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1984;2:70–84

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Consumer Research to Focus R&D Projects

John R. Hauser

R&D occurs early in the design stage of a telecommunications product that will be aimed at an unfulfilled market need. New technologies offer some exciting possibilities but the R&D team needs guidance in focusing their technologies on the right set of user benefits. In this article, John R. Hauser uses a case study to show how consumer theory and models for evaluating new product concepts can be used to provide R&D management with diagnostic information to improve the chances of innovation success. It's a good example of how management science can be applied to management problems.

Perspective

In order to survive, firms must innovate and innovation usually means new products, new technology, and new production techniques. But new technology is not sufficient for profitability. Profits come from sales and sales come from products that fill consumer needs. Utterback [15], in a review of studies spanning over 2000 products and 100 industries, indicates that 60–80% of the successful innovations come from an identification of a consumer need. To facilitate the effectiveness of R&D spending, market research must provide diagnostic information on consumer needs. This does not mean that market research directs R&D but rather that market research provides key inputs to enhance the creativity of R&D and focuses problem solving on those technologies that fulfill consumer needs.

In Allen's working model of the R&D problem solving process [1, 2], some of the key steps are to generate critical dimensions, rank these dimensions on the level of importance, and evaluate alternatives with respect to these dimensions. Von Hippel [16] suggests that successful technology fulfills consumer's "dimensions of merit." That is, criteria that the consumer values such as speed, reliability, and economy of operation. For example, for analog-to-digital converters, dimensions of merit might include resolution and sampling rate. Identifying these dimensions, establishing the importance of these dimensions, and evaluating technologies relative to these dimensions are all marketing tasks that can be accomplished by the analysis of consumer perceptions and preferences.

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J PROD INNOV MANAG
1984;2:70–84

BIOGRAPHICAL SKETCH
John R. Hauser is an Associate Professor of Management Science at Massachusetts Institute of Technology. He received an S.B. and S.M. (Electrical Engineering), S.M. (Transportation), and an Sc.D. (Operations Research) from M.I.T. His previous publications have appeared in *Operations Research, Management Science, Journal of Marketing Research, Journal of Marketing, Journal of Consumer Research, Journal of Business,* and *Transportation Research Record.* His book, *Design and Marketing of New Products,* Prentice-Hall, 1980, which he coauthored with Glen Urban, represents a major work on management science in new product management. He is department editor for marketing of *Management Science.* His current research interests include: defensive strategies in product policy; prelaunch forecasting for new consumer durables; marketing and R&D interfaces; and competitive strategies.

This article presents a case study of one way in which market research can help focus R&D. We draw on consumer theory and models of new product concept evaluation to illustrate how R&D can be focused with marketing analysis. We present the analysis through an application to the development of new telecommunication technology.

The specific case is a study funded by the National Science Foundation to develop telecommunication technology to enhance communication within government research centers and to lead to decreased travel and its inherent cost and energy usage. The particular technology is slow-scan televideo equipment which can transmit still pictures over ordinary telephone lines. This technology cannot transmit motion such as that transmitted with closed circuit telephone or with AT&T's Picturephone, but it is significantly less expensive to install and use than these technologies. The target group is scientists, engineers, and managers at one of the scientific laboratories funded by the United States Department of Energy. This laboratory, Los Alamos Scientific Laboratories, has component groups in New Mexico, Nevada, California, and Washington, D.C.

Although the basic underlying slow-scan technological capability did exist at the time of this study, the (applied) R&D task was to refine the technology to increase consumer acceptance. Possible improvements included increased resolution, faster transmission, hard copy availability, reduced size of unit, and other design improvements. Since each improvement required research effort and ultimately would increase the production cost of the units, the task of market research was to focus the development along those dimensions most likely to increase consumer acceptance.

The market research in this case is standard, thus we have chosen not to dwell upon the statistical details, but rather we illustrate how market research can be used by R&D departments. For technical details and "how to" suggestions, we refer the reader to three new product development textbooks: Urban and Hauser [14], Pessemier [10], and Wind [17]. Finally, we note that some early results of this case are contained in Urban and Hauser [14].

We begin by briefly reviewing a model of consumer (or buyer) behavior. We then present the detailed analysis and resulting managerial actions.

Consumer Model

We select our analysis procedure based on the needs of the R&D team. In particular, we want to identify the consumer benefits that the technology is to provide if it is to satisfy an as yet unfulfilled market need. Since R&D is early in the design of the technology, we focus first on perceived needs of buyers. By focusing on perceived needs rather than physical features, we identify what consumers want, but we do not limit the options of the R&D team. R&D can focus on known physical characteristics or adapt, adopt, or invent new physical characteristics in order to deliver the consumer benefits. Once R&D develops the physical characteristics that can deliver consumer benefits, follow-up market research will focus on selecting those physical characteristics that best deliver the perceived benefits.

Figure 1 is a widely accepted conceptual model of consumer behavior that isolates physical and percep-

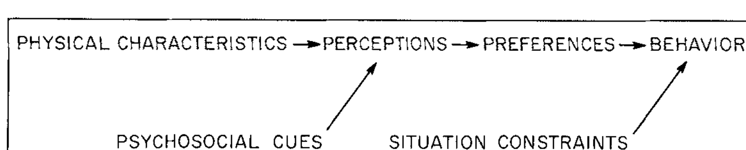

Figure 1. Conceptual model of consumer analysis.

tual dimensions of merit and shows their impact on behavior (see review in Tybout and Hauser [13]). By doing our market analyses within such a conceptual framework, we insure that we identify those needs that affect ultimate sales and profitability.

The R&D task in this case is to improve the **physical characteristics** such as transmission time or resolution, but the buyer is also influenced by **psychosocial cues** such as advertising (a marketing function), recommendations by colleagues, and social and professional norms. Also physical characteristics are mediated by consumers' abstraction of the benefits of the technology into perceptions. By **perceptions,** we mean a consumer's subjective evaluation of a product. For example, a user may look at the transmission time and resolution (physical characteristics) of still pictures and say that a technology is "good for monitoring experiments at a remote location" (a perception).

The consumer forms his **preferences** for specific technologies by evaluating technologies with respect to his perceptions of all available technologies that may fulfill his needs. By preference, we mean a ranking (or scaling) of available products in terms of which product the consumer would most like to have or use. For example, if after considering his needs, a consumer would rather use a slow scan technology than his telephone, we say he has a preference for the slow scan technology.

Finally, the consumer's **behavior** (choice of technology) is mediated by **situational constraints** such as his budget and the availability of the technology within a reasonable delivery time. In other words, we must explicitly consider reasons why a consumer may not be able to buy or use the product he prefers. This model has been widely applied in marketing and it is similar in many respects to those models used in new product concept evaluations (see review by Shocker and Srinivasan [12]).

Basic Marketing Input

To evaluate R&D projects via this conceptual model, we first expand consumers' views of what is possible. We do this by generating a series of "stretcher concepts" that represent the range of existing and potentially feasible technology. By generating stretcher concepts for potentially feasible technology (for us and for potential competitors) we assure that the analysis will remain valid over a wide range of new product introductions. The descriptions of these concepts are written to be believable to the consumer even if they are not yet technologically feasible. For example, Figure 2 is a concept description of one potentially feasible slow-scan technology. Of course, consumer reaction to a written concept will never be exactly the same as consumer reaction to the actual product. But such concepts have proven to be valid indicators of consumer reactions to actual products.

We next identify and measure how consumers react to these concepts and to existing technology. (Detailed measurement and statistical analysis is described below.) The measured perceptual dimensions consumers use to evaluate the concepts and products become dimensions of merit. We then measure **preferences** among the concepts and existing technology and use statistical models to identify how important each dimension of merit is in the consumers' decisions. These relative merits plus consumer's perceptions of existing technology identify market gaps where R&D can achieve a competitive advantage for the innovating firms.

Finally, we model the impact of preference and situational constraints on purchase **behavior** with a forecasting model that can predict how many consumers will choose a particular technology if one is developed to fill the market gap. The resulting model provides only "ballpark" estimates of demand but these estimates are usually sufficient to enable R&D to evaluate whether or not ultimate sales are sufficient to pursue the development of technology to meet the market needs. (For the telecommunications case, the National Science Foundation was interested in usage rather than sales, thus in our analyses, we focus on use rather than purchase. The existing technologies in our case were personal visits and telephone calls.)

Market Research

Figure 1 provides a guide that suggests the type of information that must be gathered from consumers in order to focus R&D research. There are a wide variety of measurement techniques to obtain the necessary data. (For reviews, see Urban and Hauser [14], Pessemier [10], and Wind [17]). Rather than review the

J PROD INNOV MANAG
1984;2:70–84

NARROW-BAND VIDEO TELEPHONE (NBVT)

The Narrow-Band Video Telephone (NBVT) allows the user to transmit *still* pictures of himself, diagrams, drawings, written material, or equipment over *ordinary* telephone grade lines. Input is via a TV camera and display is on a standard TV set. The ability of NBVT to reproduce detail and shades of gray is similar to that of ordinary TV. In essence, NBVT is like transmitting viewgraphs, such as one might use with an overhead projector, over telephone lines. However, with NBVT the user can make pictures on the spot and *edit* these pictures before transmitting them.

No modification of the telephone network is required. Units may be placed at any telephone location using either an acoustic coupler or a permanent jack. This makes NBVT portable, readily available, and allows individuals to use it in their own offices. Furthermore, because NBVT transmits over ordinary telephone lines there are no additional costs associated with its use once the basic equipment has been purchased.

While NBVT can be used with only one telephone line, ordinarily an additional line is dedicated to voice transmission. Anything which can be viewed by a TV camera may be sent, but it takes 30 seconds to transfer a completely new picture. Once a picture is received, it is stored in memory and can be displayed indefinitely on a TV monitor. In addition, because the system is narrow-band, both audio and video transmission can be recorded on the stereo tracks of an *ordinary audio cassette*. With the cassette system it is possible to call and receive calls from an unattended terminal.

A variety of additional features are possible with NBVT. These are summarized below.

- voice-grade crypto units can provide secure transmission when required
- conferencing features of the audio telephone network
- higher resolution and color
- units are available which can display more than one stored picture simultaneously (on two monitors) or switch from one stored picture to another instantaneously

You should assume that there is an NBVT unit in your office or lab and another NBVT unit in the office of the person you wish to interact with. Assume that special units with the additional features listed above will be available on a reservation basis.

Figure 2. One potentially feasible slow-scan technology.

general methods, we describe here the specific data that was collected for our case study.

The basic framework was to begin with qualitative techniques to elicit semantics with which to measure consumers' perceptions. The next step was to measure consumers' perceptions, current behavior, and intended behavior with a mail questionnaire. Measured perceptions tell us how consumers evaluate existing technology and how they evaluate the stretcher concepts. Analysis of these perceptions help us understand how consumers form preferences and make choices. Statistical analysis of measured preferences tell us which dimensions of merit to stress in R&D. Statistical analysis of current behavior and of consumers' reactions to the stretchers help us develop a means to forecast how consumers will react to fully developed technologies.

The first step was a series of focus groups [3] in which groups of six to eight scientists, engineers, and managers from the target market were brought together for a moderated, two-hour discussion of their use of telecommunications technology. By listening carefully to consumers' discussions in a relaxed state, we can identify evaluative perceptual dimensions such as the need "to express feelings" or the need "to avoid hassle.'' In our case, we were able to identify 25 such evaluative dimensions. Based on these focus groups and a series of pretests, we developed a questionnaire that was mailed to 800 scientists, engineers, and managers chosen randomly from the staff directory at Los Alamos Scientific Laboratory. The response rate was 53.6%, or a total of 429 returned questionnaires. Some key parts of the questionnaire are reproduced in the Appendix.

In the questionnaire, respondents were asked to rate on the perceptual scales personal visit, telephone, and three stretcher concepts: Narrow Band Video Telephone (NBVT), Closed Circuit Television (CCTV), and either Facsimile Transfer Device (FAX) or Teletype (TTY). (NBVT is given in Figure 2. It provides still-picture transmission to a TV monitor. FAX transmits hard copy only, and TTY is similar to a computer terminal.) Respondents also indicated which technology they now use and what their preferences were for the five technologies they rated. To achieve a random distribution across usage, we asked respondents to rate and evaluate the technologies with respect to their ''most recent interaction with a colleague, or a vendor, etc.'' We also asked respondents to describe their most recent interaction. Finally, we asked for their demographic profile so that we could segment consumers and/or identify innovators.

To test consumer reaction to the availability of NBVT, we randomly varied the NBVT concept that consumers received. Fifty percent received the concept described in Figure 2 which offered immediate transmission; 50% received a description that was identical except they were told to assume 30 minutes notice would be required. There was no significant difference (0.05 level) in response rate or demographic variables among respondents who received different questionnaire types.

Perceptions[1]

The first measured construct in the model in Figure 1 is perceptions. The focus groups identified 25 verbal dimensions to describe how they might use the proposed product. As detailed in the Appendix, these dimensions include such scales as ''exchange scientific and technical information,'' ''persuade people,'' ''save time,'' and ''no need to plan in advance.'' Note that these are not product characteristics but the values or benefits, the dimensions of merit, that consumers use to evaluate telecommunications products.

It is unlikely that all 25 dimensions are unique and independent. Instead, we expect a few basic dimensions of merit to be able to summarize the information contained in the full set of 25 dimensions. To identify these reduced ''factors,'' we use a statistical technique known as factor analysis (see also [11]). In our case, factor analysis identified two factors, ''effectiveness'' and ''ease of use,'' as being able to summarize the 25 perceptual dimensions. Table 1 lists the verbal dimensions that related to each of the two factors.

Figure 3 is a summary representation of how well each product alternative and each stretcher concept scores on effectiveness and ease of use. Note the gap in the upper right portion of Figure 1, showing that none of the product concepts scores high on both factors. The current R&D projects, NBVT, TTY, CCTV, and FAX, do not meet consumer needs on effectiveness and ease of use as well as the existing technologies of personal visit and telephone. Thus, at a minimum, R&D will need to focus on improved technologies.

Table 1. Perceptual Structure

Effectiveness
exchange scientific and technical information
can persuade people
convey all forms of information
monitors people, operations, and experiments
high level of human interaction
solve problems
express feelings
difficult to misinterpret information
good for group discussion
enhance idea development
get commitment
Ease of Use
saves time
takes little time
eliminates paper work
no hassle to use
no need to plan for in advance
eliminates red tape
inexpensive way to interact
quick response in crisis

[1]Technical details and ''how to'' suggestions are available in [14, 10, 17].

J PROD INNOV MANAG 1984;2:70–84

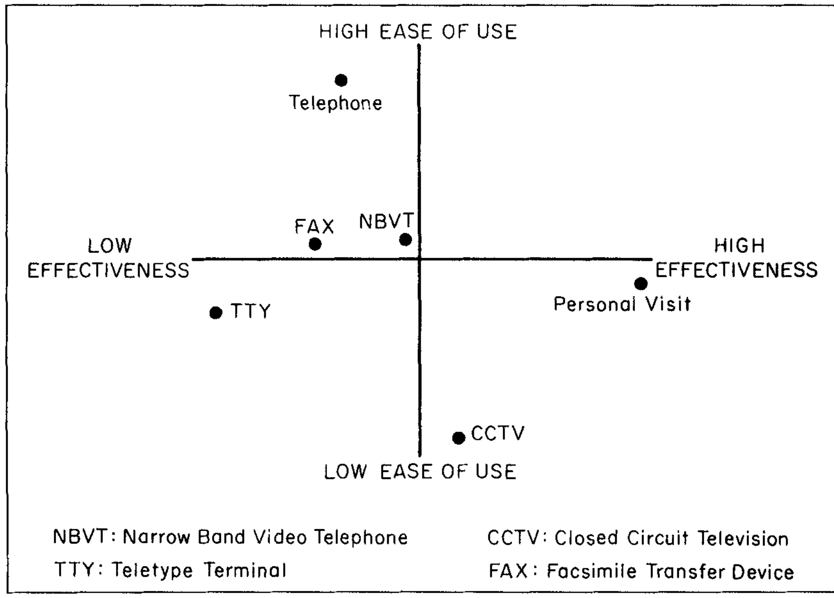

Figure 3. Consumers' perceptions of the R&D projects.

Preference Analysis[2]

Consumers want effectiveness and ease of use, but most R&D decisions will involve an engineering tradeoff among the dimensions contributing to these factors. For example, better resolution will enhance the ability to exchange scientific and technical information, and hence, increase effectiveness, but better resolution may be more expensive, and hence, decrease ease of use. Thus, market research must focus R&D development by determining whether consumers would rather have more effectiveness and less ease of use or more ease of use and less effectiveness. This market research step is called preference analysis.

For preference analysis, we used a standard statistical technique known as preference logit (see also [9]). Preference logit adjusts the relative weights of effectiveness and ease of use until the product that a consumer is most likely to prefer has the largest utility where:

$$\text{utility of a technology} = (\text{weight of effectiveness}) \times (\text{effectiveness of a technology}) + (\text{weight of ease of use}) \times (\text{ease of use of a technology}) \quad (1)$$

Effectiveness and ease of use are measured by summary statistics known as "factor scores." Since individual consumers use communication technology in different ways, they will vary in their perceptions, i.e., the score they assign to the effectiveness and ease of use, of the technologies. Hence, utility for each technology will vary by individual, causing different individuals to choose different technologies. The "weights" are initial diagnostic information which tells us how a representative consumer trades off effectiveness and ease of use. (We examine variation in "weights" among consumers later in this paper.)

Preference logit is qualitatively similar to regression analysis. We observe consumers' preferences, which become the dependent measures; we observe consumers' perceptions, which become the explanatory measures; and we use the statistical program to estimate the logit "weights." Since the preference measures are based on a concept description rather than an actual product our calculation of utility of a concept would be overstated because consumers would in reality be more likely to stick within the existing technologies they know than to switch to our proposed new product. To correct this overstatement, we subtract from the utility of each concept a constant called "preference inertia." (The logit program selects the value of the constant. See [14; p. 304] for details on the logit program and p. 312 for details on preference inertia.)

These models are reported for the telecommunications case in Table 2. The weights for effectiveness and ease of use are reported so that they sum to 100%; "preference inertia" is scaled accordingly. Two goodness of fit statistics are reported: (1) the percent of first preferences correctly predicted, and (2) a statistic that

[2]Technical details in [14]. Alternative techniques in [10, 17].

Table 2. Preference Model

Variable Name	Importance Weights
Effectiveness	0.57[a]
Ease of Use	0.43[a]
Preference Inertia	−0.16[a]
Percent Correctly Predicted	64.4%
Percent Uncertainty Explained	44.3%

[a]All coefficients are significant at the 0.05 level. The model is significant of the 0.01 level.

Table 3. Behavior Model

Variable Name	Importance Weights
Effectiveness	0.57[a]
Ease of Use	0.43[a]
Preference Inertia	−0.16[a]
Surrogate Variable	−0.13[a]
Percent Correctly Predicted	70.4%
Percent Uncertainty Explained	11.3%

[a]All coefficients are significant at the 0.05 level. The multinomial logit model is significant at the 0.01 level.

measures the percent of uncertainty that is explained by the model.

In general, the model does quite well in explaining preference. The preference logit model correctly predicts the concept or product which is most preferred for 64.4% of the consumers. Furthermore, the model explains 44.3% of the uncertainty.[3] These predictions are significantly better (0.01 level) than a model that forecasts preference randomly (20% preferences predicted, 0% uncertainty explained). In the preference model, effectiveness accounts for 57% of the preference weight in Eq. (1) while ease of use accounts for 43% suggesting that effectiveness is more important to consumers, but not by much.

Behavior Prediction Model

To predict the impact of changes in perception and preference, we link preference to behavior by way of a behavioral prediction model. (Specific situational constraints, as called for by an ideal analysis, were not included in the model since none were measured for the existing technologies—telephone and personal visit.) The statistical model used to predict behavior is the multinomial logit model. Basically, for every consumer we observe existing behavior, i.e., their choice among personal visit and telephone. The logit model then selects weights for (1) the preference index as measured by Eq. (1) and (2) a surrogate variable that substitutes for situational constraints.[4] Weights are selected such that the weighted sum of the two variables is the best possible predictor of choice behavior. The weights determined by the multinomial logit model are reported in Table 3. The weights for effectiveness and ease of use are the same as reported in preference analysis (Table 2). Table 3 tells us we must subtract a constant, 0.16, from the preference index for each stretcher concept, and we must subtract a constant, 0.13, from personal visit. No constant is subtracted from telephone.

As indicated by Table 3, the behavior model correctly predicts the choices (among existing alternatives) for 70.4% of the consumers. The "percent uncertainty explained" is smaller than Table 2 because two rather than five technologies are involved and because the shares of telephone and personal visits are nearly equal. All predictions are significantly better (0.01 level) than a random model.

The behavior model does not provide managerial diagnostics per se. It is instead a forecasting model. To forecast for a new technology, we measure effectiveness and ease of use for the new technology. Equation (1) provides the utility of the new technology (subtracting 0.16 for preference inertia). Equation (1) also provides the utility for personal visit, telephone, and any competing technologies (subtracting 0.13 for personal visit). The technology with the highest utility is most likely to be chosen. A numerical estimate of this probability is given by the logit equation (see [14], equation 11.3, page 288). Summing these probabilities across consumers gives an estimate of market share.

[3]Uncertainty is a probabilistic measure based on information theory. Total uncertainty is measured by a concept called "entropy." Perfect prediction can explain 100% of the uncertainty, but any real model will only explain a percentage of the uncertainty. Forty-four point three percent represents the ratio of "information" to "entropy." For technical details see [4].

[4]The surrogate variable in our case was an alternative specific constant added to personal visit to account for unmeasured situation specific effects. In other words, we add a constant to personal visit when predicting choice.

J PROD INNOV MANAG
1984;2:70–84

Diagnostic Information from Perception, Preference, and Behavior Analysis

Figure 4 is a perceptual map which summarizes the diagnostic information based on the consumer model. The points in the perceptual map indicate how consumers perceive the innovation relative to existing technologies and alternative innovations. The "ideal vector" represents consumer tradeoffs among the perceptual dimensions. Its slope is the ratio of the importance weights in the preference model. The further a technology moves parallel to the ideal vector, the more preferred that technology is likely to be. The "efficient frontier" (see [7]) is the northeast boundary (upper right) of the set of perceived positions. When price becomes an issue the perceptual positions must be price adjusted based on modified scale properties of the perceptual map. The efficient frontier is the set of maximum attainable perceptual positions per dollar. At this stage, when we are only identifying opportunities we deal with the unadjusted perceptual map. Thus the dotted line in Figure 4 is not a true efficient frontier in the Lancasterian sense but rather a useful analogy for the identification of R&D opportunities.

If the innovation is to be successful, it should be on or beyond the efficient frontier. For example, it is clear from Figure 4 that NBVT does not fill the perceptual gap between telephone and personal visit. If NBVT could be improved sufficiently to move it past the dotted line connecting telephone and personal visit, then NBVT will be efficient in the sense that, on average, consumers can achieve some perceptual positions better with NBVT than with a combination of personal visit and telephone.

Before we analyze how to improve NBVT along the ideal vector, we examine whether Figure 4 represents the best strategy or whether we should have a set of strategies each directed at a specific segment of the consumer population.

Benefit Segmentation

Not every consumer wants the same technology. For example, if half the population feels very strongly about effectiveness and the other half feels very strongly about ease of use, R&D would be better advised to develop either a very effective or a very easy to use technology rather than developing a technology that is moderately effective and moderately easy to use. In the telecommunications application, we are interested in **usage** of NBVT rather than **sales** of NBVT, thus our benefit segments will include **usage** segments. In other applications the segments will be based primarily on consumer characteristics rather than including usage characteristics.

To investigate such preference differences, we first segment the sample population based on characteristics that describe their most recent communications interaction and based on demographic characteristics. Separate preference models are then estimated for each seg-

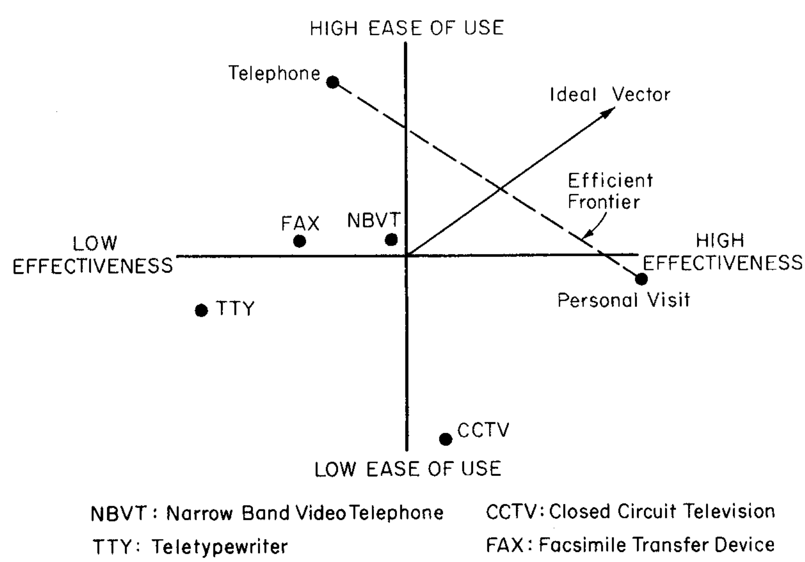

Figure 4. Diagnostic information to improve the innovation.

ment and compared to the model based on the total sample as reported in Table 2. We consider the segment differences to be important if there are significantly different relative preference weights and significantly improved predictive ability. The statistical test is a chi-squared statistic based on the likelihood ratio comparing the segmented models to the overall model (see [14], equation 11.4A-2, page 316 for details).

The analysis showed that three characteristics of communications interactions gave statistically significant (0.05 level) segmentation effects. These segmentation variables were (1) number of people participating, (2) need for visuals, and (3) preparation time. Although three usage segments were identified, segments based on demographics were not. Our respondents did not differ in their preferences based on such factors as their education, discipline of work, role in the laboratory, or years at the laboratory.

Table 4 illustrates that effectiveness is less important (importance weight of 0.49) if no visuals are needed, more important if visuals are needed but not used (importance weight, 0.56), and most important if visuals are needed and used (importance weight, 0.75). Thus, consumers who use visuals will be the target market for very effective telecommunications devices. While this may seem obvious in retrospect, it is not always so easy to see a priori. For example, there was no breakdown by managers versus scientists versus engineers, which one might also expect a priori to have different needs.

Table 4. Preference Segmentation on Need for Visuals

	Importance Weights			
Variable Name	Overall	No Visuals Needed	None Used, but Needed	Visuals Used
Effectiveness	0.57[a]	0.49[a]	0.56[a]	0.75[a]
Ease of Use	0.43[a]	0.51[a]	0.45[a]	0.26[a]
Preference Inertia	−0.16[a]	−0.15[a]	0.04[a]	−0.34[a]
Sample Size	410	162	53	195
Percent Correctly Predicted	65.4%	72.2%	53.8%	74.9%
			71.1%	
Percent Uncertainty Explained	44.5%	55.2%	22.3%	50.8%
			48.9%	

[a] All coefficients are significant at the 0.05 level. All logit models are significant at the 0.01 level.

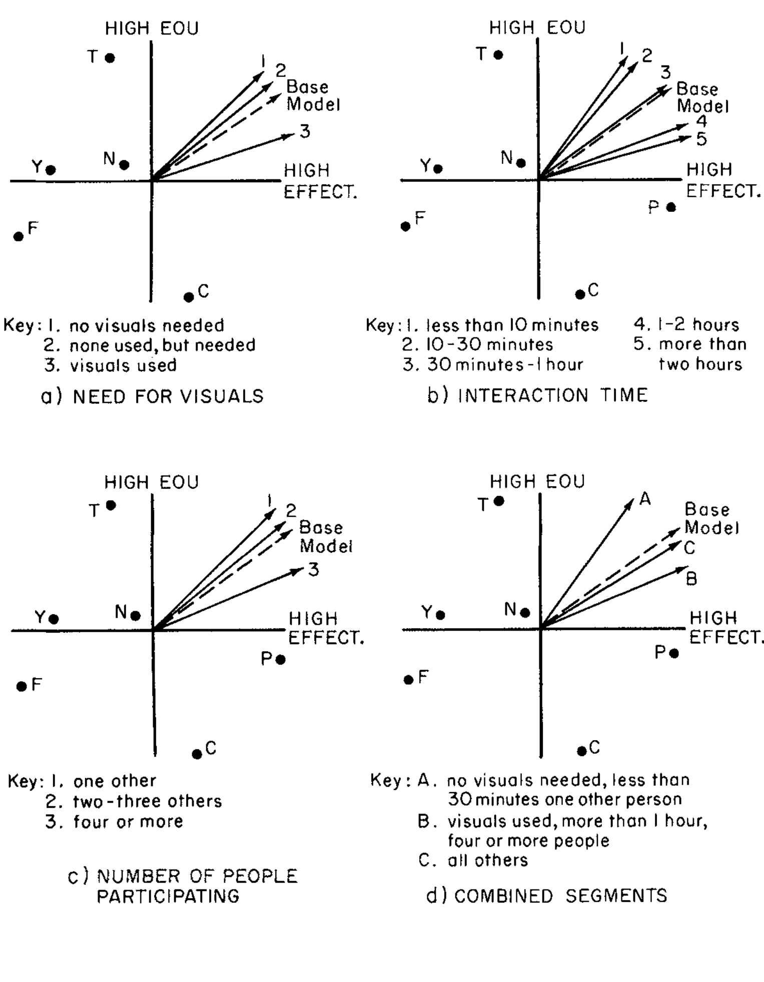

Figure 5. Preference segmentation (key to stimuli: T=telephone, P=personal visit, N=NBVT, C=CCTV, Y=TTY, F=FAX. Key to factors: EOU=ease of use, EFFECT=effectiveness.)

J PROD INNOV MANAG
1984;2:70–84

Benefit segmentation gives us a chance to identify segments or test our working hypotheses about segments. It is useful to R&D because it identifies and quantifies how needs vary by usage or by type of consumer.

To summarize our segmentation analyses, we grouped segments with similar importance weights to obtain three combined segments. Segment A (interactions that are less than 30 minutes with one other person involved, and visuals not required) places importance on ease of use. Segment B (interactions of more than an hour, involving a group of four or more people, and visuals required) places importance on effectiveness. Segment C (all other interactions) places roughly equal importance on both dimensions. The combined segments accounted for 4%, 11%, and 85% of the interactions, respectively. This segmentation was also significant at the 0.05 level.

To interpret these tests, it is convenient to represent the segmentations visually by superimposing the segmented ideal vectors (see Figure 5). Figure 5d is for the combined segments. Based on Figure 5d it appears that the majority segment, segment C-85% of the interactions, has preferences similar to the base model in Figure 4. To reach the most users, R&D should improve NBVT by placing roughly equal emphasis on effectiveness and ease of use. This type of improvement in NBVT will attract those consumers whose interactions have characteristics such as medium length, few people involved, or a potential for improvement with visuals. If simultaneous improvement along both dimensions is not possible, an alternative strategy for R&D is to concentrate on either extremely effective communication (segment B, 11% of the interactions) or extremely easy to use communication (segment A, 4% of the interactions). However each of these strategies goes head on against an existing technology—personal visit (segment B) or telephone (segment A). However, if the goal is to substitute NBVT for personal visits, then a very effective NBVT addressed at segment B may be a reasonable R&D strategy.

Identification of Innovators

As a final guide for R&D, we identify those users who most prefer NBVT and are most likely to try it should it be introduced. This information provides some creative insight into the potential NBVT users and provides marketing with some initial introduction strategies. We define innovators as those consumers significantly more likely to prefer or try the innovation given that they are aware of the innovation.

To implement this definition, two regression equations are estimated with preference and intent as the dependent variables. Intent is a categorical scale measuring the likelihood that a consumer would have chosen NBVT had it been available for his most recent interaction (see Appendix). The potential explanatory variables are situational and demographic variables identified based on previous theory and experience as potential indicators of innovators for the new product. The explanatory variables are categorical as measured in the questionnaire. (See [14], chapter 10, for a discussion of the use of regression for such categorical scales.) Note that when we use regression with categorical scales, the measure of statistical fit, R^2, will be low because of the categorical nature of the scales. Thus, low R^2 does not necessarily mean low fit to the data.)

The potential variables for NBVT are shown in Table 5. Since the technological advantage of NBVT is a visual component, a priori, we expect at least the need for visuals to be significant. The other situational variables were selected based on focus groups and discussions with experts in telecommunication. The demographic variables try to uncover any predisposition based on personal experience of the respondent. To obtain greater power in the estimates, we included a variable to account for the fact that some consumers saw an NBVT concept available on 30 minutes notice and others saw an NBVT concept described as available in every office.

Only two variables, need for visuals and interaction time, were found to be indicators of innovators (0.05

Table 5. Situational and Demographic Variables Likely to Identify Innovators

Situational Variables	Demographic Variables
Need for visuals	Years at LASL
Number of people participating	Education
Place of interaction	Discipline of training
Relationship to other participants	Discipline of work
Frequency of interaction	Role in laboratory
Purpose of interaction	Percentage of time allocated to various tasks
Preparation time	Age
Travel time or potential travel time	Sex
Travel cost or potential travel cost	Marital status
Interaction time	
Need for security	

level). Alternative analysis with subsets of the variables were consistent in that these two variables alone were consistently significant. Although we can expect one significant variable by chance out of 20 when testing at the 0.05 level, we believe the two identified variables are true effects since their significance levels are well below the 0.05 level and since similar results are obtained for both preference and intent. Nonetheless, these results must be classified as exploratory. The regressions with only these variables are shown in Table 6. Selected interactions were tried and found to be insignificant. The final model was found to be not significantly different from the full model (all variables) at the 0.05 level.

Based on Table 6, we posit that NBVT is most likely to be used for (a) interactions that required visuals but for which none was available and (2) interactions requiring moderate (10–30 minutes) interaction time. This represents about 4.3% of the interactions. Thus, if a new telecommunications technology such as NBVT is produced, initial marketing (e.g., advertising, sales calls, direct mail) should be targeted toward consumers who require visuals and have moderate interaction times. For example, a salesman may ask the laboratory director to identify these people within the laboratory or an advertising copy writer may portray this type of person in his advertising. Once the innovators adopt the new technology, word of mouth recommendations from innovators will reinforce marketing efforts to the rest of the population.

Table 6. Regressions to Identify Innovators

	Preference Rank (Best Value 5.0)		Intent (Best Value 5.0)	
Variable	Coefficient	Significance	Coefficient	Significance
Every Office	—		—	
30 Minutes	0.25	0.04	ns	
Visuals Not Used	—		—	
Visuals Not Used but Needed	0.82	0.00	0.75	0.00
Visuals Used	0.38	0.00	0.46	0.00
Interaction Time				
0–10 min	—		—	
10–30 min	0.33	0.03	0.49	0.01
30 min–1 hr	ns	ns	0.45	0.01
1 hr or Longer	ns	ns	ns	ns
Constant	2.80	0.00	2.36	0.00
R^2	0.09	—	0.11	—
F	7.31	0.00	7.20	0.00

ns = nonsignificant, then dropped from model.

R&D Strategies, Forecasts, and Managerial Actions

To get an indication of how R&D might improve NBVT, we return to the 25 attribute scales. These are qualitative perceptual scales, but they are more rich in their representation than the two-dimensional map, and hence, provide useful insights. Figure 6 is a perceptual plot based on these (standardized) scales. Negatively worded scales have been reversed so that movement to the right indicates improvement and the scales have been reordered so that the effectiveness and ease of use scales appear together.

By carefully examining Figure 6, we see that NBVT is perceived poorly relative to personal visit on all effectiveness scales. This indicates a need for overall improvement along all effectiveness dimensions. Perhaps the greatest improvement is needed in the ability of NBVT to "monitor people, operations, and experiments" and "convey all forms of information." NBVT needs the least improvement for "persuasion," "expressing feelings," and "solving problems." Similarly, telephone dominates on all ease of use scales. Relative to telephone, NBVT needs the most improvement on "need to plan in advance," "get a quick response," and "expense."

Before beginning extensive R&D, we make preliminary forecasts to determine the magnitude of usage achievable with these improvements. We use decision calculus [8] to make preliminary estimates of the impacts of changes on the attribute scales in Figure 6. The statistical models (factor analysis and the preference and behavioral logit models) are then used to forecast the resulting change in usage. (For complete equations, procedures to enhance judgement, and applications to urban transportation, see [6] and [14, chap. 11]). Predictions are automated with an interactive computer information system so that the R&D team can quickly and easily get forecasts based on their judgments.

For example, Table 7 shows estimates of the effects of three strategies for NBVT design. Strategy 1 improves the effectiveness of monitoring experiments and the ability to convey all forms of information. Strategy 2 improves the availability of NBVT (plan in advance and quick response). Strategy 3 combines strategies 1 and 2. In each case the effect is simulated as follows: the score on the relevant perceptual dimension is increased by a value equal to one-half the distance from NBVT to the best rated technology (telephone or personal visit) as measured horizontally in Figure 6. The

Table 7. Forecasts for Improvements in the Innovation (percent change in share)

	NBVT	Personal Visit	Telephone
Strategy 1	6.7%	−0.5%	−0.7%
Strategy 2	1.9	−0.2	−0.2
Strategy 3	8.8	−0.8	−0.8
Major R&D	110.0	−8.8	−10.6

results are the percentage change in the ultimate usage share of the various technologies. Based on Table 7 it is clear that these strategies are useful but have only a minor impact on share. Further simulations reveal that this type of change can only lead to improvements in the range of 5–10%. Since this is not sufficient for managerial goals, major R&D is needed. For example, if major R&D were able to move NBVT to the efficient frontier along the ideal vector, the share of NBVT would be improved by 110%.

Based on these forecasts, R&D management is faced with a decision to introduce the modified innovation (GO), return to R&D (ON), or abort the investment in the innovation (NO GO). In this case, it is clear that NBVT is not yet ready for introduction, but with major R&D it can become a viable force in the market for telecommunications.

The managerial action was ON. Implementation of the NBVT technology described in Figure 2 was postponed and the technology was returned to R&D for major improvement. Based on Figure 4 and technical judgment, the R&D team chose to focus on improved resolution, hard copy availability, reduced transmission time, and increased accessibility of the technology. As a further guide, a conjoint study [5] was undertaken to determine the impact of these physical changes on perceptions of effectiveness and ease of use. Accessibility had the largest impact on ease of use. The availability of hard copy had the greatest impact on effectiveness. Resolution had no significant effect on either dimension. One potential profile (increased accessibility, hard copy, and 10-second transmission time) would be efficient in Figure 4, but a less expensive profile (30 minutes notice on accessibility, hard copy, and 10-second transmission time) was near the efficient frontier. This second profile was selected as a guide to the best initial strategy for R&D. However, the ultimate success of the technology still depends on successful R&D.

Summary

This paper demonstrates how consumer theory, market research, and quantitative analysis can improve the effectiveness of R&D. The methodology presented is feasible and provides managerially relevant diagnostic information to the R&D team. However, it is only a guide. R&D and further market research is necessary to physically design the product.

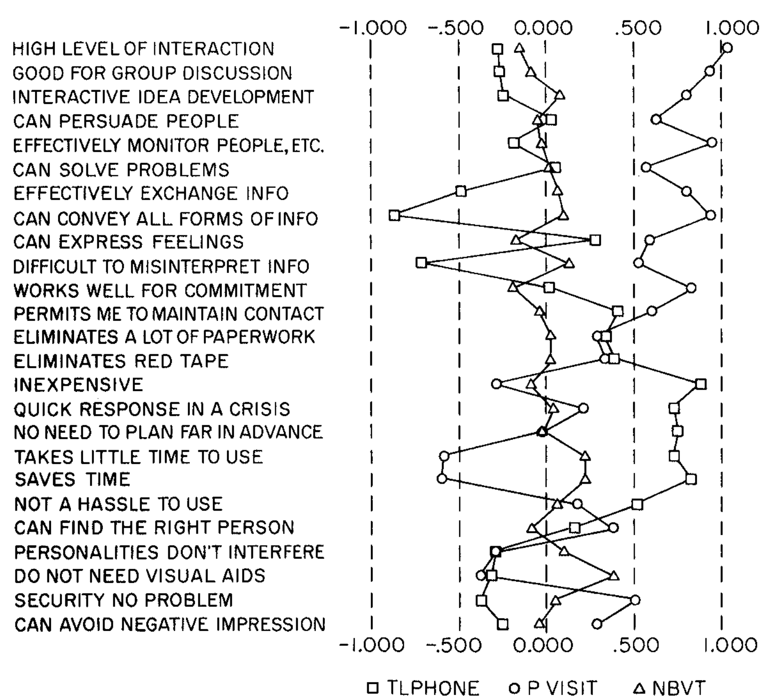

Figure 6. Average attribute ratings of three communications alternatives.

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Appendix

The actual questionnaire was 20 pages long and came in four versions depending upon the stretcher concepts the consumer saw, i.e., NBVT available on 30 min notice or available in every office, and facsimile transfer devices or teletype terminals.

We reproduce here examples of questions to measure (1) preferences, (2) intended choice of the new technology, NBVT, and (3) perceptions.

(Question types 1 & 2) Preferences and Intended Choice

You have just read and rated three hypothetical communication systems. We would like to know your preferences for these systems. Imagine that NARROW-BAND VIDEO TELEPHONE, CLOSED CIRCUIT TELEVISION, TELETYPE, TELEPHONE, and PERSONAL VISIT were available for your most recent interaction with a colleague outside of your building. (Consider the interaction you described earlier in this questionnaire.) These alternatives are listed below.

1. Please place a "1" beside your first choice, a "2" beside your second choice . . . and a "5" beside your last choice. Be sure that you assign a number to every alternative.
   ____ NARROW-BAND VIDEO TELEPHONE
   ____ CLOSED CIRCUIT TELEVISION
   ____ TELETYPE TERMINAL
   ____ TELEPHONE
   ____ PERSONAL VISIT

J PROD INNOV MANAG
1984;2:70–84

2. How likely would you be to choose NARROW-BAND VIDEO TELEPHONE?

	Definitely not Choose	Probably not Choose	Might Choose	Probably would Choose	Definitely would Choose
If it were exactly as described:	[ ]	[ ]	[ ]	[ ]	[ ]
If every office had one:	[ ]	[ ]	[ ]	[ ]	[ ]
If hard-copy were available:	[ ]	[ ]	[ ]	[ ]	[ ]
If transmission time were improved from 30 seconds to 10 seconds:	[ ]	[ ]	[ ]	[ ]	[ ]
If resolution were improved to 4 times that of a home TV:	[ ]	[ ]	[ ]	[ ]	[ ]

(Question type 3) Perceptions
My Rating of Narrow-band Video Telephone (NBVT) (for the interaction I described earlier)

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. By NBVT I could not effectively exchange scientific and technical information.	[ ]	[ ]	[ ]	[ ]	[ ]
2. I could always find and reach the person I want by NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
3. NBVT would save me time.	[ ]	[ ]	[ ]	[ ]	[ ]
4. I would not need other visual aids beyond what can be provided by NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
5. NBVT would take very little time to use.	[ ]	[ ]	[ ]	[ ]	[ ]
6. Using NBVT would eliminate a lot of paper work.	[ ]	[ ]	[ ]	[ ]	[ ]
7. I could not persuade people over the NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
8. With NBVT personalities would not interfere with issues.	[ ]	[ ]	[ ]	[ ]	[ ]
9. I could convey all forms of technical information with NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
10. It would be a real hassle to use NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
11. I could avoid making a negative impression when interacting with NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
12. Security would be no problem with NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
13. I would need to plan far in advance to use NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
14. Using the NBVT would eliminate a lot of red tape.	[ ]	[ ]	[ ]	[ ]	[ ]

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
15. I could effectively monitor people, operations, or experiments.	[ ]	[ ]	[ ]	[ ]	[ ]
16. NBVT would yield a high level of human interaction.	[ ]	[ ]	[ ]	[ ]	[ ]
17. I could not solve problems with NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
18. I could express my feelings with NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
19. Information would be easy to misinterpret when interacting by NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
20. NBVT would be good for group discussion.	[ ]	[ ]	[ ]	[ ]	[ ]
21. NBVT would be an expensive way to interact with others.	[ ]	[ ]	[ ]	[ ]	[ ]
22. In a crisis I could get quick response or action with NBVT.	[ ]	[ ]	[ ]	[ ]	[ ]
23. NBVT would enhance the interactive development of ideas.	[ ]	[ ]	[ ]	[ ]	[ ]
24. When I need a commitment, the NBVT would work well.	[ ]	[ ]	[ ]	[ ]	[ ]
25. NBVT would permit me to maintain contact with others in my field.	[ ]	[ ]	[ ]	[ ]	[ ]