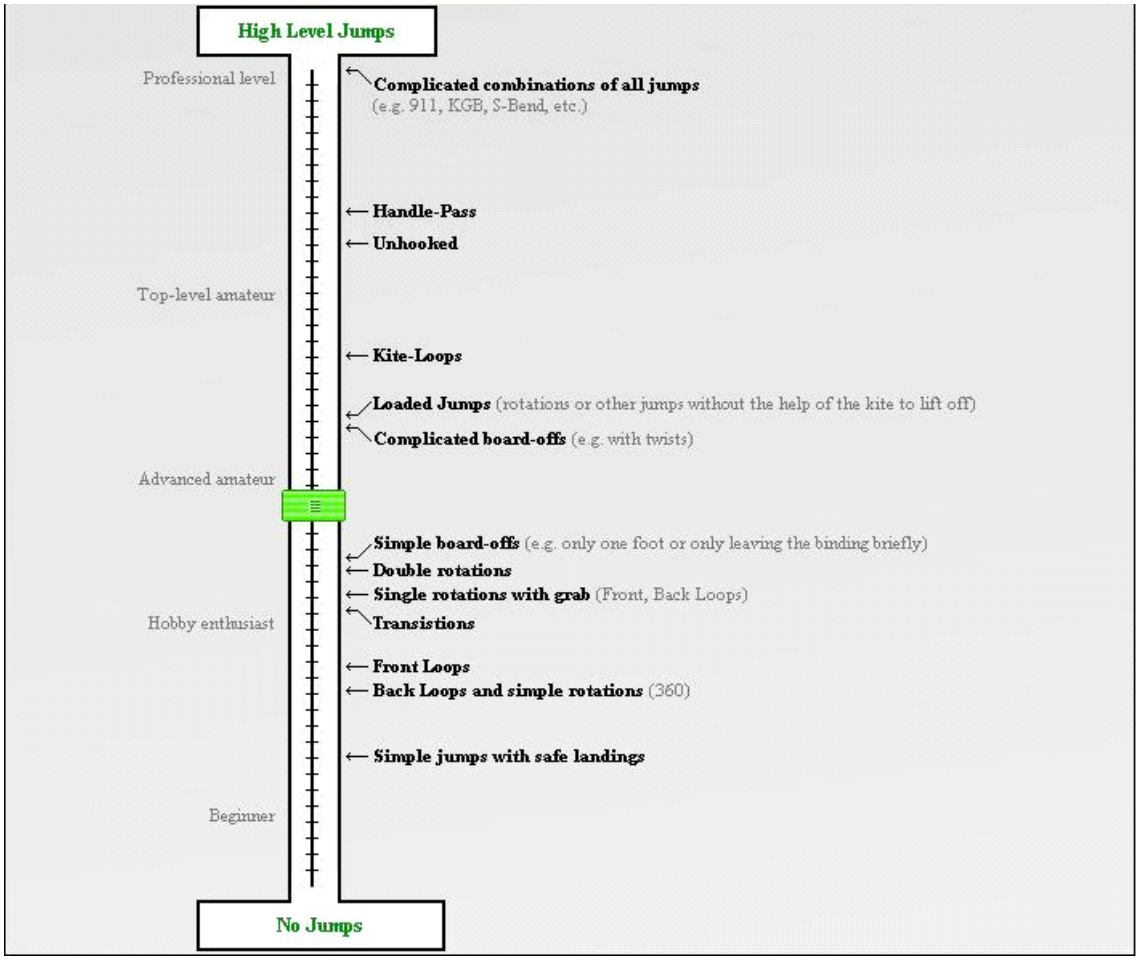
APPENDIX 1

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 which can not 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 which 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 which 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 and/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 advice. I encounter technical problems, I know exactly who to ask for.	0.63		
	- CR 3: When I encounter technical problems, I know exactly who to ask for advice.	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 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 5-point scales (1=strongly disagree; 5=strongly agree)
[b] Eliminated after validity tests in main study