Testing care-giver acceptance of new syringe technologies

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Abstract: The research design and empirical results of an exploratory study are reported of an experiment to estimate care-giver (n = 29) acceptance of alternative syringe technologies. The experiment included five independent factors: four syringe technologies in four sizes (1, 2, 3, and 5 ccs), offered by four manufacturers, and sold by two distributors at five prices; an orthogonal, fractional factorial design of 25 factor combinations was used. The dependent measures included the subject’s ‘short-listing’ and constant-sum ‘purchase’ of 100 syringes. Main results: estimated purchase share increased 6.9 per 100 syringes due to the new syringe technology that combined automatic needle protection and syringe-locking features; after syringe technology, most subjects had strong preferences to buy syringes manufactured by Becton & Dickinson; increasing price had a strong, negative impact on purchases; while less important, most subjects preferred to buy the 3 cc size and to order from the (known) large versus small distributor. The results did not vary significantly among care-givers working (n = 16) versus not working (n = 11) with HIV/AIDS patients.

Keywords: Care-givers; syringe/needle-point technologies; brand awareness.


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1 Introduction

While the specific number of cases is unknown, since the late 1980s documented cases of accidental needle exposure and acquisition of HIV/AIDS among care-givers (e.g., nurses and physicians) have occurred (see: Jagger, Hunt, Brand-Elnaggar, and Pearson [1]; Seligmann, McKillop, Gonzalez, Hager, and Joseph [2]). While the dangers of care-exposure and contracting the virus appear low, most care-givers administering injections to patients report experiencing one or more accidental, syringe needle-point, self-infections one or more times per year [2].

New syringe/needle-point technologies are being developed and tested to reduce such risks as accidental self-injection among care-givers and exposure to HIV/AIDS. In this article the details of a field study designed to test the relative impact of some of these new technologies on care-giver acceptance are reported. Other factors examined in the study include syringe sizes (four sizes), four enterprises designing the syringe technologies, two distributors, and five prices. A fractional-factorial, orthogonal, hybrid conjoint design was the research method used (see Churchill [3]). The results include: a strong care-giver preference for one of the new technologies; preference for the 3 cc syringe size; a strong preference for Becton & Dickinson being the syringe designer, and no strong preference toward either of the two distributing firms. The results are limited to the responses to a small sample of care-givers (n = 29). The findings do indicate that dramatic changes in market share of syringe technologies are likely to occur based on ability of the technologies to reduce accidental care-giver exposure to syringe needle-points.

2 Hypotheses

The following specific hypotheses were tested. The tests were performed at both individual and group levels. At the group level, the care-givers included in the sample were segmented into users who deal mostly with HIV/AIDS patients (n = 16) and users who have no known HIV/AIDS patients (n = 11); data were missing on this segmenting variable for two respondents. Also at the group level the responses of care-givers involved directly in buying syringes (n = 20) were compared to the responses of care-givers with no syringe buying involvement (n 9).

Given the small sample sizes and the convenience sampling procedure, the reported empirical test serves only to explore the hypotheses. Large-scale surveys of random samples from well-defined populations of segments of service-providers are needed before reaching conclusions.

With large samples and responses, service-providers could be grouped by their sensitivities to levels of product features. Most likely, most service-providers could be assigned to one of five to seven groups according to each individual’s sensitivities to product features. The groups formed by their sensitivity profiles could be then compared to naturally occurring service-provider segments; such comparisons would indicate the potential impacts of different syringe designs (including prices) on sub-segments of service providers.
H$_1$: the syringe technology most protective of the care-giver is preferred most (i.e., substantially increases the intention-to-buy share) by care-givers.

H$_2$: price has a strong negative impact on care-giver preferences toward syringe technologies.

H$_3$: care-givers prefer syringe sizes 3 and 5 ccs compared to 1 or 2 ccs.

H$_4$: (a) care-givers prefer the most well-known syringe manufacturer (i.e., Becton & Dickinson) to be the designer of new syringe technologies; (b) a university medical centre not known to be working on developing new syringe technologies is preferred the least as a new technology designer of syringes.

H$_5$: among care-givers, a well-known large distributor of medical products is preferred as the supplier versus a small distributor.

H$_6$: (a) care-givers of HIV/AIDS patients prefer the most protective syringe technology more than care-givers of patients not known to have HIV/AIDS; (b) care-givers involved directly with buying syringes are less influenced by new syringe technologies compared to care-givers not involved directly with buying syringes.

3 Rationales

The rationale for H$_1$: almost all care-givers using syringes to administer medications to patients recognize an increase risk of HIV/AIDS exposure to themselves via being accidentally stuck by a used syringe needle. Physically capping a syringe needle with a plastic cap may be a dangerous practice because such capping involves moving a hand toward the needle point. Most health care facilities have policies banning syringe needle-capping. Thus, automatically activated technologies designed to eliminate exposure to used syringe needle-points without capping are likely to be preferred.

The rationale for H$_2$: for medical facilities in the USA, syringes are a planned disposal medical supply-item. Almost all patients entering medical facilities experience one or more treatments and tests involving syringe administrations. Consequently, care-givers may prefer to hold-down the cost of purchasing syringes (based on volume of use and the requirement to dispose each syringe after one-time use).

The rationale for H$_3$: the 2 cc syringe size is the most popular size among drug abusers; larger sizes are used more often to administer prescription medication in medical facilities. Thus the 3 and 5 cc syringe sizes may be more preferred by care-givers over the smaller size 1 and 2 cc sizes.

The rationale for H$_4$: research studies in buyer behaviour have found a strong association between brand awareness (unaided) and brand preference (see Howard [4]). This finding is likely to hold among care-givers in their knowledge of manufacturers of syringes: known syringe manufacturers are expected to be preferred to unknown manufacturers. Becton & Dickinson is a syringe manufacturer well-known among care-givers to manufacture medical syringes (e.g., mentioned first most often in an unaided pretest among ten care-givers; mentioned by all care-givers, aware of manufacturers of syringes).

The rationale for H$_5$: care-givers are more likely to experience and trust a large distributor of syringes and other medical products compared to a smaller, less well-
known, specialized distributor of syringes. Brand purchase-and-use experience has been found to be highly predictive of future purchase behaviour (see Howard [4]). A well-known distributor of medical products was included along with a relatively unknown, specialized distributor, as one of the factors in the study.

The rationale for H₀: care-givers of known HIV/AIDS patients are more likely to worry about infection of the virus from needle-point sticks following administering patient syringe medications compared to care-givers of patients not known to have HIV/AIDS. Such worry is likely to translate into a higher perceived utility for highly protective syringe needle-point protection for HIV/AIDS patient care-givers.

Care-givers involved in buying syringes are more likely trained to be concerned about price and delivery by distributors than care-givers not involved in buying syringes. Consequently factors other than syringe technologies, such as price and distributor reputation, are more likely to be of greater concern among care-givers involved versus not involved with buying decisions.

4 Method

How each construct was operationalized is described in this section. Also, the selection of two orthogonal, fractional-factorial experimental designs used in the study is reviewed. The population and sampling procedure of subjects are then described, followed by a review of the data collection procedure. Finally, the principal method used for data analysis is explained.

4.1 Operationalizations of constructs

4.1.1 Syringe technologies

Four types of syringe technologies were included in the study. The following written descriptions of each technology were provided to each care-giver participating as a subject in the study.

(1) The standard syringe offers no special safety features to prevent a person from reusing the syringe or preventing needle sticks. This is the standard, widely-used, disposable syringe.

(2) The self-destruct syringe does not allow the syringe to be used more than once. Existing designs for this technology include a needle clogging feature and a plunger breakdown mechanism. This technology offers no needle protection.

(3) The manual needle protection syringe allows the user to initiate a needle covering mechanism that protects against needle sticks. This mechanism locks into place, thus, preventing further use. Existing mechanisms for this technology include slipdown sheathes, retracting needles, and special needle removal devices. These mechanisms must be initiated by the user after completing patient-injection.

(4) The automatic needle protection syringe is similar to the manual needle protection syringe except that the onset of the needle covering and locking mechanism occurs automatically.
The automatic needle protection syringe (ANPS) had been developed by a research team at a medical college at a large, southern US university in the late 1980s. Field trials of this new technology confirmed that the syringe performed as designed with a high degree of reliability. Care-givers participating in the study were given only limited information about each of the four technologies. At the end of the data collection procedure, each subject was asked if they had prior awareness of, and had used, each of the four technologies. Data only for subjects with no prior knowledge of ANPS were included in the study; only three care-givers interviewed reported awareness of the ANPS.

4.1.2 Syringe sizes

Four syringe sizes were included in the study: 1, 2, 3, and 5 ccs. We wanted to test the assumption that many care-givers preferred not to have the 2 cc size readily available and preferred to use the 3 and 5 cc syringe size. The assumption is that the 2 cc syringe size is the most popular with drug abusers. From a manufacturing viewpoint, including syringe size as an independent variable might provide initial information on the relative quantities to manufacture of each size.

4.1.3 Designers

Four possible designers were included in the study.

(1) Becton & Dickinson (B&D) is a designer and manufacturer of syringes well-known by care-givers.

(2) Safety-Ject Corporation (S-J) is a small start-up company with no history of designing and manufacturing syringes. S-J does market special safety catheters; at the time of the study, S-J had designed a new, safety syringe technology but had not tested the product in field trials.

(3) Johns-Hopkins University was selected as a designer category in the study because this institution had designed a self-destruct syringe that had received substantial publicity in both popular and medical news media.

(4) Vanderbilt University was selected because this institution has a medical college similar in size and reputation to the medical college planning to market the new ANPS technology. Because the medical college developing the ANPS technology was well-known to most of the respondents in the study (both the members of the sample and the medical college are located in the same US city), Vanderbilt University was selected to be more representative of care-giver awareness and experience levels.

4.1.4 Distributors

Two category levels of distributors were used: Becton & Dickinson and Safety-Ject Corporation. B&D distributes its own and competitors’ medical products. S-J is a small manufacturer distributing its own medical products.

4.1.5 Prices

Five syringe prices were used in the study, in US dollars: 0.10; 0.18; 0.32; 0.56; 1.00.
These prices were based on the assumption of an annual purchase contract. The two endpoint prices were selected first to be representative of price extremes not often provided to medical facilities; the price points in-between the two extremes represent 78% increases from the previous, lower price.

4.2 The two fractional-factorial designs used in the study

A full-factorial design of the five factors described includes 640 syringe feature combinations: 4 technologies by 4 sizes by 4 designers by 2 distributors by 5 prices. To reduce the number of combinations to a manageable set, the Sawtooth Software [5] program was used. A total of 25 feature combinations was necessary to achieve independence of levels of the five factors ($r = 0.00$).

Two unique sets of 25 feature combinations were created for the study. The study was planned to include having each subject complete two evaluation and choice tasks—once for each set of 25 combinations. This procedure was planned to enable a validation of utility estimates of factor levels from each set of 25 combinations.

4.3 Population and sample

A quota sample of care-givers was selected from ten different health care facilities located in a large, southern, metropolitan area of the USA. The attempt was made to have the sample include equal proportions of health care workers providing care to HIV/AIDS patients and providing care to patients not known to have HIV/AIDS; also, the attempt was made for 50% of the sampled care-givers to be involved directly in buying syringes and 50% having no direct involvement in buying syringes. All care-givers participating in the study administered medications via syringes to patients on a daily basis.

4.4 Data collection procedure

Personal on-site interviews were used to collect the data for the study. Each care-giver in the sample was interviewed individually. Each interview was 20 to 35 minutes.

Two choice problems were presented to each subject: one problem for each of the two sets of 25 syringe feature combinations. For each problem written descriptions of each of the 25 syringes were presented on separate cards to the subject. An example of one of these cards is shown in the Figure 1. The subject was asked to divide the set of 25 cards into two piles: one pile of syringes s/he would prefer to use and the second pile of syringes s/he would prefer not to use.

Each subject was then asked to allocate 100 points among the syringes in the pile they would prefer to use with each point representing a usage requirement s/he experienced typically. Each subject was informed that the 100-point allocation could be made in any way preferred among the syringes in her/his consideration pile.

Following the completion of the first choice problem, the second choice problem was presented to each subject. The same procedure was used to complete this second task by each subject as was used in solving the first problem.
Figure 1 Example of card of syringe alternative shown to respondent

**Technology:** A self-destroy syringe that does not allow the syringe to be used more than once because the syringe has a needle clogging feature and the plunger operates for one use only. This technology offers no needle protection.

**Syringe size:** 2 ccs

**Designer:** Safety-Ject Corporation, a small start-up company with no history of designing and manufacturing syringes.

**Distributor:** Becton & Dickinson, a designer, manufacturer, and wholesaler of medical supplies

**Price:** $0.32 per syringe

**instructions:** If you place this design in the pile of syringes which you prefer, how many of the 100 points available do you allocate to the syringe described on this card? Please feel free to assign 0, 1, 2, 5, 10, 20 or any number of points to the design shown on this card, given that the total number of points you assign to all cards sums to 100 points.

The points you assign to the syringe shown above:

4.5 Data analysis

For analyzing the data, each syringe in the reject pile was assigned a zero; each syringe included by the subject in her/his consideration set was assigned a minimum value of 1. A normalized score was assigned to syringes assigned points by the subject based on the number of points left after assigning a minimum of 1 point for each syringe in the consideration set.

For example, if a subject selected 12 syringes for consideration, but awarded 60 points to one syringe and 40 points to a second syringe, then we assigned one point each to the ten syringes considered by not awarded points and divided the remaining 90 points 60 and 40% to the two syringes awarded points by the subjects: 54 points to the syringe originally assigned 60 points and 36 points to the syringe originally assigned 40 points by the subject.

This procedure enabled us to distinguish between syringes ‘short-listed’ (considered) but not finally chosen for use by subjects versus syringes rejected from the start of the exercise. The two-step selection procedure reflected how many firms actually buy products [6].

Ordinary least squares (OLS), multiple regression analysis was used to estimate the utilities of factor levels on the dependent variable (i.e., share of points). Effect coding (see Pedhazur[7], pp.289—296) was used to assign values to all independent variables. Because a negative linear price and share-points relationship was found, the models reported in the results section include the raw values for prices not the partial regression coefficients based on effect coding. When effect coding is used, the total values of the b-coefficients for a given variable sum to zero.

For example, distributor as a variable in the study had two categories: B&D and S-J.
B&D was coded +1 arbitrarily and S-J was coded –1. The resulting b-coefficient for distributor from the multiple regression analysis for the full-factor model was + 0.06. Consequently, the b-coefficient for B&D was + 0.06 and the b-coefficient for S-J was –0.06. These values indicate a very small increase or decrease in share-points for the change in distributor, that is, the influence of distributor on syringe choice is minor.

Both individual and group-level analyses were performed on the data. Details of the results are reported next.

5 Results

Two individual, multiple regression models were run for each respondent — one for each conjoint design problem. The model from the first, survey data set was used to predict the scores of the second survey data set, and vice versa.

| Table 1 Regression model and significance test results for total sample of care-givers |
|-----------------|--------|--------|--------|--------|
| Variable        | b      | Sb     | t      | p<     |
| Constant        | 6.47   | 2.81   | 2.30   | .05    |
| Size: 1cc       | a      |        |        |        |
| 2cc             | -1.61  | 0.46   | -3.51  | .001   |
| 3cc             | 2.21   | 0.60   | 3.67   | .001   |
| 5cc             | -0.14  | 1.40   | -0.10  | n.s.   |
| Technology:     |        |        |        |        |
| Manual          | -0.50  | 2.94   | -0.17  | n.s.   |
| Automatic       | 6.92   | 1.09   | 6.36   | .001   |
| Self-destruct   | -1.77  | 0.81   | -2.19  | .05    |
| Regular         | a      |        |        |        |
| Distributor     |        |        |        |        |
| B & D           | 0.06   | 0.07   | .81    | n.s.   |
| Safety-Test     | a      |        |        |        |
| Designer        |        |        |        |        |
| Safety-Test     | -1.00  | 0.52   | -12.92 | .10    |
| Johns-Hopkins   | -0.08  | 0.50   | 0.16   | n.s.   |
| B&D             | 2.31   | 0.55   | 4.18   | .001   |
| Vanderbilt      | a      |        |        |        |
| Price           | -5.73  | 0.56   | -10.16 | .001   |

The main findings reported in Table 1 are based only on the data from the second survey. Some of the respondents did not fully understand the ‘buying’ task until they had completely gone through the first exercise (i.e., made choices in the first set of 25 syringes). During the first survey some respondents asked questions about the task during their deliberations. For the second task, all respondents appeared very confident in their abilities to complete the task as assigned; almost no questions were asked by any subject. We concluded that the second survey provides higher accuracy of how the subjects would make choices of syringes.
For the grouped data, the adjusted $R^2$ of .52 in Table I is highly statistically significant ($p < .0001$). However, a substantial variance was found in the $R^2$'s for the individual models. On an individual basis, about half of the subjects had useful models (i.e., with significant $R^2$'s and half did not). The degree of usefulness of the models did reflect the respondents' involvement in buying syringes: 80% of the respondents involved with buying syringes had useful models, while only 34 percent of the respondents not involved in buying syringes had useful models.

Similar levels of explained variance are reported in previous studies using conjoint research methods as described here (see Scott and Keiser [8]; Page and Rosenbaum [9]). The high levels of adjusted $R^2$'s found for some subjects likely reflects the use of substantial degrees of freedom available in the regression models tested and these subjects strong preference orderings for specific feature levels. As noted, some other subjects appear to provide almost a random walk in making responses; consequently, very low adjusted $R^2$'s were found for these subjects.

$H_1$ supported: the new syringe technology is preferred

The results include confirmation of the first hypothesis. Share increased 6.92 points the new ANPS (automatic needle protection syringe). This $b$-coefficient was highly significant ($t = 3.67$); details are reported in Table 1.

$H_2$ supported: price has a strong negative influence on share-points

The $b$-coefficient of -5.73 for price was highly significant (see Table 1). The results lead to the strategy implication that a high price, ‘skimming strategy’, would likely lead to substantially lower penetration that could be otherwise achieved for the new ANPS technology.

$H_3$ partially supported: the 3 cc size is preferred

Share for a syringe increased for the 3 cc size by 2.21 points; this result was significant statistically. See Table 1.

The results do not support the hypothesis that care-givers prefer the 5 cc size. However, the results do confirm the hypothesis that care-givers prefer not to select the 2 cc size.

The strategy implication of these findings include the suggestion that if one-size only is to be offered of the new ANPS that the size be 3 cc.

$H_4$ supported: respondents prefer the well-known designer-manufacturer

The results include an increase in share for the syringe offered by B&D by 2.31 points. The $b$-coefficients for the other three identified manufacturers were negative but not highly significant statistically. Details are reported in Table 1.

The strategy implication of these findings include the observation that associating the new ANPS technology with a well-known syringe manufacturer will likely help increase care-giver adoptions of the new technology.

$H_5$ not supported: distributor named does not impact share-points

The findings include a non-substantial influence of distributor on the respondents’ award of share-points. Detailed findings are included in Table 1.
The strategy implication of these results includes the suggestion that using a less well-known distributor is likely to be more acceptable to buyers of syringes compared to offering the new ANPS by a less well-known manufacturer.

**H₆ partially supported: non-buyers more strongly prefer the new ANPS**

The results did not support H₆a: a more positive b-coefficient was not found among care-givers of HIV/AIDS patients (n = 16) versus care-givers of patients not known to have HIV/AIDS (n = 11). The two resulting b-coefficients were nearly identical (i.e., in standardized, beta units, .45 and .44, respectively for the two care-giver segments).

The results did support H₆b: syringe non-buying care-givers more strongly preferred the new ANPS technology compared to syringe buying care-givers. In standardized units, the beta coefficients were .51 versus .37, respectively for the two groups. Differences in beta coefficients larger than .08 can be considered to be substantial [7].

The strategy implications of these results include the suggestion to reach beyond care-givers responsible for buying syringes in promoting the new ANPS technology. The need for such a new technology is widespread; concentrating marketing strategy only on care-givers of HIV/AIDS patients may not be as beneficial as reaching multiple segments of care-givers classified by patient-type.

**Validation results**

The overall, average R² results for using the model from the first data set to predict the scores of the second data set, and vice versa, were .39 and .42, respectively. Details are provided in Table 2.

<table>
<thead>
<tr>
<th>Explained Variance (R²)</th>
<th>Model 1 Predicting Data Set 2</th>
<th>Model 2 Predicting Data Set 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above .45 (p&lt;.01)</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>.35 to .45 (p&lt;.05)</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Below .35 (n.s.)</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Average R²</td>
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<td>.42</td>
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<tr>
<td>p&lt;</td>
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<tr>
<td>n</td>
<td>28</td>
<td>28</td>
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</tbody>
</table>

These validation results provide substantial support for the usefulness of the regression models in understanding and predicting care-giver choices of alternative designs of syringe technologies and marketing approaches. However, on the basis of individual respondents, the regression models were not useful in all cases. Details appear in Table 2.

The strategy implications from these validation results include the observation that the selection of subject for decision task is very important. Some care-givers may be found to be less able or willing than others to provide accurate information on how they are likely to make choices and rejections of syringes.
6 Conclusions, limitations and suggestions for future research

Research on care-giver acceptance of new health care technologies is likely to provide valuable information for the physical design of the new technologies and marketing strategies to gain user acceptance. Manufacturers and marketers of health care products need concrete estimates of how much impact different product designs will have on the buying decisions of individual and segments of customers.

The main objective of this report has been to provide specific findings on how much positive and negative impact is likely to occur by changing the product design and marketing mix on a potentially important new health care technology. A second objective has been to illustrate a useful health care research approach to learn such information.

The reported study is based on a small sample of care-givers located in one metropolitan area of the USA. Additional studies are needed that confirm the results described before firm conclusions are reached on the sizes of influence of the different factor levels tested. The findings from the empirical study are exploratory only.

Suggestions for future research include testing service-provider acceptance of alternative syringe designs using operational prototypes (working models) of the alternative technologies. Are the results from pencil-and-paper tests of preferences match well with preferences found from actual experienced-based, that is, touching and using, the alternative technologies?

Such behavioural-based testing might be limited to only a few of the most preferred designs. However, a more scientific approach to adopt would be to include two to three alternative product designs tentatively found to be low, moderate, and high in service-provider acceptance. Behavioural-based testing of only the designs found to be most preferred from pencil-and-paper tests reduces the ability to discriminate the impact of realistic alternatives in feature levels. More importantly, some key results from pencil-and-paper tests of service-provider acceptance may be disconfirmed by behavioural-based tests of operational prototypes.

Thus, not placing all eggs-in-one-basket is sound advice for researchers in user-acceptance of new medical technologies. Preferring a written description of a new versus old technology is not the same as actually adopting the new and eliminating the old.

References