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A Study of Influential Factors in Doctor's WOM Effect Within Online Medical Community

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Abstract: Online medical communities have bestially alleviated the traditional medical field problems that uneven distribution of medical resources and difficulty seeking medical treatment to a certain extent. Patients in the online medical community pay more attention to the doctors' word-of-mouth (WOM), resulting in the doctors' WOM effect. There are few studies on the influencing factors of doctors' WOM effect in online medical communities, hence this study has theoretical and practical application value. By integrating trust theory, social network theory, online reputation feedback mechanism and the research framework of WOM under the Internet, this study constructs factors' four dimensions that have an impact on doctor's WOM effect, combined with control variables to construct influential factors of doctor's WOM effect in the online medical community. The corresponding indicators that affect the doctor's WOM effect were built and sorted by random forest regression with the doctor's online medical community data. This study performed random permutations and multiple regression based on the selected variables integrated with the control variables to obtain the optimal model. The multiple regression analysis illustrates doctor's WOM effect with control variables exploring the interaction effect. This study explores the optimal model that affects the doctors' WOM effect in the online medical community and aims to reasonably guide the scientific operation of the online medical community platform.

Keywords: Online Medical Community, WOM Effect, Random Forest Regression, Multiple Regression

1. Introduction

The expansion of the network medical field has gradually enlarged, resulting in the continuous discovery of new models, such as online consultations with AI doctors. Online medical communities are developing rapidly, such as PingAn Doctor, Chunyu Doctor and Haodaifu Online. The "Internet + Medical" model is increasingly integrated into public life and the rapid development has improved the current situation of the traditional medical field [1]. The online medical community is a community network medical ecosystem that involves doctors and patients, integrates relevant resources of physical hospitals, provides efficient and convenient medical services for patients, reduces the cost of medical treatment for patients, and provides a platform that partakes experiences and exchange feelings for patients [2-4]. Doctors accumulate WOM in the online medical community, and patients choose doctors based on WOM information to expand the doctors' WOM effect. The continuous enhancement of the doctors' WOM effect is conducive to the platform development, the doctors' service and the patients' medical treatment, and eliminates the risks brought by information asymmetry and network uncertainty in the online network.

The study examines that the WOM effect is relatively sparse in online medical treatment and seldom involves network data for empirical research. Li X et al. proposed that neighbors influence purchasing decision behavior through the informal exchange of product or service related information [5]. Amblee et al. believed that consumers were influenced by WOM and increased their product knowledge, which in turn led to an increase in sales [6].

The method conforms internet data, artificial intelligence machine algorithms and statistical analysis in the existing literature research to explore the influence of Haodaifu online related indicators on the doctor's WOM effect, obtain the optimal research model. To more accurate anticipate the model that affects the doctor's WOM effect, it is necessary to add the control variables and analyze the interaction effect of the index variables. The results of this study recommend that rational operation of the platform, the scientific improvement of the doctors' WOM effect and the convenience for patients to find adaptable doctors.

2. Literature Review

Britt excavates WOM based on social science theory research results, while introducing WOM research into the behavioral consumption field [7]. Arndt delimits WOM as the communication between people concerning products under the premise of non-commercial entities [8]. This study argues that WOM is the doctor-patient communication, which is informal and non-commercial in online medical community. Katz E disclosures that the influence of WOM is more brilliant than that of advertising or personal promotion [9]. Then Whyte believes that people often influence each other inadvertently [10]. Chatterjee believes that online WOM effect refers to the non-profit communication between product providers and customers [11]. Based on previous literature, this study defines the doctor's WOM effect as the communication between patients about doctor-related information and have an impact on the patient's psychology or behavior, comprising the patient's medical treatment choice or the willingness to spread.

In line with the trust theory content, it can be seen that trust exerts an enormous function on between doctors and patients [12]. Harvir et al. and Xu Lin illustrated that trust push forward an immense influence on WOM spread [13, 14]. Homogeneous individuals in social networks have more intimate relationships, and relationship strength is positively correlated with homogeneity. The proliferation of WOM effect is based on the WOM spread, which composes a social network through disseminators [15].

Ground on the online reputation feedback mechanism theory, it is known that online reputation feedback potently responses information asymmetry and opportunism problem [16, 17]. The online reputation feedback in the online medical community can reflect the doctors' WOM, thereby converting the patients' psychology or behavior and expanding the WOM effect. Based on the research on the WOM model framework under the network, receivers have preferable confidence in transmitting WOM information as experts [12]. Zhang Jingjing believes that the source professionalism plays a consequential role in the WOM effect [18].

3. Methods

3.1. Theoretical Model

Trust stems from psychological research. By introducing trust into psychology through the Prisoner's Dilemma experiment, Deutsch defined trust as the individuals' irrational choice behavior in the face of uncertain events [19]. In the study of e-commerce, trust has always been a crucial and one of the most influential factors [20]. Online transactions are impossible if consumers suspect the seller [21]. Trust is defined as "The aspiration of one party to accept the actions of the other party" [22]. Trust is "Willingness to rely on reliable partners who keep their promises" [23].

Weak tie advantage theory sourced from Granovetter's "The Power of Weak Ties", published in 1973, first proposed bond strength idea [24]. Granovetter distinguishes strong and weak relationships from four dimensions (intimacy, interaction frequency, emotional strength and reciprocal exchange). Hu et al. reviewed that the impact of strong ties on the horizontal spread of the WOM market is more excellent than that of weak ties, which drive growth and the advantages of strong ties increase with the connection between consumers [25]. "Social capital" was first proposed by French sociologist Bourdieu. Coleman pointed out that the strength and quantity of social capital are reflected in the measurement of the social structure resources and property owned by social individuals [26].

Resnick et al. defined the online reputation feedback system as a reputation management mechanism, which refers to the fact that based on the relevant information collection of user historical feedback in the Internet environment, coupled with stimulating the cooperative behavior between unfamiliar users in the network [27]. On the one hand, online reputation feedback in the online medical community reflects the doctors' excellent reputation, thereby bringing about patients' psychological or behavioral changes. On the other hand, promote the healthy development of online medical community platforms.

Gilly et al. constructed the classic WOM model for the first time [28]. They believe that WOM affects consumers' decision-making behavior mainly in three dimensions: the characteristics of information sources, the similarity between consumers and information sources and the consumers' characteristics. The characteristics of information sources comprise expertise and opinion leader. The similarity incorporates demographics and perception. The consumers' characteristics embrace expertise and partiality.

This study combines the research on the WOM model under the Internet with the above three theories: trust theory, online reputation feedback and social network theory, then analyze from four dimensions: relationship strength, doctor's professionalism, trust and online reputation feedback. Based on literature research, 24 independent variables and 2 control variables representing four dimensions selected from the Haodaifu online community and the WOM effect is used as the dependent variable so that the research model is formed, as shown in Figure 1:

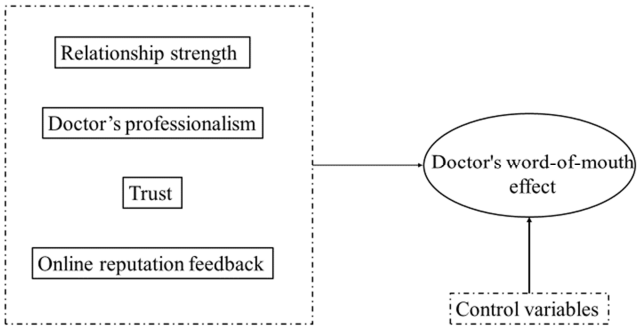

Figure 1. *Research model of doctor's WOM effect in online medical community.*

3.2. Variable Selection

Relationship strength refers to physician-patient intimacy and patient-to-patient intimacy. High relationship strength has a remarkable impact on the doctors' WOM effect. This study measures the relationship strength from the two aspects. On the one hand, the strength of the doctor-patient relationship is measured by featured consultations, the total number of doctor-patient conversations, doctor-patient conversations count per time, doctor-patient conversations count per time, and patient conversations count per time. The increase in the number of doctor-patient conversations weakens the information asymmetry problems, thereby enhancing the strength of the doctor-patient relationship. On the other hand, the indicators for the relationship strength between patients based on patient-friend associations count, the number of patient-friend association members, the number of patient-friend association topics and patients in each patient-friend association amount.

Trust refers to the level that patient believe doctor. In the online medical community, trust affects the doctor-patient relationship and promotes the dissemination of WOM information from patients to doctors, thus affecting the doctors' WOM effect. Trust in the online medical community affects not only the patients' gladness to choose a doctor, but also the patients' enjoyment to disseminate WOM information about doctors. Indicators explaining trust in the Haodaifu online medical community comprise online consultations amount, online service satisfaction, efficacy satisfaction and text readings. Patients choose the doctor they trust most. The research on relationship between satisfaction and trust found that satisfaction has vigorous impact on trust [29-31].

A doctor's professionalism refers to the technical ability. In the online medical community, doctors display their identity, so that patients understand their professionalism, which promotes WOM spread. Chaiken et al. pointed out the significance of WOM information source identity [32]. In Haodaifu online medical community, the indicators that explain the doctors' professionalism are mainly considered from the doctors' presentation. Therefore, we selected the doctor's title, patients count after diagnosis, distinguished characters, introduction characters, valuable comments and articles.

Online reputation feedback refers to the patients' feedback on the doctors' recognition after treatment. Every feedback is exceptionally significant to the patient, because of the medical field specificity. The continuous increase of online reputation feedback affects the doctors' WOM effect. In the Haodaifu online medical community, online reputation feedback is explained diametrically and oblique. The flush point of view refers to the results obtained from the patient, such as post-diagnosis service stars, thank-you letters and gifts; the oblique point of view refers to the platform's results based on the feedback indicators after the patient's visit, such as the Haodaifu title.

In the online medical community, patients receive doctors' WOM information, which affect patients' psychological or behavioral changes, thereby spreading the WOM effect. In addition to 24 variables in four dimensions, including relationship strength, trust, doctor professionalism, online reputation, the hospital level and the city affect patient. To construct a more reasonable model, the hospital level and the city should be considered as control variables [33, 34]. Use python to crawl relevant data of the Haodaifu online. Quantify doctor titles, hospital grades coupled with hospital cities and integrate data filtering to form tables.

4. Results

4.1. Random Forest Regression

Variable Importance Measure (VIM) demonstrates random forest regression and based on Mean Squared Error (MSE). The principle randomly assigns each variable to obtain the corresponding predicted value and MSE. The larger the MSE, the more vital the variable.

$$MSE_{OOB} = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i^{OOB})^2 \quad (1)$$

$$R_{RF}^2 = 1 - \frac{MSE_{OOB}}{\hat{\sigma}_y^2} \quad (2)$$

There are two substantial parameters in the random forest regression model operation. They are n-tree (regression trees number) and m-try (random variables amount of the regression tree branches). When the value of n-tree is 400, the decline of the forest regression error tends to be balanced. When m-try=7, the MSE takes the minimum value and the running time is within the acceptable range. The "var explained" represents the fitting effect. Fix the parameters and run the model to get % Var explained= 67.75, indicating that the fitting effect is excellent and this parameter is suitable for variable consequential model analysis.

The evaluation of variables in the random forest regression model is measured by the average decrease of the mean square error, which is %IncMSE [35]. By setting the parameters above, the result is shown in Table 1.

Table 1. *Summary of variable importance results.*

Importance interval	Variables
Upper intervals	X4, X12, X14, X21, X22, X23
Median intervals	X1, X3, X5, X7, X15, X17, X20
Low intervals	X2, X6, X8, X9, X10, X11, X13, X16, X18, X19, X24

According to Table 1, the ponderance of the 24 variables is divided into three intervals. The first six variables are divided into upper intervals, which comprise: doctor's conversations number per time (X4), the efficacy satisfaction (X12), the doctor's title (X14), votes count (X21), thank-you letters (X22), heart gift (X23); The variables from the 7th to the 14th are divided into median intervals, which are: selected consultations (X1), doctor-patient conversations number (X3), patient conversations amount (X5), patient-friend associations count (X7), online consultations number (X10), the patients number after diagnosis and treatment (X15), characters introduced count (X17), the service stars after diagnosis and treatment (X20); and the remaining variables are low intervals: the total number of doctor-patient conversations (X2), patient friend associations amount (X6), the number of patient friend association topics (X8), the patients number in each patient friend association (X9), online services satisfaction (X11), articles read count (X13), character expert count (X16), useful comments amount (X18), articles number (X19), Haodaifu title (X24). In the online medical community, the variety affects the patient's mentality or behavior mainly come from the online reputation feedback dimension. Relationship strength, doctor's professionalism and trust have an impact on patients. In the median interval, the relationship strength has the most decisive influence, followed by the doctor's professionalism and finally the online reputation feedback.

4.2. Multiple Regression

According to the previous research, 15 models were obtained by permuting and combining four variables from six variables, and the models were evaluated by multiple linear regression. The study selected six variables in the upper interval for correlation analysis. After measurement, it was disclosed that there was no multicollinearity among the variables.

The 15th model has the largest R^2 (R^2=0.593), so the fitting effect is momentous. The four variables of the model are the number of doctor's conversations per time (X4), efficacy satisfaction (X12), the doctor's title (X14) and votes count (X21). Correlation analysis and multicollinearity tests are required, because of the control variables. The Table 2 illustrates that the correlations are all less than 0.8 within the acceptable range and the VIF is less than 2, thus there is no multicollinearity.

Table 2. *Variable correlation coefficient and collinearity diagnosis.*

Variable	1	2	3	4	5	6	2	2
X4	1						.723	1.383
X12	.506	1					.555	1.801
X14	-.299	-.426	1				.794	1.259
X21	.355	.487	.355	1			.793	1.352
K1	-.032	-.054	-.032	-.005	1		.908	1.101
K2	.032	.014	.032	.084	.289	1	.908	1.101

Multiple regression modeling analysis was performed based on the correlation and collinearity test results. Build Equation (3).

$$Y = \beta_1 X_4 + \beta_2 X_{12} + \beta_3 X_{14} + \beta_4 X_{21} + \beta_5 K_1 + \beta_6 K_2 + \varepsilon \quad (3)$$

Table 3 and Table 4 manifest the results. Model 1 only added control variables and model 2 added independent variables on the basis of control variables. Table 3 demonstrates the model fitting effect is enhanced after adding the independent variable. The adjusted-R^2 is 0.597 indicating that the model fitting effect is excellent. Sig. is 0.000 represents that the model is considerable and crucial.

Table 3. *Model summary.*

Model	R	R^2	Adjusted-R^2	F	Sig.
1	.125	.016	.015	21.132	.000
2	.773	.598	.597	661.103	.000

The results of Model 2 in Table 4 indicate the number of doctor's conversations per time (regression coefficient=0.030, p<0.05), satisfaction with curative effect (regression coefficient=0.351, p<0.05), doctor's professional title (regression coefficient=0.078, p<0.05) and votes count (regression coefficient=0.537, p<0.05) had an active impact on the doctor's WOM effect. This declares that relationship strength, trust, doctor's professionalism and online reputation feedback positively effect doctor's WOM effect. Hospital city (K2) affects relationship strength, trust, physician professionalism and online reputation feedback. Economically developed cities affect patients' perception and understanding concerning doctors, thereby affecting the WOM effect.

Table 4. *Model regression results.*

Model		B	Unstandardized Cofficients	Standardized Cofficients	t	Collinearity Statistics		
			Std. Error	Beta		Sig	Tolerance	VIF
1	K1	-.006	0.20	-.006	-.323	.747	.793	1.091
	K2	.127	0.20	.127	6.31	.000	.908	1.091
2	K1	.021	.013	.021	1.653	.098	.908	1.101
	K2	.064	.013	.064	4.962	.000	.908	1.101
	X4	.030	.014	.030	2.066	.039	.732	1.383
	X12	.351	.016	.315	21.276	.000	.555	1.801
	X14	.078	.014	.078	5.687	.000	.794	1.259
	X21	.537	.014	.537	37.280	.000	.739	1.352

4.3. Interaction Effect

The hierarchical regression analysis of the four variables aims to inspect the interaction effects' existence. The result in Table 5 indicates that there was no interaction effect in other models except for model 2 and model 3, therefore we conducted the further simple effect analysis.

Table 5. *Summary of hierarchical regression analysis results.*

variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
K2	.070**	.070**	.070**	.608**	.069**	.072**	.069**
X4	.030*	.024	.026*	.041**	.029**	.027	.027
X12	.350**	.353**	.353*	.319**	.357**	.537**	.316**
X14	.080**	.081**	.085**	.078**	.104**	.083**	.091**
X21	.537**	.535**	.537**	.601**	.539**	.007	.533**
X4*X12		.061					
X4*X14			-.018				
X4*X21				-.087**			
X12*X14					-.041**		
X12*X21						.468**	
X14*X21							-.064**
F	792.262	660.591	660.716	671.384	663.269	668.355	671.087
R^2	.598	.598	.598	.602	.599	.601	.602

Note. * evinces 0.05 significant level;
** evinces 0.01 significant level.

The study divides the explanatory variables into categorical variables. The mean becomes the cut point after normalizing the data, distinguishing the continuous variable into two dimensions and high levels are represented by 1 and low 0.

Table 6. *Simple effect test.*

X21	X4	X4	Average difference	Standard error	salience
Low	Low	High	-.020	.038	.609
	High	Low	.020	.038	.609
High	Low	High	-.138	.062	.027
	High	Low	.138	.062	.027

According to the simple effect test: (1) Regardless of the relationship strength, online reputation strongly influences the doctors' WOM effect. In high online reputation feedback, the relationship strength positively impacts the doctor's WOM effect, but the relationship strength has no apparent impact on the doctor's WOM effect in low cases. (2) No matter the trust, the doctors' professionalism positively impacts the WOM effect. Regardless of professionalism, trust has an energetical impact on the WOM effect. (3) In the low trust, online reputation feedback does not affect the doctor's WOM effect, and online reputation feedback has a beneficial impact on the doctor's WOM effect in the high trust. In the low online reputation feedback, the doctor's professionalism impacts the doctor's WOM effect. However, the doctor's professionalism has no essential impact on the doctor's WOM effect in the high case whether online reputation feedback trust has an aggressive impact on the doctor's WOM effect. (4) Whether the doctors' professionalism or not, online reputation feedback has a feisty impact on the doctors' WOM effect.

The variables with interactive effects were curative effect satisfaction (X12) and doctor's professional title grade (X14), while other variables' interaction effect partially exists not considered. To further examine the influence mechanism of main effects and interaction effects, multiple linear regression performed by using Equation (4).

$$Y = \beta_1 X_4 + \beta_2 X_{12} + \beta_3 X_{14} + \beta_4 X_{21} + \beta_5 K_2 + \beta_6 X_{12} X_{14} + \varepsilon \quad (4)$$

Table 7 reveals the R^2 is 0.599 after adding the interaction effect and excellent simulation fit. The fundamentality of the coefficients is less than 0.05, therefore each variable has an essential impact on the dependent variable.

Table 7. *The results of model regression.*

Model		Unstandardized Cofficients		Standardized Cofficients	t	Sig.
		B	Std. Error	Beta		
1	K1	.070	.012	.070	5.668	.000
	X4	.030	.014	.030	2.053	.040
	X12	.350	.016	.350	21.241	.000
	X14	.080	.014	.080	5.817	.000
	X21	.537	.014	.537	37.577	.000
2	K2	.069	.012	.069	5.577	.000
	X4	.029	.014	.029	1.992	.047
	X12	.357	.017	.357	21.455	.000
	X14	.014	.016	.104	6.440	.000
	X21	.539	.014	.539	37.722	.000
	X21*X14	-.043	.015	-.041	-.821	.005

Note. * evinces multiplication.
Model 1 R=0.773, R^2=598, Adjusted-R^2=597, Sig.=0.000;
Model 2 R=0.774, R^2=599, Adjusted-R^2=598, Sig.=0.000.

5. Conclusion

The study integrates the WOM model, trust theory, social network theory and online reputation feedback to construct the model in Haodaifu online medical community. The ponderance of variables was screened ground on random forest regression. In the light of the %IncMSE results, vote number comprises the largest proportion of the upper interval variables, which implies that online reputation feedback change the patient's mind coupled with diffusion WOM effect. The variable with the maximum proportion in the median interval is the number of doctor-patient conversations per time confirms that the doctor-patient communication in online medical community affects patients most, and has excellent impact on doctors' WOM effect. The exceptional variable in lower interval pertain to the total number of doctor-patient dialogues indicates the relationship strength essentiality again.

This study performed random permutations and multiple regression based on the selected variables integrated with the control variables to obtain the optimal model. Ultimately, the interaction effect analysis expounds that the four variables in the optimal model positively impacted the doctor's WOM effect. The four variables originate from four dimensions, respectively. The votes number in the online reputation dimension has the most extraordinary impact, followed by the trust efficacy satisfaction, the doctor's professional title, and the number of the doctor-patient conversation representing the relationship strength. Patients who opt for doctors originate from other patients' feedback in the online medical community, and the vote number is the most intuitive affirmation after doctor treatment. Efficacy satisfaction is a trust indicator that denotes patients' trust level. The doctor's professional title is characteristic of the doctor's specialized subject indicates the doctor's discipline. The doctor's conversations number delegates relationship strength while each doctor's speech affects the diversification of patients' psychology or behavior, diffusing the doctors' WOM effect.

In the light of modelling results, the four variables bring about the doctors' WOM affect proliferation. The influential factors in WOM effect analysis suppose that platform operation should maintain patient-oriented, focus on doctor-patient trust, doctor's professionalism and community member relationship strength. The doctors' WOM effect diffusion should be patient-oriented; paying attention to building up patients' trust and displaying professionalism reinforces the doctor-patient relationship strength. Patients enhancing information availability aim to notice compatible doctors by comparison with votes amount, efficacy satisfaction, doctor titles, and doctor-patient conversations count. There are shortcomings in the study. For instance, the study data stem from Haodaifu platform are mostly quantifiable and exist single problem. The future study shall look forward to improving data processing by involving textual analysis while simultaneously amplifying data source platform to obtain still further universal results.

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