EVALUATING INNOVATIVE PROTOTYPES

Assessing the role of lead users, adaptive structuration theory and repertory grids

Carl Magnus Olsson[1] and Nancy L. Russo[2]
[1]Viktoria Institute, Gothenburg, Sweden; [2]Operations Management & Information Systems, Northern Illinois University, DeKalb, USA

Abstract: Innovation evaluation approaches have primarily focused on studying the adoption and use of existing technologies. However, as development timelines and product life cycles continue to shrink, it is useful to be able to evaluate emerging innovative technologies. Recognizing this, the research outlined in this paper shows how lead users (Von Hippel 1988) can be combined with adaptive structuration theory (DeSanctis & Poole 1994) and the repertory grid technique (Kelly 1955) in evaluation of innovations at the prototype stage. A context-aware application, co-developed by the researchers and industrial representatives, is presented as an illustration of such a prototype. The paper demonstrates how IT researchers can take an active stance in the evaluation of on-going technological innovation designs.

Key words: Adaptive structuration theory, repertory grids, lead users, context-aware applications

1. INTRODUCTION

In the diffusion of innovation (DOI) realm, we typically think of how the user will evaluate the innovation, such as a new technology, to determine likelihood of adoption and diffusion. Traditional measures of the "adoptability" of an innovation include ease of use, fit, trialability, and visibility (Rogers, 1995). The importance of the context of the innovation and other social issues has been recognized (Swanson 1994; Hedström, 2003; Lyytinen & Rose, 2003), as has the need to examine the innovation process from the appropriate viewpoint, be it individual, group, or network (Prescott & Conger, 1995; Lyytinen & Damsgaard, 2001).

However, as the pace of change accelerates, and organizations feel the pressure to introduce new product innovations ever more rapidly, there is a need to evaluate innovations that are still in the development stage to determine if the design is on the right track. As Lyytinen and Yoo (2002) discuss, this rapid pace of change is challenging the distinction between technical (developmental) research and behavioral (use) research, and thus IT researchers should be actively involved in studies where technologies are being built and tried out – not after the fact when they have entered the market

The type of IT innovation that is of particular interest in this paper is in the context of mobile, pervasive, and ubiquitous computing; in other words, systems that are being integrated into everyday activities through mobile phones, PDAs and other handheld devices, systems that are integrated non-obtrusively into everyday objects such as appliances and wearable computing devices. Lyytinen and Yoo (2002, p. 337) call this a "nomadic information environment" which is described as "a heterogeneous assemblage of interconnected technological, social, and organizational elements that enable the physical and social mobility of computing and communication services between organizational actors both within and across organizational borders." This nomadic information environment is identified by high levels of mobility, large-scale services and infrastructures, and diverse ways in which data are processed and transmitted.

This paper addresses a particular aspect of nomadic information environments: Context-Aware Applications (CAAs). Context-aware applications typically use location-based data to trigger predefined behavior (Schmidt, Beigle & Gellersen 1998). Examples of earlier context-aware applications included the notification agent, the meeting reminder agent, call-forwarding applications, and active badge systems (Siewiorek, 2002; Dey et al., 2001). Other contextual information includes human factors such as the user (habits, emotion, physical condition), social environment (co-location of others, social interaction, group dynamics), and tasks (spontaneous activity, engaged tasks, general goals). Aspects of the physical environment, such as conditions (noise, light, pressure) and infrastructure (surrounding resources, communication, task performance) are also relevant (Schmidt et al. 1998)

The purpose of this research is to examine a method for evaluating innovations in the prototype stage. A prototype of a particular context-aware application called CABdriver (Context-Aware Backseat Driver) is used to outline how this approach has contributed to the innovation process. CABdriver is a handheld, interactive in-car application developed in conjunction with a major European automaker. It is described in detail in the following section.

As Lyytinen and Yoo (2002) suggest, the technical and social issues involved in using this type of system cannot be separated easily. Advanced technologies, such as CABdriver, are more likely to impact social aspects than traditional business computing systems are (DeSanctis & Poole 1994). Therefore, our approach to evaluating CABdriver must take into account both social and technical aspects. The approach taken to evaluate the innovation includes the use of lead users (Von Hippel 1988), the repertory grid technique (Kelly 1955), and adaptive structuration theory (DeSanctis & Poole 1994). Adaptive structuration theory provides a useful framework to examine the use of CABdriver. The repertory grid technique is used as the method of capturing the structuration process through interviews with lead users. Because the innovation is in the prototype stage, evaluation by a large group of users is not feasible. Lead users, selected for their early experience with the innovation, can provide “early warning” evaluation perspectives.

After the description of CABdriver, the research approach is detailed, followed by a discussion of the analysis and contribution of the research. The concluding section summarizes what we have learned from this study and identifies future avenues of research in this area.

2. CONTEXT-AWARENESS FROM AN IN-CAR PERSPECTIVE

Development of the concept CABdriver (Context-Aware Backseat Driver) was initiated in January 2003 as a joint project with Saab, Mecel and Vodafone. This first prototype of the CABdriver concept is a handheld game that is influenced by contextual information from three areas – the car, the immediate surrounding and the distant surrounding. In addition to giving the passenger something to do at the same time as contextual information affects the behavior of the CABdriver game, the intention is to supply this information in a way that allows the player to convey what may be interesting or even critical to the driver.

2.1 Background

From a research perspective, the main focus related to in-car use of IT has so far been on adapting traditional human-computer interfaces to the car in order to reduce risks of distracting the driver. For instance, Goose & Djennane (2002) look at WIRE3, an adapted HTML browser, Salvucci (2001) compares manual with voice controlled phone dialing, while Brookhuis, De Vries & Waard (1991), McKnight & McKnight (1993), Alm

& Nilsson (1994, 1995) and Redelmeier & Tibshirani (1997) focus on the most commonly talked about issue – how a driver's mobile phone conversation affects driving and the risk of having an accident. With respect to the safety of a car in motion, it is perhaps no surprise that the driver has been the primary focus of most research so far.

While the driver is preoccupied with the continuous negotiations of driving the car, passengers often have nothing specific to do. Handheld games and games available on mobile phones often serve the purpose of killing time during travel, especially among youngsters and teenagers. However, passengers still show considerable subconscious attention and interest for the changing surroundings (Appleyard, Lynch & Myer 1964).

2.2 CABdriver

Responding to this, the first prototype of the CABdriver concept is a handheld game for passengers. The game is a cross between the space shoot-em-ups of the eighties and more strategic games. The game runs solely on the PDA at the moment, although server like behavior in the Infotainment Center of the Saab 9-3 has been discussed. Contextual information is either supplied by a Saab 9-3 via an IP network over Bluetooth to a PDA, or via an IP network over Bluetooth or W-LAN from a computer to the PDA.

The game has two primary parts that the player spends her time in – one is the radar (Figure 1 and Figure 2) and the other is playing missions (Figure 3). On the radar, events within 5000 meters (approximately 3 miles) of the car – which represents the center of the radar – are shown. Missions are created on the radar based on real-world points of interest (gas stations, tourist attractions, hospitals, parking lots, shopping centers, airports, train stations, etc) and traffic messages (TMC data). These traffic messages are sometimes broadcasted live on radio (RDS-TMC), but those are only a small fraction of the thousands of traffic messages that the TMC standard supports. TMC information consists of data combined into a description of a specific situation that affects driving. The data includes accident types, closures and lane restrictions, carpool information, roadwork, dangerous situations, road conditions, temperature and precipitation, air quality and visibility, security alerts and so on. The gaming experience changes based on the content of traffic messages and car status. For example, special missions are automatically selected if the car is within close proximity of important events such as accidents, road blocks and animal warnings and if the car is low on gas, the game will only allow for missions close to the car (the center of the radar) to be started.

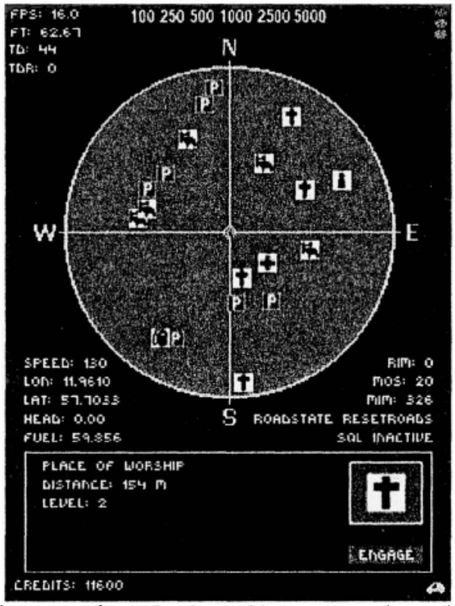

Figure 1. **From the radar, a number of points of interest are shown in the surrounding area. Currently, the player is reading about a place of worship which is in danger of being invaded by enemy spaceships. The scale is shown above the radar (500 meters radius is chosen here).**

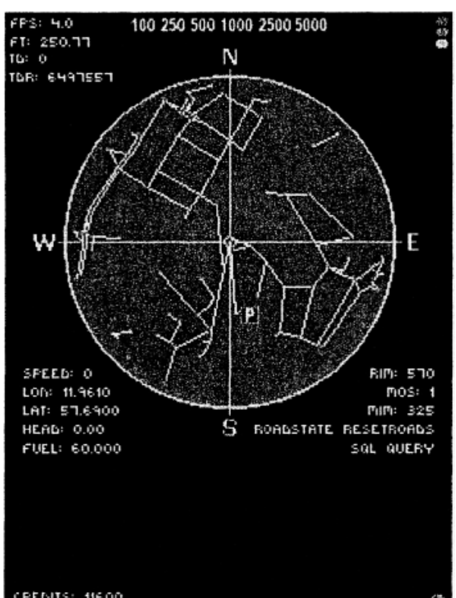

Figure 2. **The road network is drawn on the radar with one parking space showing. A flashing car in the bottom right corner shows that the game is currently receiving data from the car.**

Once a mission is generated (Figure 3), it is in turn influenced by information such as the actual car speed, speed limit, fuel consumption, outside temperature and driver work-load (a combination of anti-spin control and electronic stability program activity, breaking, hard acceleration, navigation system indicating a turn is close-by and recent use of the turn signal). Furthermore, certain missions may require the player to go to the trading section to upgrade her spaceship in order to stand a better chance of completing them.

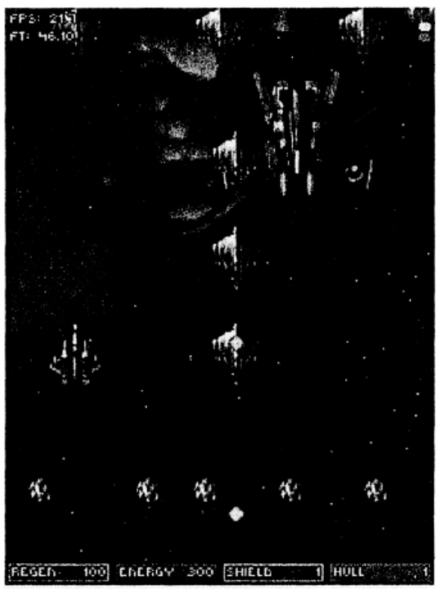

Figure 3. **The dreaded driver work-load monster (indicating an occupied driver; big spaceship in upper right corner) enters a mission at the same time as space mines (string of small round balls at the bottom) from an excessive speeding violation can be seen. The game compares actual speed with speed limit for the current road; not shown here is the flashing blue and white line at the bottom of the screen that warns when the driver is speeding excessively. Driver work-load is at all times shown to the gamer (small ovals in the upper right corner). Fortunately, the driver still seems to drive environmentally sound (indicated by the full regeneration bar in the bottom left corner), something which affects the ability to recover from being hit by enemy shots, move your own space ship (mid-left, pointing up) and shoot back. The T-shaped formation of space ships is also enemy ships.**

Future plans on how CABdriver could evolve include various support for multiplayer games such as in-vehicle (passengers interact with the game from different handheld devices), inter-vehicle (play with others who are traveling in cars close to you through an ad-hoc peer-to-peer network or 3G mobile network) or multiplayer internet (play with anyone connected to the internet, where the in-car player interacts with the game in a different way than those playing on stationary computers). Other game plans that have been discussed include never-ending simulation and evolution games (i.e. Sim City; SIMS) and quiz-games (i.e. Trivial Pursuit; Backpacker). Gender equality and other forms of pastime entertainment that attracts a wider range of ages are also under deliberation.

3. RESEARCH APPROACH

This research focuses on how adaptive structuration theory (DeSanctis & Poole 1994), in-depth qualitative interviews using the repertory grid technique (Kelly 1955) and carefully selected lead users (Von Hippel 1988) can be used in evaluation of innovations at a prototype stage. A context-aware application, CABdriver, is used as an illustration of such a prototype. Each of the components of the research approach is discussed below.

3.1 Adaptive structuration theory

This research uses adaptive structuration theory (AST), an extension of structuration theory (ST), of which the major constructs and propositions can be seen in Figure 4. At this point in the research process, AST is primarily used as a background for the two-month evaluation of CABdriver and is thus only touched on very briefly in this paper. [Readers are referred to Jones and Karsten (2003) for a description of the history and critique of the application of ST.]

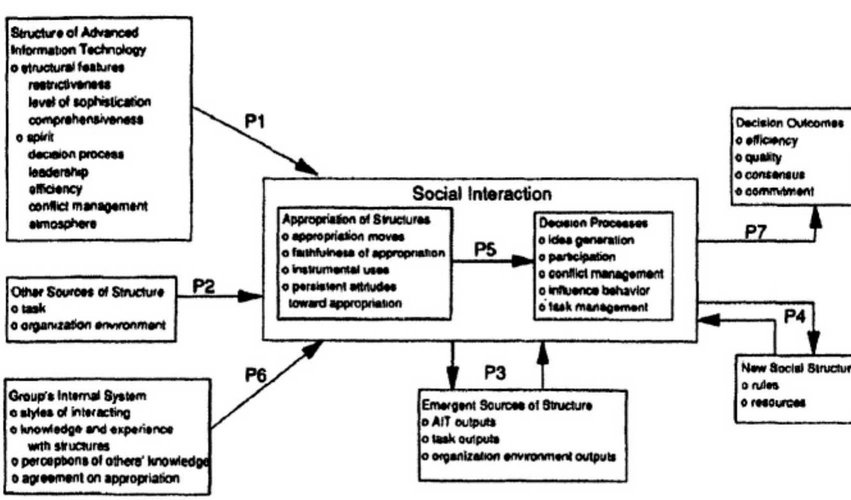

Figure 4. Major constructs and propositions of AST (DeSanctis & Poole 1994, p. 132).

AST was selected for this study because it offers a means of examining a variety of social and contextual factors that influence the use of a technology. As illustrated in Figure 4, AST takes into account the importance of interactions within the use situation, as well as different methods of use with varying degrees of fit with expected use patterns. This model provides a broad view of the innovation adoption and use-context, which was desired in this situation where it is not initially evident what factors are relevant to an evaluation of the prototype.

It should be noted that four aspects of this research differ from traditional use of AST. First, AST has previously been used primarily in organizational settings, often on groups using groupware, rather than on the individual level in an every-day situation as is the case with CABdriver. Second, CABdriver directly influences one user, rather than a group of users. This individual's use of CABdriver is intended to spawn attempts at influencing the behavior of the small group of non-users in the car. The interaction within the group is thus the result of one group member using the application rather than the common case within AST of multiple users of the same technology. Third, although the empirical results in this paper are used to discuss how lead user interviews can provide value, the upcoming every-day use evaluation will not be as long as traditional AST studies. However, AST is still an applicable theory in innovation processes; "...a second direction for this research is to directly test the explanatory and predictive power of AST" (DeSanctis & Poole 1994, p. 144). Fourth, we are bringing the technology to the group, rather than studying an already existing technology within that group. This means that we, as researchers and as part developers, have strong structural features we hope to see, which thus forces us to take extra care in not overlooking results that do not conform to our expectations.

3.2 Interviews: the repertory grid technique

Based on Tan & Hunter (2002), this research uses repertory grids – a cognitive mapping tool in personal construct theory (Kelly 1955) – to capture the structuration process of AST as well as to assist in not overlooking results that do not match our expectations. The repertory grid technique is used to empirically elicit and evaluate peoples' subjective perceptions. The technique is relatively straight-forward since a person, according to Kelly (1955), judges what she encounters in terms of dualities, such as *Fun—Boring, Nice—Rude,* and so on. The objects under investigation are called elements, and may be supplied by the researcher (Reger 1990) or elicited from the participants (Easterby-Smith 1980). Several rules apply for what makes valid elements (i.e. discrete – Stewart & Stewart 1981; homogenous – Easterby-Smith 1980; not evaluative – Stewart

& Stewart 1981; representative – Beail 1985; Easterby-Smith 1980). Constructs, i.e. the dualities for use as a grading scale, may also be either elicited or supplied. Elicitation is typically used (and is here as well), primarily by presenting the elements to the participants in combinations of three, a technique referred to as *triads*. The participant is asked to identify one of the elements in the triad that stands out in some way. This quality is then labeled by the participant, using her own terminology, after which she is asked to label in what way the other two elements differ from the first one in that aspect (thereby creating a duality). This process is iterated until all combinations of elements have been presented to the participant. Previous research has shown that seven to ten triads are sufficient to elicit all the participant's constructs in a particular domain (Reger 1990). Variants of the triadic process include using *dyads* (Keen & Bell 1980), combining elicited with supplied constructs (Easterby-Smith 1980), using a sample of the entire repertory of elements (Dutton et al. 1989) and asking for the opposite label rather than how the identified element differs from the other two (Epting et al. 1971).

After a set of constructs relating to a particular set of elements have been created by the participant, she is asked to grade each element on a scale – in this case set to be a five point scale, as recommended by Stewart & Stewart (1981) – with the dualities at each end of the scale (i.e. the construct *Fun—Boring* would mean Fun is 1 and Boring is 5). Techniques for analyzing the grids created include *content analysis* (Hunter 1997; Moynihan 1996; Stewart & Stewart 1981), *rearranging* (Bell 1990; Easterby-Smith 1980), transforming (Shaw & Thomas 1978) and *decomposing* (Bell 1990; Easterby-Smith 1980) repertory grids, and finally *analysis of content and structure* (Kelly 1955).

For this paper, the data has then been fed into Web Grid III, a frequently used and feature-rich tool for collecting, storing, analyzing and visually representing repertory grids. In particular, two statistical methods of data analysis have been used to transform and represent the data collected – the FOCUS cluster algorithm (Gaines & Shaw 1995; 1997; Shaw 1983), and PRINCOM mapping (Gaines & Shaw 1980; Slater 1976). An in-depth description of this process is given in section 4. One drawback with using only three participants is that the results cannot be considered to approximate a "universal result". For the results to be applicable in general, a sample of 15 to 25 participants is sufficient (Dunn, et al. 1986; Ginsberg 1989). However, in true qualitative fashion, we have not strived for "generally applicable" results, but rather chosen to focus our efforts on in-depth analysis of a few carefully selected lead users (section 3.3) and their perceptions of a particular in-car application and the surrounding environment (outlined as important by AST).

3.3 Identifying lead users

Von Hippel (1988, p. 107) characterizes how lead users are particularly useful for providing insight into evaluation of novel products, processes or services. "Although the insights of lead users are as constrained to the familiar as those of other users, lead users are familiar with conditions that lie in the future for most – and, so, are in a position to provide accurate data on needs related to such future conditions." Lead users are characterized as facing general marketplace needs months or years before the bulk of the marketplace encounters them. Typically, they are also positioned to benefit significantly by finding solutions to those needs.

Rather than adopting a quantitative approach to finding lead users, much like Von Hippel (1988) does in his illustration of this, we have taken a more subjective stance, as we hand-picked three individuals we had extensive experience from dealing with, in one way or another. Having lead user interviews as a part of this research serves three purposes: (1) it allows identification of any major design problems with CABdriver (and if need be, redesign of it) ahead of the more demanding every-day evaluation; (2) it permits us to discuss the research approach chosen (i.e. using a few carefully selected lead users for in-depth qualitative interview sessions to provide design feedback and preliminary results ahead of a more in-depth study of every-day use, in combination with repertory grids and adaptive structuration theory); and, (3), it will enable us to compare the results gained from lead users with the data we will receive in the every-day use evaluation (captured in forthcoming work).

Table 1. Lead users

Person H: Female, 28 years old. H is a PhD student with less than 6 months to her defense. She is studying the development process of commercial off-the-shelf software, using a computer game development company as her case study.
Person M: Male, 30 years old. M is a systems administrator with excellent technical skills. M actively plays many computer games and is well versed in development of applications on handheld devices, including for in-vehicle use.
Person J: Male, 32 years old. J has a history with a major international computer consultancy company, where he worked with data warehousing for customers with large amounts of database information. From the various roles he held in projects, he gained much experience from how innovative solutions are born, developed and commercialized.

4. ANALYSIS AND DISCUSSION

Recorded, in-depth interviews (Wolcott 2001; Patton 2002) were performed individually with each of the three participants (section 3.3), using the repertory grid technique. In addition to the grids containing supplied elements, constructs were elicited from each participant, later used for grading all elements. *Laddering* (Reynolds & Gutman 1988) was further employed to allow participants to extensively explain and discuss their constructs as well as each grading of elements. In laddering, a series of general probing questions are asked (i.e. how and why), in order to stimulate participants to elaborate on their choices. Compared to open-ended questions prepared by the researcher, this technique enable participants to freely choose the aspects they themselves feel are most relevant for discussion. Each session lasted between two and three hours and participants were allowed to create as many constructs as they could think of, after being exposed to a selection of possible combinations of elements in each grid. This resulted in slight variations in the number of constructs for each grid, but it insured that all constructs that participants considered relevant were identified.

The intent of the analysis has been to identify differences and similarities between the elements used by the participants. The process of identifying these requires a number of stages during the analysis. During this analysis, the recorded sessions with clarifications, hesitation, confusion and elaboration expressed by the participants has helped in making qualitative judgments as to how to treat their constructs as well as grading of elements. In this sense, repertory grid analysis has served as a starting point for further analysis of the interview sessions rather than as any kind of “final results”.

4.1 Stage one: data collection

At the first stage, each person was queried about three main areas – (1) different purposes of traveling by car, (2) different types of traffic situations one encounters in a car, and (3) the use of different applications related to CABdriver (with which all were familiar) in cars.

Elements in the first grid all focused on different aspects of car travel. The grid was labeled Travel, in order to clearly separate the grid from the other two grids. The elements (E) all relate to travel by car with the purpose of going to, for or on...:

Table 2. Travel elements

E1)	Vacation
E2)	Leisure pursuit
E3)	Work
E4)	Errand
E5)	Business

Elements in the second grid all focused on different aspects of car traffic. The grid was labeled Traffic, in order to clearly separate the grid from the other two grids. The elements all relate to travel by car in each of the following types of traffic:

Table 3. Travel type elements

E6)	Downtown
E7)	Highway
E8)	Rush-hour
E9)	Traffic jams

Elements in the third grid were all applications used during car travel. The grid was labeled Application, in order to clearly separate the grid from the other two grids. The elements all relate to in-car use during travel:

Table 4. Application type elements

E10)	Navigation system
E11)	RDS-TMC (traffic messages that interrupt the radio transmission)
E12)	CABdriver
E13)	Mobile phone game
E14)	Nintendo Gameboy

This means that each participant produced three grids. As the focus in this paper is how all three lead users perceive the three areas of investigation, all constructs and grades were put into one large grid for each domain of investigation (Travel, Traffic and Application). Below, we have chosen to show the stages of refinement only for the Application grid, as the process was the same for each grid. (Our intent is to show the feasibility of our evaluation approach rather than to conduct a full evaluation of CABdriver.) For the sake of completeness, the full Travel and Traffic grids are included in the Appendix.

4.2 Stage two: FOCUS cluster analysis

At the second stage, these elements were entered into Web Grid III for FOCUS cluster analysis. Here, we looked for relationships between the constructs, pondered contradicting results, consulted the recorded sessions and if need be, asked follow-up questions to the participants. Concluding this stage was a subjective re-labeling or re-use of constructs that seemed to represent the same aspect. This meant breaking up some of the links that the

FOCUS algorithm suggested. One example that can be seen of this (Figure 5) is the association of *No control—User control* with *Sound based—Screen based.* This had to do with the nature of our elements used in this grid, rather than what might be true in general. Among our elements, this was true, however. At this stage of analysis, we can also see how CABdriver shares more aspects with navigation systems and traffic messages through the radio (RDS-TMC) than the two more traditional games. It may also be noted that all participants, even the hard-core gamer, considered mobile phone games as the same type of element as a Nintendo Gameboy. When queried about this, M explained that the difference in hardware was not at all as important to him as the actual game plan of games on these two devices. Furthermore, contradictive results, such as the *Mobile—Stationary* construct which suggests that a Nintendo Gameboy and a mobile phone game are stationary rather than mobile was put down as accidental reversal of the scale by that participant (which he agreed likely when asked later).

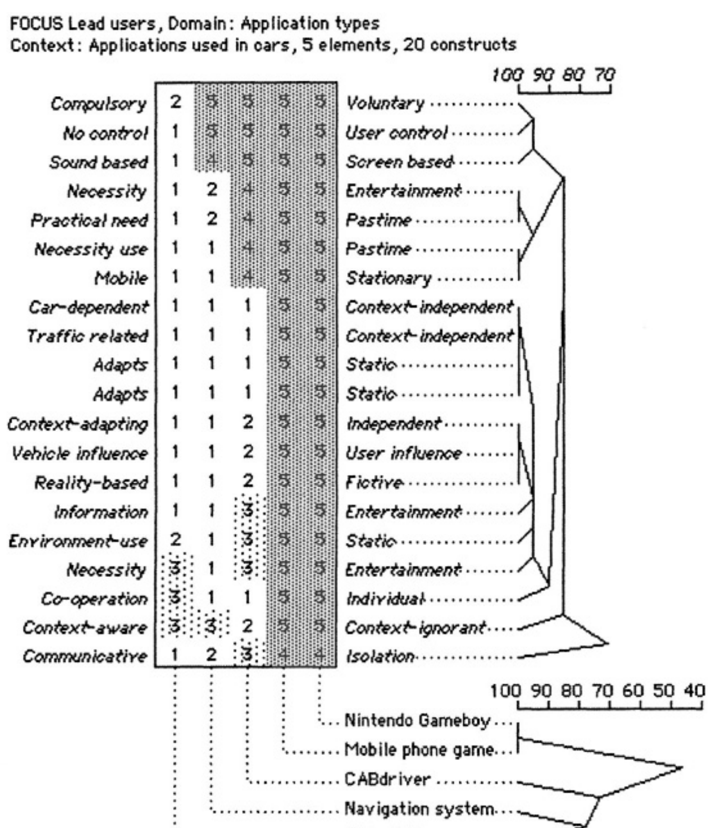

Figure 5. **A FOCUS cluster analysis shows at which threshold the constructs relate to each other as well as the threshold at which the elements relate to each other.**

Thus, after careful semantic review and interpretation, constructs were grouped and re-labeled when judged appropriate. Based on these new groups another FOCUS cluster analysis was performed (Figure 6), now displaying the vital differences. In this cluster, we can see the formation of a somewhat unexpected result from a designer perspective. CABdriver was, as expected, perceived as primarily a pastime entertainment. However, although recognized as reality-based and adapting to the context, the game remained worryingly close to a Nintendo Gameboy and a mobile phone game regarding in-car isolation. Actually, rather than making the player support the driver, the game was perceived as primarily pulling the driver into the game. This can be seen by the strong co-operation required by the game. Analysis of the interviews supported that this co-operation was strongly perceived by the participants, i.e. CABdriver influences driving. At design time, the game was intended to be entertaining, providing the player with a better understanding of the current environment (in-car, the immediate surrounding as well as the distant surrounding) and finally be able to provide some useful help in finding a parking spot nearby, the next gas station, traffic message warnings, and so on. Fortunately, this result is not all bad. As CABdriver is nearly impossible to play if the driver does not adapt a smooth, environmentally sound, driving style as well as stay away from excessive speeding, CABdriver seems to be very well positioned. At one time during the technical testing preceding these evaluations, a developer/player prevented the driver from passing a car in an area where he would have had to accelerate as hard as possible since the developer/player was out of energy already and he did not want a driver work-load monster entering his mission (let alone face the space mines that would come from excessive speeding).

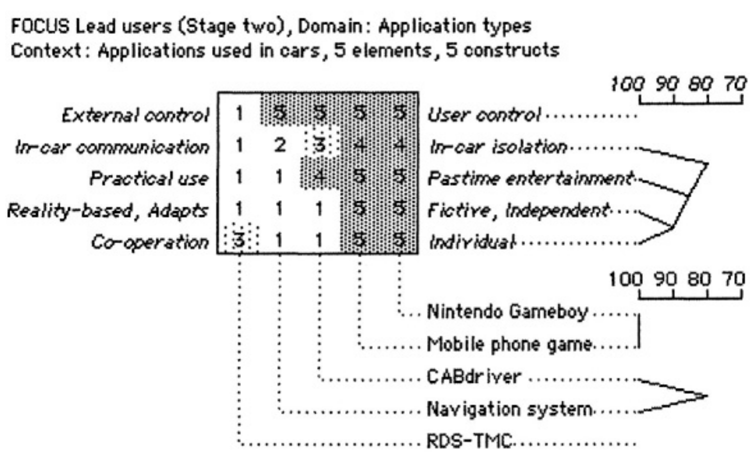

Figure 6. A FOCUS cluster analysis of the re-labeled and grouped constructs.

Furthermore, after grouping all constructs dealing with *Practical use—Pastime entertainment* together, CABdriver came out to share many aspects with a navigation system, something which can be explained by Figure 2 earlier. It may be a very crude navigation system, but turn-by-turn guidance is easily given by the CABdriver user when searching for that parking space or gas station.

4.3 Stage three: PRINCOM map illustration

At the third stage, a PRINCOM map was created (Figure 7). Care must be taken when analyzing a PRINCOM map since constructs have been rotated freely for maximum distribution in unlimited dimensions, while the elements have been placed on the map as if it was two dimensional. For instance, this explains why the construct In-car isolation—In-car communication is shorter than the others. As it is impossible for us to model an unlimited dimension space (although mathematically relatively simple to show using vector analysis), the very nature of a PRINCOM map requires qualitative judgment as to what to explain and what to avoid. Again, going back to the recorded sessions has helped this task. The model shown here is visualized in vector space to facilitate maximum separation of elements in two dimensions (Gaines & Shaw 1980; Slater 1976)

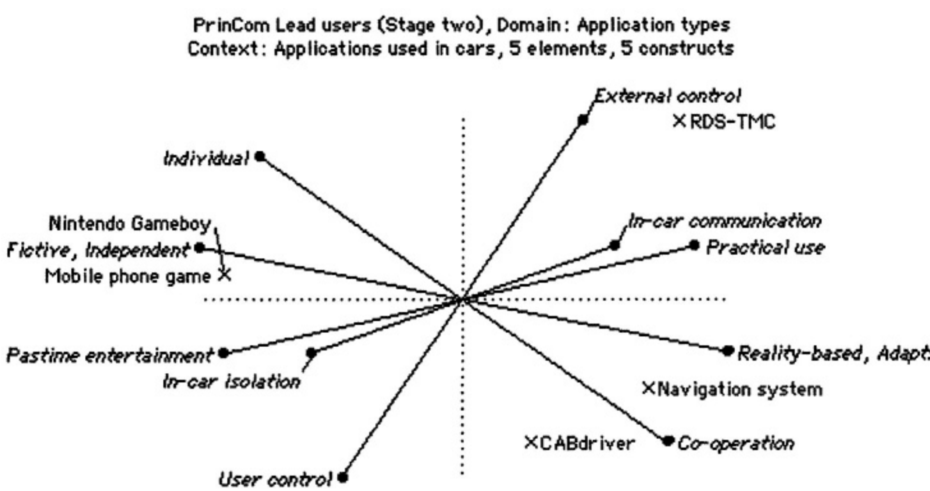

Figure 7. **A PrinCom map provides an overview of how the lead users relate to different types of applications used during car travel.**

Again, but possibly more clearly illustrated, we see how CABdriver and a navigation system are relatively similar in terms of the constructs. We can also see how *Pastime entertainment—Practical use* seems quite close to the construct *In-car isolation—In-car communication.* Careful review of the recorded sessions as well as mathematical analysis of these two vectors shows that the two constructs are only visually represented in this two-dimensional image as close, rather than having actual strong similarity.

4.4 Contributions

The contribution of this paper lies in illustrating how three established ways of conducting research can be brought together, forming a useful research approach in a new setting. In our case, this setting is the evaluation of innovative prototypes. Specifically, by using the approach on CABdriver, four valuable experiences emerge. First, the repertory grids in this paper contribute by showing how the structural features of technology, travel type and traffic situation are perceived by the lead users. These grids correspond to the existing sources of structures affecting the social interaction according to AST and demonstrate how repertory grids can be integrated with AST. Forthcoming every-day use evaluation will expand this integration by focusing on appropriation moves, emerging structure and decision processes. It is also noteworthy that four aspects of this research differ from traditional use of AST (which has been critiqued for being applied too mechanistically – Jones & Karsten 2003). This research differs by (1) having a non-organizational setting, (2) having an individual focus, (3) exploring the explanatory and predictive power of AST, and (4) bringing the technology to the group.

Second, the repertory grid technique provides a highly established tool for capturing individual cognition. This is of particular importance if strong hopes and expectations regarding the impact of the technology already exist. Using repertory grids and laddering grants a structured way for allowing the participants themselves to form the aspects of particular meaning to them, rather than having the preconceptions of the technology and intended impact guiding the research questions.

Third, in using the repertory grids as a starting point for further analysis of the recorded sessions rather than as "final results", we show an effective way to approach the recorded sessions. Using the grids as a first lens for analyzing cognitive data also helps meeting challenges from having strong preconceptions of desired outcomes.

Fourth, including lead user evaluations prior to the main evaluation is fruitful. These lead users were carefully selected based on extensive experience from dealing with them in one way or another, and thus represent our subjective point of view. Since the results were not intended to imply any general point of view representing an entire user group, the in-depth qualitative interviews with subjectively chosen users still apply. Using the participants to test the prototype design ahead of the every-day use evaluation, in search of any major design flaws previously missed, provided some unexpected results compared with what was intended at design time. In this case, the prototype did not require re-design based on these unexpected results since they still answered to CABdriver's purpose of influencing driving.

5. CONCLUSIONS

In this paper we have explored the use of a particular approach for evaluating innovative prototypes. We found the combination of adaptive structuration theory, the repertory grid technique, and interviews with lead users to be a useful method of evaluating a prototype. The use of this method on the context-aware application CABdriver has provided insights on four areas: (1) repertory grids can be a useful addition to AST, (2) repertory grids supported by neutral probing questions offers a valuable means to investigate cognition from an interviewee perspective rather than a researcher-driven perspective, (3) using the grids as a lens for approaching the collected data is an efficient way to start data analysis, and (4) by introducing carefully selected lead users, innovations can effectively be tested for design flaws and possible unexpected outcomes prior to any major evaluation or product launch.

Whereas this approach has been used with only one technology on a small level, nothing we found would prohibit its use with other types of innovative technologies. Forthcoming work will focus on a two month evaluation of every-day use of CABdriver in five families, and will also address the effectiveness of qualitative interviews with lead users in relation to the more demanding every-day use evaluation. This more extensive evolution process will not only provide more information on the usefulness of the evaluation method, but will also provide more detailed results regarding perceptions of the use of the technology itself.

REFERENCES

Alm, H. and Nilsson, L. (1994). Changes in Driver Behaviour as a Function of Handsfree Mobile Phones – a Simulator Study. *Accident Analysis & Prevention,* 26, 441 -451.

Alm, H. and Nilsson, L. (1995). The Effects of a Mobile Telephone Task on Driver Behaviour in a Car Following Situation. *Accident Analysis & Prevention,* 27, 707-715.

Appleyard, D., Lynch, K. and Myer, J. R. (1964), *The View from the Road,* M.I.T. Press, Cambridge, Massachusetts, USA.

Beail, N. (1985). *An Introduction to Repertory Grid Technique. Repertory Grid Technique and Personal Constructs,* N. Beail (ed.), Brookline Books, Cambridge, MA, pp. 1-26.

Bell, R. C. (1990). Analytic Issues in the Use of Repertory Grid Technique. *Advances in Personal Construct Psychology* (1), pp. 25-48.

Brookhuis, K. A., De Vries, G. and Waard, D. (1991). The Effects of Mobile Telephoning on Driving Performance. *Accident Analysis & Prevention,* 23, pp. 30-316.

DeSanctis, G. and Poole, M.S. (1994) Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory. *Organization Science,* Vol. 5, No. 2, pp. 121-147.

Dey, A. K., Abowd, G. D. and Salber, D. (2001). A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. *Human-Computer Interaction,* Volume 16, pp. 97-166.

Dunn, W. N., Cahill, A. G., Dukes, M. J., and Ginsberg, A. (1986). The Policy Grid: A Cognitive Methodology for Assessing Policy Dynamics, in *Policy Analysis: Perspectives, Concepts, and Methods,* W. N. Dunn (ed.), JAI Press, Greenwich, CT, pp. 355-375.

Dutton, J. E., Walton, E. J., and Abrahamson, E. (1989). Important Dimensions of Strategic Issues: Separating the Wheat from the Chaff. *Journal of Management Studies* (26:4), pp. 379-396.

Easterby-Smith, M. (1980). The Design, Analysis and Interpretation of Repertory Grids. *International Journal of Man-Machine Studies* (13), pp. 3-24.

Epting, F. R., Suchman, D. J., and Nickeson, K. J. (1971). An Evaluation of Elicitation Procedures for Personal Constructs, *British Journal of Psychology* (62), pp. 512-517.

Gaines, B. R. and Shaw, M. L. G. (1980). New directions in the analysis and interactive elicitation of personal construct systems. *International Journal Man-Machine Studies,* 13, pp. 81-116.

Gaines, B. R. and Shaw, M. L. G. (1995). Concept mapping on the web. *Proc. Fourth International World Wide Web Conference,* O'Reilly.

Gaines, B. R. and Shaw, M. L. G. (1997). Knowledge acquisition, modeling and inference through world wide web. *Human Computer Studies,* 46, pp. 729—759.

Ginsberg, A. (1989). Construing the Business Portfolio: A Cognitive Model of Diversification. *Journal of Management Studies* (26:4), pp. 417-438.

Goose, S. and Djennane S. (2002). WIRE3: Driving Around the Information Super Highway, *Journal of Personal and Ubiquitous Computing,* Vol. 6-3, Springer-Verlag, London.

Hedström, K. (2003). The socio-political construction of Care-Sys: How interests and values influence computerization, *Proceedings of IFIP WG 8.6 conference,* Copenhagen.

Hunter, M. G. (1997). The Use of RepGrids to Gather Interview Data About Information Systems Analysts. *Information Systems Journal* (7), pp. 67-81.

Jones, M. and Karsten, H. (2003). Review: Structuration Theory and Information Systems Research. Research Papers in Management Studies, University of Cambridge, Judge Institute of Management.

Keen, T. R. and Bell, R. C. (1980). One Thing Leads to Another: A New Approach to Elicitation in the Repertory Grid Technique, *International Journal of Man-Machine Studies* (13), pp. 25-38.

Kelly, G. (1955). *The psychology of personal constructs.* Vol 1 & 2. Routledge, London, UK.

Lyytinen, K. and Damsgaard, J. (2001). What's wrong with the diffusion of innovation theory? The case of a complex and networked technology, in *IFIP 8.6 Conference Proceedings,* Banff, Canada.

Lyytinen, K. and Rose, G. M. (2003). Disruptive information system innovation: The case of internet computing. *Information Systems Journal,* Vol. 13, No. 4, pp. 301-330.

Lyytinen, K. and Yoo, Y. (2002). Research Commentary: The Next Wave of Nomadic Computing. *Information Systems Research,* Vol. 13, No. 4, pp. 377-388.

McKnight, A. J. and McKnight, A. S. (1993). The Effect of Cellular Phone Use upon Driver Attention. *Accident Analysis & Prevention,* 25, 259-265.

Moynihan, T. (1996). An Inventory of Personal Constructs for Information Systems Project Risk Researchers. *Journal of Information Technology* (11), pp. 359-371.

Prescott, M. B. and Conger, S. A. (1995). Information technology innovations: A classification by IT locus of impact and research approach. *Data Base Advances,* Vol. 26, No. 2 and 3, pp. 20-41.

Redelmeier, D. A. and Tibshirani, R. J. (1997). Association Between Cellular-Telephone Calls and Motor Vehicle Collisions. *The New England Journal of Medicine,* 336, 453-458.

Reger, R. K. (1990). The Repertory Grid Technique for Eliciting the Content and Structure of Cognitive Constructive Systems. *Mapping Strategic Thought,* A. S. Huff (ed.), John Wiley & Sons Ltd., Chicester, pp. 301-309.

Reynolds, T. J. and Gutman, J. (1988). Laddering Theory, Method, Analysis, and Interpretation. *Journal of Advertising Research,* February-March, pp. 11-31.

Rogers, E. M. (1995). *Diffusion of Innovations.* The Free Press, fourth edition.

Salvucci D. (2001). Predicting the Effects of In-Car Interfaces on Driver Behavior using a Cognitive Architecture. *Proceedings of Human Factors in Computing Systems,* ACM Press, New York.

Schmidt, A., Beigl, M. and Gellersen, H.-W. (1998). There Is More to Context Than Location. *Computers & Graphics* 23 (1999) 893-901.

Shaw, M. L. G. and Thomas, L. F. (1978). FOCUS on Education: An Interactive Computer System for the Development and Analysis of Repertory Grids. *International Journal of Man-Machine Studies* (10), pp. 139-173.

Shaw, M. L .G. and Gaines, B. R. (1983). A computer aid to knowledge engineering. *Proc. British Computer Society Conference on Expert Systems,* pp. 263—271.

Siewiorek, D. P. (2002). New Frontiers of Application Design. *Communications of the ACM.* Vol. 45, No. 12, pp. 79-82.

Slater, P. (1976). *Dimensions of intrapersonal space.* Vol 1. John Wiley, London, UK.

Stewart, V. and Stewart, A. (1981). *Business Applications of Repertory Grid.* McGraw-Hill, London, 1981.

Swanson, E. B. (1994). Information systems innovation among organizations. *Management Science,* Vol. 40, No. 9, pp. 279-309.

Tan, F. B. and Hunter, M. G. (2002). The Repertory Grid Technique: A Method For The Study of Cognition In Information Systems. *MIS Quarterly* Vol. 26 No. 1, pp. 39-57.

Von Hippel, E. (1988). *The Sources of Innovation.* Oxford University Press, New York, Oxford, USA.

APPENDIX

Princom and Focus of Travel and Traffic Grids

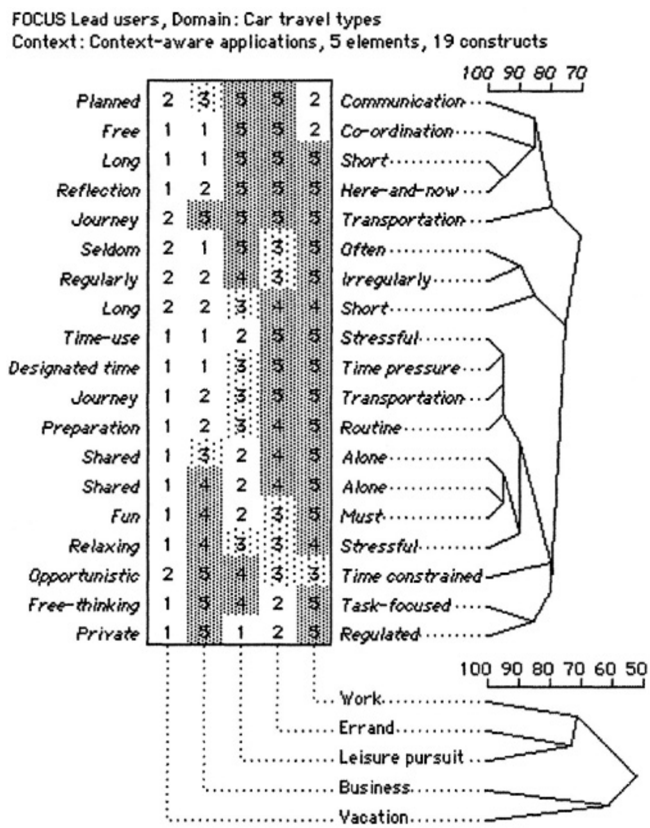

Figure 8. A FOCUS cluster analysis shows at which threshold the constructs relate to each other as well as the threshold at which the elements relate to each other.

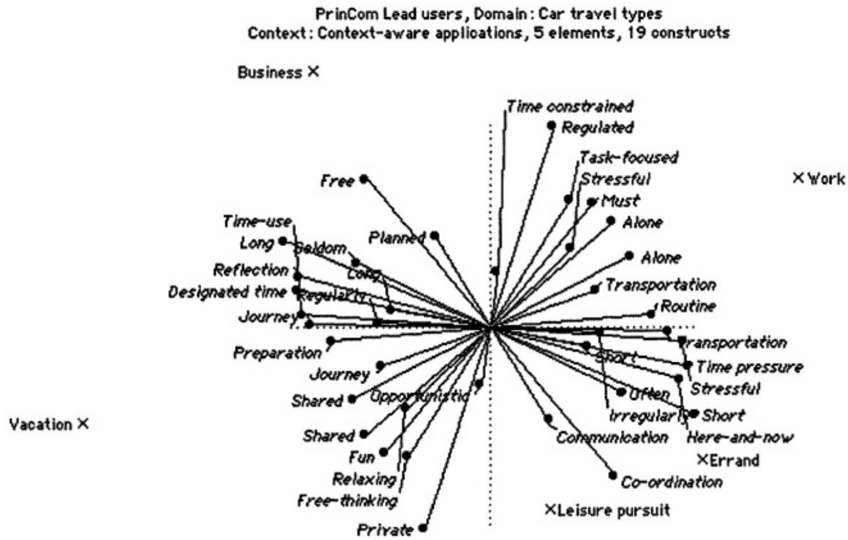

Figure 9. A PrinCom map provides an overview of how the lead users relate to different types of car travel.

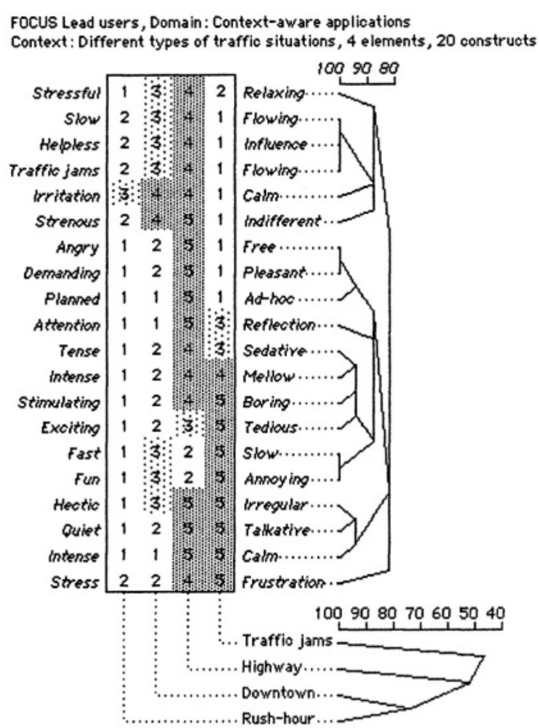

Figure 10. A FOCUS cluster analysis shows at which threshold the constructs relate to each other as well as the threshold at which the elements relate to each other.

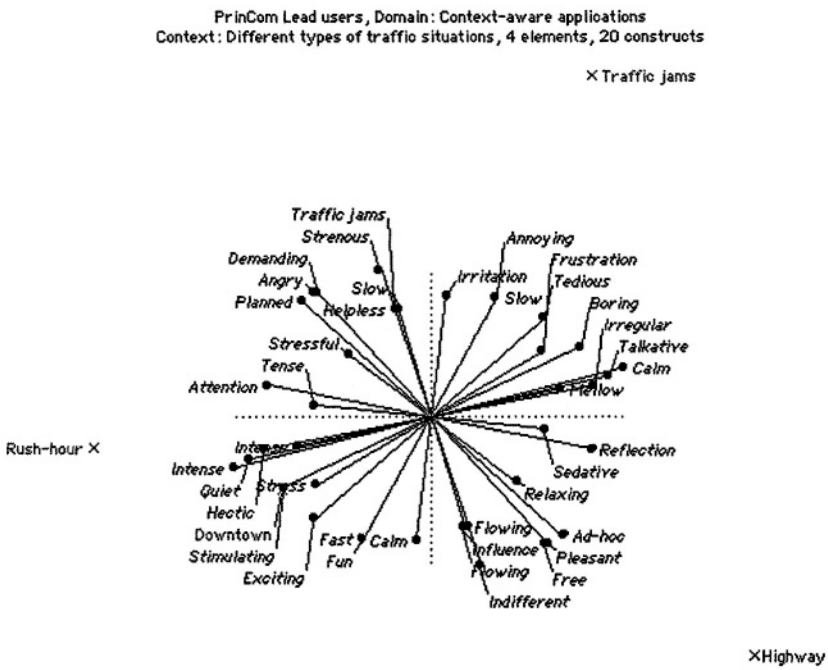

Figure 11. A PrinCom map provides an overview of how the lead users relate to different types of traffic situations.