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Maximum-Accuracy Multiple Regression Analysis: Influence of Registration on Overall Satisfaction Ratings of Emergency Room Patients

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Quality improvement research conducted in an effort to obtain and maintain the maximum possible level of patient satisfaction is an on-going process at many hospitals. This study analyzes survey data from 773 patients receiving care at a private Midwestern hospital's Emergency Room (ER). Multiple regression analysis, optimized by UniODA to maximize predictive accuracy, was used to assess the extent to which ratings concerning the registration process are predictive of overall satisfaction ratings. Results indicated that ratings of helpfulness of the triage nurse, ease of the process to obtain insurance/billing information, waiting time before going to the treatment area, and convenience of parking together explained 50.1% of the variance in overall satisfaction ratings, corresponding to moderate accuracy (ESS=32.8). The maximum accuracy was obtained using UniODA to adjust model decision thresholds, and improved by 20.1% but remained moderately strong (ESS=39.4).

A broadly accepted marker of quality of medical care, patient satisfaction is widely studied and many measures are used in its assessment.[1] The modeling of satisfaction ratings as a function of rated aspects of the medical encounter usually involves linear regression models including five to fifteen attributes, explaining less than 70% of the variance in overall satisfaction ratings.

In the present investigation patients rated different aspects of care they received in initial registration, and from nurses and doctors, and in the laboratory (blood, radiology), and in treatment of family and friends, if applicable. Multiple regression analysis[2] (MRA) was used to identify ratings exerting strongest influence on overall satisfaction ratings. Rather than use all the ratings in a single grand analysis, the present study adopts the manufacturing approach of assessing how to maximize quality (satisfaction) at every stop in the assembly line (the patient's journey into and through ER). This study thus investigates the influence of the registration process in affecting patient ratings of overall satisfaction with ER services.

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Method

Survey data were obtained for a sample of 773 patients who received care in the ER of a private Midwestern hospital. The dependent measure for the MRA is overall satisfaction with care received in the ER. Independent variables used in analysis included helpfulness of the triage nurse; helpfulness of the person at the registration desk; courtesy of security personnel; privacy felt during the intake interview; process to obtain billing/insurance information; waiting time to go to the treatment area; comfort in the registration waiting room; and the convenience of parking. Ratings were made using categorical ordinal 5-point Likert-type scales: 1=very poor, 2=poor, 3=fair, 4=good, 5=very good.[3] Decision thresholds used to evaluate the predicted score (*Y**) computed using the MRA model were optimized by UniODA to explicitly maximize accuracy as assessed using the ESS index.[3,4] There were no missing data because MRA uses casewise deletion: any observation with a missing value on any variable included in the model is omitted from analysis.[2]

Table 1: Descriptive Statistics for Study Measures (n=773)

Rating	Mean	SD
Overall satisfaction	4.10	1.14
Helpfulness of triage nurse	4.28	0.96
Helpfulness at registration desk	4.20	0.98
Courtesy of security personnel	4.20	0.95
Privacy felt during intake interview	4.02	1.03
Billing/insurance process	4.20	0.93
Waiting time in registration area	3.71	1.34
Comfort in registration area	3.65	1.19
Parking Convenience	3.65	1.27

Note: All ratings were obtained using 5-point Likert-type scales: 1=very poor; 5=very good.

Results and Discussion

Descriptive statistics for study measures are given in Table 1. All means exceeded the 5-point scale midpoint value of 3, distributions are negatively skewed, and modest variability indicates relatively homogeneous responding among patients. The final MRA model was: Y^*=0.55+ 0.20*(billing and insurance)+0.27*(helpfulness of triage nurse)+0.26*(wait time in registration area)+0.17*(parking convenience). The model was statistically significant: $F(4,768)=192.8$, $p<0.0001$, $R^2=0.50$. All four independent variables made a statistically significant independent contribution to overall R^2 (all p's< 0.0001).

Table 2 presents cutpoints used on Y^* to obtain predicted "target" values, for each of the five values of the dependent variable: first for standard regression analysis (these cutpoints are used for making classification decisions for all 5-point Likert-type scales); and second for optimized regression analysis (explicitly optimized for the sample, cutpoints are computed by UniODA[3]). For example, for Y^*=3.02 the dependent measure is predicted to be 3 by standard MRA, versus 2 by optimized MRA.

Table 2: Cutpoints on Y^* used for Obtaining Predicted Target Value, for Standard and Optimized MRA Models

Target	Standard MRA	Optimized MRA
1	$Y^*<1.5$	$Y^*<2.4$
2	$1.5 \leq Y^*<2.5$	$2.4 \leq Y^*<3.1$
3	$2.5 \leq Y^*<3.5$	$3.1 \leq Y^*<3.5$
4	$3.5 \leq Y^*<4.5$	$3.5 \leq Y^*<4.4$
5	$Y^*\geq 4.5$	$Y^*\geq 4.4$

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Table 3 summarizes classification results obtained using standard *vs*. optimized regression to predict observations' overall satisfaction ratings. Shown for both regression approaches, for all target values, is the total number of correct predictions of the target value divided by total number of instances of the target value in the sample, and the corresponding sensitivity (accuracy) of the MRA model for each target value.

Table 3: Predicting Individual Target Values by Standard *vs*. Optimized MRA

Target	Standard Regression		Optimized Regression	
1	10/43	23.3%	20/43	46.5%
2	6/44	13.6%	14/44	31.8%
3	43/77	55.8%	32/77	41.6%
4	172/240	71.7%	163/240	67.9%
5	246/369	66.7%	257/369	69.6%
ESS	32.8		39.4	

Note: Tabled for each Target Value (for each different integer between 1 and 5) are the number of correctly predicted (numerator) Target Values; total number of each Target Value in the sample (denominator); and percentage accuracy or *sensitivity* obtained classifying each target Value. ESS is tabled for both standard and optimized MRA models. Greatest sensitivity obtained for each Target Value is indicated in red.

While standard MRA achieved greatest accuracy in predicting responses of 3 (fair) or 4 (good), optimized MRA achieved greatest accuracy in predicting responses of 1 (very poor), 2 (poor), and 5 (very good). Overall, the accuracy achieved by standard MRA (ESS=32.8) reflects a moderate effect, as does the accuracy achieved using the optimized model (ESS=39.3), which nevertheless reflects 20.1% higher classification performance.

Table 4 presents confusion tables for the standard and optimized MRA models. These clearly show the dominant positive skew: both actual and predicted overall satisfaction ratings are primarily either 4 or 5.

Table 4: Confusion Tables for Optimized and Standard MRA Models

Rating of Overall Satisfaction

Actual	Predicted 1	2	3	4	5
1	20	8	6	7	2
	10	10	14	7	2
2	5	14	13	11	1
	0	6	24	13	1
3	4	14	32	24	3
	0	5	43	26	3
4	1	13	30	163	33
	0	1	39	172	28
5	1	2	10	99	257
	1	0	10	112	246

Note: Cross-tabulation of predicted (columns) by actual (rows) overall satisfaction rating: results for the optimized MRA model are indicated using red.

An enhanced conceptual understanding of the findings is achieved by examination of *aggregated confusion tables* for the models, that consist of two columns and rows if the rating scale has an *even* number of rating categories, and three columns and rows for an *odd* number of rating categories—in which case the midpoint rating (e.g., 2 on a 3-point scale; 3 on a 5-point scale; 4 on a 7-point scale, etc.) constitutes the second row and second column (Table 5). For rating scales having an even number of response options the midpoint falls between two ratings, so the middle value is omitted from the aggregated table. As shown in Table 5, entries in the confusion table (Table 4) *lower* than midpoint are summed and entered on the left-hand side of the aggregated table, and entries in the confusion table *higher* than midpoint are summed and

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entered on the right-hand side. For example, for the intersection of actual and predicted ratings of 1 or 2: for the optimized model the entry in Table 5 (see Table 4) is 20+8+5+14=47; and for the standard model this entry is 10+10+0+6=26.

Table 5: Aggregated Confusion Tables for Optimized and Standard MRA Models

Rating of Overall Satisfaction

	Predicted		
Actual	1 or 2	3	4 or 5
1 or 2	47	19	21
	26	38	23
3	18	32	27
	5	43	29
4 or 5	17	40	552
	2	49	558

Note: See notes to Table 4.

Table 5 clearly shows the standard and optimized MRA model performance was essentially identical for patients predicted to score 4 or 5—that is, for the patients who are predicted to be basically satisfied. In contrast, the standard model predicted that 43% more patients used a midpoint rating of 3 compared to the optimized model (130 versus 91 patients, respectively): the most notable difference occurred for basically dissatisfied patients using values of 1 or 2 on the scale: as seen, the standard model misclassified 100% more patients who in reality were dissatisfied as being ambivalent, versus the optimized model. The greatest difference between standard and optimized models occurs for patients predicted to score 1 or 2—basically dissatisfied (33 *vs*. 82 patients, respectively). If the phenomena assessed by items in the scale were actionable in real-time, and if a potent intervention existed to address such phenomena in real-time, then the optimized MRA model would be able to prevent many more cases of dissatisfaction as compared with the standard model.

A jackknife or "leave-one-out" validity analysis was run to estimate the potential cross-generalizability of the optimized model, were it used to classify an independent random sample drawn from the same population.[3] An identical pattern of results emerged but ESS fell to 34.5% in jackknife analysis for the optimized model: lower accuracy was obtained for ratings of 1 (34.9%), 2 (29.6%), 3 (37.7%), and 4 (66.2%). We are unaware of statistical software that computes jackknife validity in this manner for MRA models. A total of 1,000 Monte Carlo experiments were used to estimate Type I error for the optimized results (p<0.0001), and analysis was completed in 1.27 CPU hours running UniODA[3] on a 3 GHz Intel Pentium D microcomputer.

References

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