Research article

How do patients' perceptions and doctors' images impact patient decisions? Deconstructing online physician selection using multimodal data

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A B S T R A C T

In the post-pandemic era, medical resources are uneven, and access to healthcare is complicated. Online medical platforms have become a solution to bridge the information gap and reduce hospital pressure. This study uses the stereotype content model and signaling theory to explore the impact of patient perception of patient decision making (PDM) on online medical service platforms. Also, it tests the moderating effect of physician image. We collected information on 12,890 physicians and 746,981 patient reviews from online medical platforms in China. Unsupervised machine learning was used to construct a topic model to extract patients' perceptions of physicians' competence and warmth. Meanwhile, the facial features of physicians, such as age, smile, and glasses, are recognized by convolutional neural networks. Finally, the influence of PDM concern on decision-making and the moderating effect of physician image were analyzed by multiple linear regression. The results of the study showed that (1) patients' perceptions of physicians' competence and warmth had a positive effect on decision-making; (2) physicians' age and wearing glasses enhanced the positive effect of perception on decision-making; and (3) however, physicians' smiles weakened the positive effect of perception on decision-making. This study provides new insights into patients' online physician selection, guides the construction and promotion of medical service platforms, and provides an effective avenue of exploration to alleviate the problem of uneven distribution of offline medical resources.

1. Introduction

With the arrival of the post-epidemic era, the field of digital healthcare is experiencing rapid development, making online medical service platforms gradually become an essential way for people to obtain medical services. Accompanied by the development of Web 2.0 technology and the imminent arrival of Web 3.0, online medical service platforms will further integrate intelligent technology to provide users with a more personalized and intelligent medical service experience [1]. With its unique characteristics, the online health community has become one of the essential channels for providing medical services and redistributing medical resources [2]. Physicians can provide patients with a wide range of healthcare services virtually through online health communities [3]. Patients can

receive emotional and informational support through online health communities [4]. The process of the patient visit includes at least three steps: the patient's choice, the patient's interaction with the physician, and the patient's feedback to the physician. It is a continuous process, and the patient's choice becomes crucial as it is the beginning of the process.

However, patients often face information overload and variable quality when choosing a physician due to the overwhelming amount of information online health communities provide [5]. In online health communities, much information about physicians and healthcare organizations exists, including their backgrounds, qualifications, experiences, and patient reviews. Patients need to sift through this information to find a physician who meets and trusts their needs, which can be quite a troubling process for patients [6]. Online health communities utilize various methods to alleviate problems such as selection and service evaluation and build trust between doctors and patients [7]. Existing studies have identified several factors that influence patient choice, including patient factors, such as patient ratings [8], and physician factors, such as physician title [9], service attitudes, and the number of online reviews [10]. Many studies have shown that images significantly impact online communities [11,12], but only some have incorporated image factors into online healthcare delivery platforms.

The visual appeal of an online image plays a crucial role in attracting users, conveying information, and promoting products. Users can build their brand, increase their influence, and gain access to more opportunities and partners by displaying a compelling online presence [13]. Similarly, business brands must have a visually appealing online presence to promote their products and attract potential customers [14]. Overall, the visual appeal of an online presence provides critical support for individual users to build their brands, increase their influence, and for commercial brands to promote their products and attract customers [15].

Online medical service platforms allow physicians to upload images to give patients more information. In the case of Haodf.com, for example, when a patient is browsing for information about a physician, he or she will be guided by navigation to the physician's homepage, where the patient can see the details uploaded by the physician, such as his or her self-introduction, work experience, and area of specialization. However, the image photo of the physician will be the first thing that comes into the patient's view. Some studies have shown that the first impression influences consumer behavior and attitude [16]. Therefore, it is necessary to explore the influence of a physician's image on a patient's decision-making. This study will be centered on two questions: Based on user-generated content, what influences the patient's choice of physician? What is the role of physician image in patients' choice of physician? Existing studies consider the influence of a physician's face value on PDM (PDM) based on physician avatar [1] or the influence of PDM based on patient evaluation [17]. However, scholars have yet to prove the role of physician image characteristics and patient concerns in PDM through scientific and practical methods, which has become the breakthrough of this study.

The Stereotype Content Model (SCM) is a theoretical framework for studying the formation and influence of stereotypes in society. The model aims to explain how people form stereotypes about different social groups and how these stereotypes influence people's behavior and attitudes. The SCM model divides stereotypes into two dimensions: enthusiasm and competence. Each dimension has two extremes, high and low. The warmth dimension relates to whether a social group has positive traits such as warmth, friendliness, and empathy.

In contrast, the competence dimension relates to whether a social group is perceived as having positive traits such as competence, intelligence, and competitiveness. We attempted to analyze patients' post-diagnosis evaluations in terms of patients' perceived physician competence. We perceived physician warmth with the help of the Social Stereotype Content Model. We empirically analyzed the mechanism of the influence of patients' perceived competence and perceived warmth in choosing a physician by potential patients.

Signaling theory suggests that an image is a medium for transmitting information through symbols and language and that the recipients of an image do not just passively receive information; they can also interpret and give feedback [18]. A physician's image (age, smile, and wearing glasses) can be used as signals for patients to make decisions, and all three signals are associated with physician competence and trustworthiness [19,20]. Thus, signaling theory provides a basic framework for understanding the impact of metrics extracted from physicians' online images on patient choice.

The primary contribution of this study lies in its advancement of research on user behavior and Patient Decision-Making (PDM) within online medical service platforms, particularly by illuminating the moderating role of physician image in influencing PDM. While the initial claim of addressing the issue of uneven medical resource distribution may lack clarity in its connection to factors like age, smile, and glasses, the study's more compelling contribution emerges as a potential calibration tool for online platforms.

Specifically, our findings offer insights into how image factors, such as age, smile, and glasses, influence patient decision-making. Our study's significance lies in its potential application as a calibration tool for online platforms. Understanding the impact of these image factors enables platforms to address biases and stereotypes, fostering a fairer representation of each doctor. Overall, this study underscores the importance of physician image in shaping patient choices, emphasizing its potential role in enhancing the fairness and accuracy of online medical service platforms. It's noteworthy that, while doctor images may influence patient selection, they do not inherently contribute to treatment efficacy.

2. Literature review and hypotheses development

2.1. Theoretical background

2.1.1. Stereotype content model

The Stereotype Content Model (SCM) was first proposed by Fiske and her collaborators in 2002, and its core idea is that people's stereotypes of different groups can be categorized by two primary dimensions: warmth and competence [21]. These two dimensions reflect the group's level of closeness and competence in social interactions, respectively. In SCM, groups can be categorized into four stereotype types: high warmth and high competitiveness, high warmth and low competitiveness, low warmth and high

competitiveness, and low warmth and low competitiveness.

Research has shown that SCM has been applied in two main areas: interpersonal relationships within organizations and cross-cultural management. SCM can help explain employee interactions and relationships within an organization [22]. By stereotyping employees' roles and positions, researchers can better understand cooperation, competition, and group conflict [23]. Through SCM, researchers can deeply analyze stereotypes in different cultural contexts, thus providing helpful guidance for cross-cultural communication, teamwork, and international business management [24,25].

Drevs et al. showed that in healthcare, patients tend to assess the competence and affinity of hospitals based on hospital characteristics such as ownership, size, and teaching status when choosing a hospital, which aligns with the Stereotype Content Model [26]. Oldmeadow's study combined the Stereotype Content Model with the theory of mind perception to reveal how societal stereotypes of healthcare providers' competence and warmth affect moral agency and patient perceptions, affecting the ethical value of healthcare interactions [27]. Jain's study experimentally validated the Stereotype Content Model's explanation for healthcare providers' perceptual biases and found that gender and race, among other factors, influence perceptions of a physician's ability to communicate, trust, and willingness to visit [28]. Another study focused on the effect of physicians' physical appearance on patients' first impressions and found that the physical appearance of physicians of different genders affects patients' evaluations of their medical and social competence [29]. The Seemann study analyzed patients' perceptions of different types of hospitals, with a particular focus on religious hospitals, and found that patients were more trusting and attracted to religious hospitals, which corroborates the Stereotype Content Model on the role of warmth and competence on stereotypes [30]. In summary, these studies reveal the applicability and impact of the Stereotype Content Model in the healthcare domain.

2.1.2. Signal theory

The primary function of signals is cognition and communication; it is a simplified way of knowing things. First proposed by the American economist Spence, signal theory consists of three key elements: the signal sender, the signal, and the signal receiver, and it is developed on the premise of information asymmetry, where one party has complete quality information, and the other party lacks it [31]. Despite the information asymmetry, the party lacking information can still use the signal collection to assess the credibility and validity of the sender [32], realizing potential trading gains.

Signaling theory aims to attenuate information asymmetry between two parties, and many empirical studies support the validity of signaling theory in practical applications [33]. In online healthcare services, the signal theory is widely used to elaborate on patients' multi-perspective evaluations of physicians' services and patients' final consultation decisions after assessing signals [34]. Nonverbal cues such as beauty, facial features, and physical behavior are potentially related to physician competence and trustworthiness. They can be used as signals to form impressions and judgments about physicians [18,35,36]. Different signals also possess substitution relationships; for example, there is an overlap between physicians' knowledge contribution and reputation signals, both of which can reflect physicians' technical competence and attitudes [37].

2.2. Literature on patients' decision-making on the online medical service platform

Online physician reviews are an essential source of information for potential patients, which can help improve the doctor-patient relationship and rational allocation of medical resources by understanding the personality differences in the patient experience [38]. According to the Stereotype Content Model, the current factors affecting patient choice can be focused on both perceived physician competence and perceived physician warmth.

Healthcare is a service based on professional competence, and the physician's professional competence is at the service's core [39]. Competence, as an essential component of a physician's personal qualities, can give him or her significant influence in a particular field. It has been shown that a physician's competence is not only a critical factor in determining whether a physician can provide high-quality health counseling to patients but also an essential criterion for patients to choose whether or not to undergo online health counseling. Blodt [40] analyzed the population's perceptions of the physician's quality through empirical surveys, and the study showed that a physician's competence affects the patient's satisfaction. A study conducted by Gong [39] demonstrated that a physician's work competence significantly positively affects patients' counseling decisions. Patients are more likely to engage in online health consultations if they can perceive the physician's competence through cognitive information from the physician on the online healthcare service platform that indicates the physician's professional skills and characteristics. In summary, patients' perceived information about physicians' professional competence, i.e., perceived competence obtained on online medical service platforms, may influence their choice to undergo online health counseling. Therefore, we propose the following hypothesis.

Hypothesis 1a. (H1a): Patient perceived physician competence significantly and positively influences PDM.

Attitude is one of the key factors that reflect physician care. When undergoing medical consultations, patients are usually susceptible to physicians' attitudes and behaviors [41]. It has been shown that a physician's attitude as an emotional expression significantly influences customer experience and satisfaction. Zhou [42] assessed the quality of the physician-patient relationship. It influences factors during COVID-19 in China through a questionnaire survey, and the study showed that the physician's attitude is one of the significant factors affecting the physician-patient relationship. Patients always expect physicians to adopt a proactive attitude, and patient satisfaction tends to be higher for courteous and friendly physicians and nurses [43]. Tracy [44] explored physicians' attitudes toward patients' questions by conducting semi-structured interviews with physicians. Physicians were recognized by their patients by creating a conducive environment for patients to ask questions and providing professional answers through positive attitudes of encouragement, expectation, and responsibility. In summary, patients' perceptions of physicians' attitudes, i.e., perceived

warmth, may influence their decision to engage in medical counseling. Therefore, we propose the following hypothesis.

Hypothesis 1b. *(H1b)*: Patient perceived physician warmth significantly and positively influences PDM.

Consumer reviews on online platforms have become one of the most persuasive pieces of information influencing choice or purchase decisions [45]. Reviews on online healthcare platforms support patients' counseling choices and provide guidance for improving the doctor-patient relationship [46]. However, most previous studies are based on questionnaires, semi-structured interviews, or experimental methods and seldom explore the influencing factors of PDM through text analysis. In this paper, we explore the influence of patients' perceived physician competence and perceived warmth on patients' choices to undergo online physician consultation by conducting content and sentiment analysis of patient review texts on online medical service platforms.

2.3. Influence of physician image on decision making

The facial features of a physician include factors such as the physician's age, gender, facial expressions, and appearance. Based on signal theory, a doctor's facial features can be considered a signal that conveys information about the doctor's competence and reliability to the patient. The physician's facial features visually transmit information to the patient, and the patient responds accordingly. It has been shown that the physician's image, especially facial features, can have a differential impact on the patient's experience during the consultation process. Chang investigated the effects between the physician's gender and facial maturity and the physician-patient relationship through an experimental approach [47]. The results showed that baby-faced doctors outperformed mature doctors regarding patients' expectations, satisfaction, and expected loyalty and that younger and female doctors were likelier to be trusted and liked by patients. Ouyang and Wang used R language to develop a theoretical model based on signal theory to assess the effects of beauty, smile, and skin feature attributes in doctors' images on online health community patient choice [1]. The study showed that physician beauty or physical attractiveness did not have a significant effect on patient choice and that smile and skin condition positively influenced patient choice. Annadate used different algorithms to extract facial features such as hairline, smile, skin, and wrinkles, and analyzed feature changes as well as patient perceptions through image processing software [48].

Complex human emotions can be displayed through facial expressions, and facial emotion recognition can be used to understand patients' perceptions during consultations and help improve the doctor-patient relationship [49]. Borth proposed a new approach to understanding visual concepts closely related to emotions by building a large-scale visual emotion ontology: emotion analysis from images [50]. Studies have shown that doctors with friendly facial expressions may make patients feel more friendly, considerate, and professional healthcare professionals, thus quickly gaining patients' trust and influencing their consultation decisions. Ouyang showed that physician avatars with smiling faces significantly impacted online patients' consultation choices.

The relationship between physician age on patient perception and PDM has received much attention. Studies have shown that patients are influenced by physician age when choosing a physician, particularly in assessing physician competence and warmth. One study showed that age-differentiated leadership plays a positive role in predicting work competence, especially when considering older and younger staff needs [51]. Additionally, physician age affects physician assertiveness in clinical decision-making, which may further influence patient perceptions and PDM [52].

Smile intensity differentially affects consumers' perceptions of a marketer's warmth and competence, with those with high smile intensity being more likely to be perceived as warm but less competent, and this effect shows differences across consumer types and consumption environments [53]. Subsequent scholars have delved into the interaction between consumers' sense of power and service providers' smile intensity on perceptions of warmth and competence, pointing out that servers with high smile intensity are more warm to consumers with a low sense of power and less competent to consumers with high sense of power [54]. On the other hand, Min has further emphasized that smile intensity-induced warmth perceptions influence judgments of competence, which enhances purchase intentions, and that this effect showed variability across industries [55].

By combing the existing image analysis studies, it can be found that the existing image analysis mainly focuses on face value, age, and gender, and there are fewer studies on facial expression analysis and facial decoration analysis. Based on the combing and integration of the literature on image analysis only, we used computer vision techniques to disentangle physician image features into age, smile, and whether to wear glasses. In summary, physicians' facial features may moderate the relationship between patient attention and consultation decisions. Therefore, we propose the following hypothesis.

Hypothesis 2a. *(H2a)*: Physician age moderates the relationship between patient perception and PDM. Specifically, physician age has a significant positive moderating effect on the relationship between patient-perceived physician competence and warmth and PDM.

Hypothesis 2b. *(H2b)*: The physician smiles the influential relationship between patient perception and PDM, and a smile strengthens the relationship between the two.

Hypothesis 2c. *(H2c)*: Whether the physician wears glasses or not has a moderating effect on the influential relationship between patient perception and PDM, and if the physician wears glasses, patient perception more positively influences PDM.

3. Method

3.1. Data acquisition and preprocessing

The data for this study came from the Good Doctor Online platform. The reasons for choosing it as the data source are as follows:

first, the Good Doctor Online platform is rich in data resources, and as one of the largest medical platforms in China, it has many medical services and information resources [56]. Second, the data quality of the Good Doctor platform is high, and the website audits and manages the comments posted by users to ensure the authenticity and credibility of the comment content [46]. This study collected data from 14,130 physicians on the Good Doctor online platform. After removing invalid data such as blank avatars and avatars with no faces, there were a total of 12,890 physicians' basic information, which included the physician's avatar, the physician's title, the number of e-gifts received from patients, and the platform's recommendation of the physician. We crawled all post-visit patient reviews of these 12,890 physicians since December 31, 2018, using a self-compiled crawler program in Python. After removing invalid data, such as blank comments and duplicates, 919,089 valid sample data were finally obtained.

Then, data cleaning was performed. Specifically, punctuation marks, numbers, and non-Chinese characters were removed from all comments. After that, natural language processing techniques were used to preprocess the documents for this study. Segmentation using *jieba* Segmentation using Python's *jieba* Segmentation tool was used to segment the comments. At the same time, common deactivated words were removed, resulting in 746,981 valid texts that can be used in the next step of unsupervised text mining analysis.

3.2 Model selection and set-up.

In the context of the rapid development of information technology, the concept of "Text-*as*-Data" has become the focus of interdisciplinary research [57]. The maturity of natural language processing technology and semantic analysis technology also lays the foundation for studying unstructured text. Topic modeling is an unsupervised machine-learning approach for analyzing user-generated content, such as online reviews [58]. This study uses structural topic modeling to reveal potential patients' concerns about high-quality physician services. The details of the model are given below.

3.2. The illustration of STM

The *searchK* function from the *stm* and *furrr* packages in R is used to find the best number of topics. The topic numbers (K) from 4 to 14 are associated with the semantic coherence of the topics, held-out likelihood, and residuals, as shown in Fig. 1.

Fig. 1 shows that as the number of topics in a model increases, the semantic coherence decreases while the held-out score increases. A 6-topic model solution is chosen for this study after considering the semantic coherence of the topics, held-out likelihood, and residuals.

3.3. The illustration of face feature recognition model

To obtain image features of physicians, we built a ResNet-18 model as a feature recognition model using the *Pytorch* framework [59]. Specifically, we use ResNet-18 as the backbone network, as shown in Fig. 2, after which we train the model using the relevant dataset to extract image features and save the model weights. Finally, we use the trained model to predict the image of a physician.
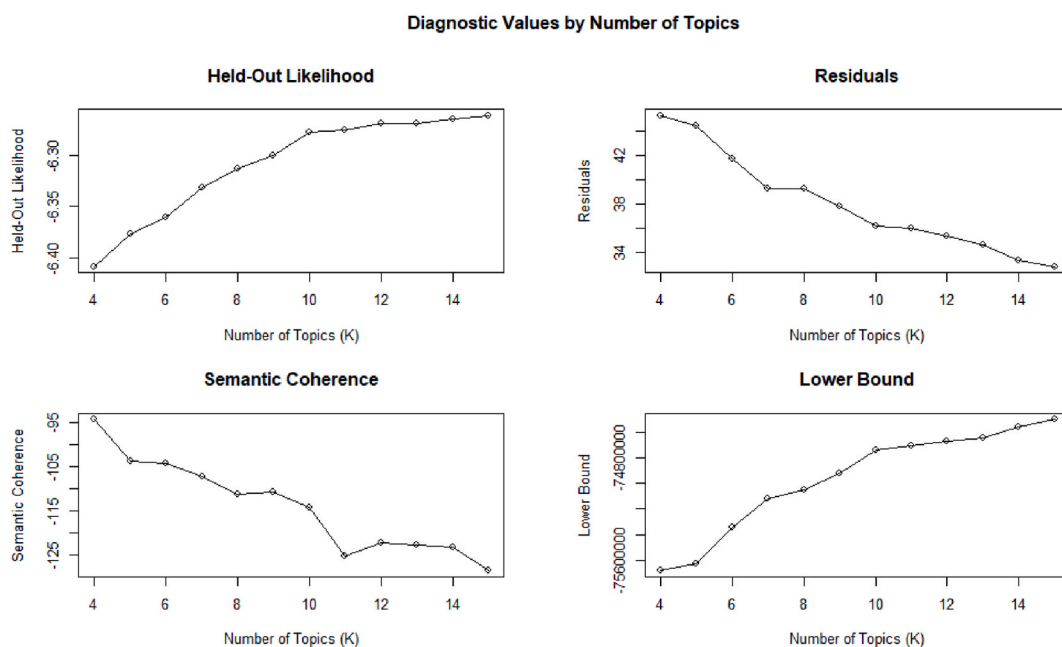

Fig. 1. The selective topic model solution (Held-Out Likelihood, Residuals, Semantic Coherence and Lower Bound).

3.4. The illustration of the empirical analysis

The empirical analysis method was used in this study, as shown in Fig. 3. In this model, the independent variable topic represents the topic labeling obtained from the post-diagnosis patient evaluation after STM processing, and the dependent variable recommends the ability to represent PDM. In addition, we used physician image characteristics as a moderating variable to test the moderating effect of physician image.

The process of data collection, analysis, and processing of the research data involved above is shown in Fig. 4.

4. Analysis and finding

In this section, we first introduce each theme and each theme's percentage, then we disassemble each feature of the physician image. We conduct an empirical analysis to explore the relationship between patient concern and PDM, and finally, we empirically analyze the moderating effect of physician image.

4.1. Topic labeling and summary

Our model identifies six themes, and Table 1 summarizes the extracted theme results. The fourth column is the percentage of topics output by the STM model. The fifth column is a list of the top 5 words output for each topic, which has the highest probability of appearing in that topic but the lowest probability of appearing in other topics and can be used to differentiate between topics. As mentioned earlier, each topic represents a potential distribution of words to which every word in the document could be assigned. Our project recruited two social science researchers to determine the assignment of topic labels by analyzing the top vocabulary for each topic and reviewing a large sample of representative comments. Based on the assignment of tags, topics were categorized into different classes, as explained in detail in a later section.

Based on the Stereotype Content Model, we have divided these six themes into two dimensions: Perceived Warmth and Perceived Competence, which represent the two categories of patients' perceived warmth and perceived competence of physicians, and help patients to choose the correct physician from a psychological perspective. We theorize the influencing factors of potential patients' choices on online medical platforms from the psychology perspective, break the information gap, help patients choose the correct physician, and rationally allocate medical resources.

Physician attitude is the focus of potential patients' attention when choosing a physician. First of all, the high morality of physicians (Topic 3) is the top priority, with a topic share of 24.5%, indicating that potential patients pay the most attention to the professional ethics of physicians when choosing a physician, which is something that physicians need to pay extra attention to. In the medical industry, a physician's professional ethics is the cornerstone of his or her practice and one of the most critical factors in gaining patients' trust and respect. Secondly, in online medical service platforms, patients are more concerned about the communication ability of physicians (Topic 4, accounting for 23.1%), and they hope that physicians can patiently listen to their problems, provide accurate diagnoses and treatment recommendations, and maintain timely and effective communication during the treatment process.

In addition, the physician's professional ability is also one of the patients' concerns. First of all, Surgical skills occupy 13.90%, which means that patients are very concerned about physicians' surgical skills and operation ability. Surgery, as an essential part of the medical process, is directly related to the health and safety of patients. Secondly, Therapeutic effects accounted for 13.70%, reflecting that patients value the outcomes of their physician's treatment. Patients often hope to obtain significant improvement in their conditions through their physicians' treatment. Thus, Therapeutic effects become a critical indicator for evaluating physicians' comprehensive ability. Physician's honorific, as well as Team collaboration, occupied 12.80% and 12.00%, respectively. The physician's honorific is another important factor in patients' evaluation, which is usually related to the physician's qualifications and professional background, and directly affects the patient's trust in the physician. In addition, the proportion of teamwork was also quite significant, which may reflect the increasing emphasis on multidisciplinary cooperation in the medical field, where patients expect their physicians to work closely with other professionals to provide them with more comprehensive healthcare services.
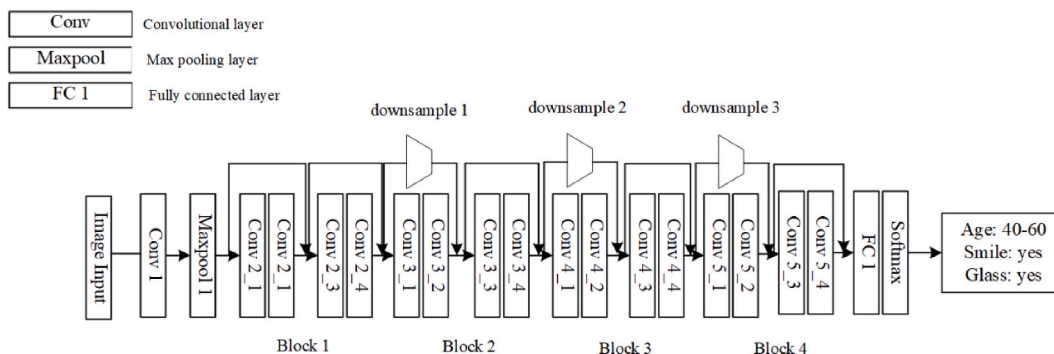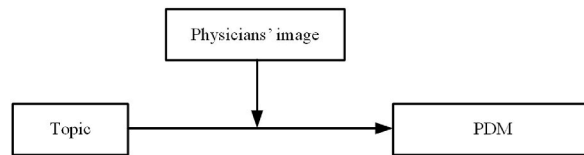

Fig. 2. ResNet-18 model.
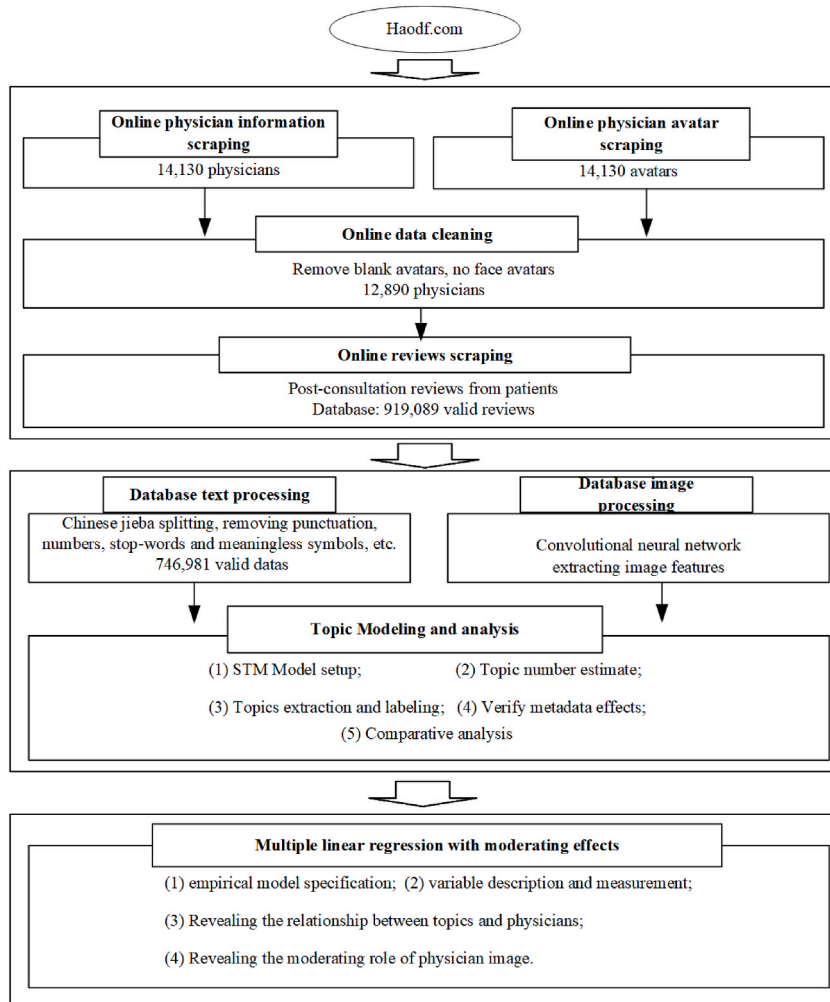
Fig. 3. Empirical research framework.

Fig. 4. Overall framework for research design.

4.2. Deconstruction of doctor image characteristic

To obtain the image features of doctors used in this study, we used ResNet-18 as an image feature recognition network to identify doctors' images. In this paper, we formulate the age, smile, and whether or not to wear glasses as image variables for recognizing doctors, and the process of their calculation is described below.

Smile recognition and glasses-wearing recognition can be regarded as dichotomous tasks. As for the age detection problem, due to the different differences in human age in the image, in order to better reflect the difference in sensory aspects of the doctor's age to the patient, this paper divides the age into three categories, which are less than 40 years old, 40–60 years old and more than 60 years old. In this paper, after building the proposed network model using the *PyTorch* framework, we use the relevant dataset for training. Specifically, we choose GENKI-4K and Eyeglasses-Dataset to train the model to recognize smiles and glasses worn [60,61]. However, the age detection problem is different from the above, and the model is trained using the mega age dataset because the data collected in this study are primarily Asian, and different races bring different sensory perceptions [62]. We divided the dataset into training and

Table 1
Topic labeling.

Topic No.	Belonging category	Topic label	Topic proportions (%)	Top words
Topic 3	Perceived warmth	High ethics	24.50%	医德 (Medical Ethics), 高尚 (Noble), 态度 (Attitude), 认真 (Diligent), 负责 (Responsible)
Topic 4		Easy communication	23.10%	耐心 (Patience), 关心(Caring), 仁心 (Compassionate),易懂(Easy to Understand), 详细(Thorough)
Topic 2	Perceived competence	Surgical skills	13.90%	手术(Surgery), 病情(patient's condition), 恢复 (recovery), 顺利(smoothly), 康复 (Rehabilitation)
Topic 5		Therapeutic effects	13.70%	治疗(Treatment), 效果(Effectiveness), 好转(Improvement), 建议 (Recommendation), 明显(Noticeable)
Topic 6		Physician's honorific	12.80%	教授(Professor), 医院(Hospital), 希望(Hope), 高超(Expertise), 医术(Medical skill)
Topic 1		Team collaboration	12.00%	主任(Director), 团队(Team), 成功(Success), 感谢(Gratitude), 医者(Physician)

test sets in the ratio of 7:3. On the test set, the model achieves 90%, 94%, and 97% accuracy for age, smile, and glasses wear recognition, respectively, proving that the model can accomplish the task of image feature recognition. To address potential biases, especially considering the focus on Asian individuals in our data, we conducted additional steps. In smile recognition, where the model primarily focuses on the amplitude of mouth corner uplift, and differences across various ethnicities are minimal, reliable results were obtained. Furthermore, to ensure data accuracy, we enlisted the assistance of three volunteers in subsequent phases of our work to manually inspect and correct the model's predictions, thereby enhancing data correctness.

To ensure the presence of doctor face information in the images before recognizing image features, we utilized the HOG face detector in the **dlib** library to identify and retain images with face information [63]. The trained model weights were then applied to predict the doctor image features from the collected dataset. While the suggestion to test the model on a randomly selected subset of our physician dataset or conduct manual evaluations is acknowledged for enhanced robustness, the limited size of our dataset (14130 images) poses challenges for manual annotation. To address this constraint, we chose to train the model on similar publicly available datasets, avoiding unnecessary data waste. With a model accuracy exceeding 90%, we further ensured robustness by inviting three volunteers to perform manual corrections on the model's predictions, thereby validating the accuracy and reliability of our data.

4.3. Empirical analysis of the relationship between patient perceived impression and PDM

After the above method, we obtained the percentage of each theme. However, the six themes under the dimensions of patients' perceived physician warmth and perceived physician competence, while providing feedback on patients' concerns in choosing a physician, could not reveal whether and how these concerns influence PDM. Therefore regression models also need to be constructed for the next step of empirical testing. To make the empirical testing process more transparent, our regression analysis will be divided into four parts, and the experimental design is shown in Fig. 5.

We first tested the direct effects of the six themes on PDM to reveal how patients' perceived physician warmth and perceived competence affect potential PDM, constructing the model (Model 1) as follows:

$$PDM = \sum_{k=1}^{K} A_i^k \cdot Topic_i^k + D \cdot T_i + E \cdot G_i + \delta + \varepsilon_i \tag{1}$$

Where the independent variable $Topic_i^k$ denotes the proportion of topic k in comment i, $k \in [1\text{–}6]$. The value of $Topic_i^k$ can be output through the stm package in the R programming tool. And A_i^k is the corresponding coefficient of ic_i^k, δ is the intercept, and ε_i is the standard errors of the model. The dependent variable *Patient decision – making$_i$* was calculated as follows:

$$PDM = \frac{PPR}{TP} \tag{2}$$

Where PPR stands for Number of patients for post-consultation reporting and **TP** stands for Total patients. D and E are the
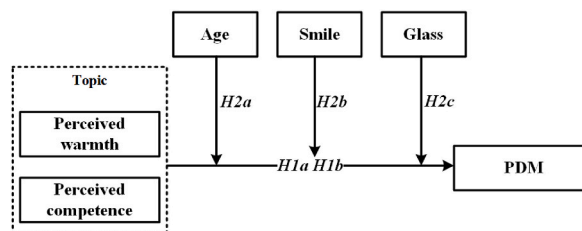

Fig. 5. The conceptual framework.

corresponding coefficients of the control variables *Title$_i$* and *Gift$_i$*, which represent the effects of physician title and the number of e-gifts received by physicians on the dependent variable, respectively.

We conducted multiple regression on the constructed model through Stata software, and the summarized results are shown in Table 2. In the analysis of main effects, all six themes of both dimensions were proved to significantly and positively influence PDM, which means that patients will not only consider the professional skills and competence of physicians but also pay attention to the attitude of physicians and the feedback of other patients after their visits.

First, the results of Topic 2, Topic 5, and Topic 6 indicate that patients want to choose a primary care physician with enough experience and skills to provide effective treatment programs for different conditions. Also, patients want their physicians to maintain high responsibility and professionalism in the treatment process to ensure it goes smoothly. In addition, patients are more likely to choose a physician with a high moral character who can establish trust and good communication with patients, which is consistent with our common sense.

Secondly, the significant positive effect of Topic 3 and Topic 4 on PDM suggests that patients are more likely to be cared for by a physician and need a warm response rather than a cold one for a test result. Meanwhile, when choosing a physician, patients will pay attention to the physician's communication ability, and a physician with good communication ability will make patients feel more trust and comfortable, improving the effectiveness of medical treatment. therefore, a physician should be able to clearly express medical terms and complex concepts while using simple language to explain problems and diseases to gain patients' recognition.

It is worth mentioning that the results of Topic 1 indicate that the professional competence of the physician's team is of particular interest to patients when choosing a physician. Patients need to obtain professional and high-quality medical services, and the professional competence of the physician's team is one of the most important criteria for patients to judge the quality of medical services.

4.4. Empirical analysis of the effect of doctor image regulation

First, the physician age variable was added as a moderating variable to the main effects to investigate whether physician age is moderating effect on the effects of physician attitudes, physician competence, and patient feedback on prospective PDM. We will use

Table 2
Regression results.

Variables	Model1	Model2	Model3	Model4	Model5
Direct Effect					
Topic1	0.550***	0.641***	0.568***	0.576***	0.669***
Topic2	0.646***	0.680***	0.653***	0.629***	0.668***
Topic3	0.610***	0.643***	0.612***	0.613***	0.645***
Topic4	0.583***	0.607***	0.587***	0.574***	0.602***
Topic5	0.562***	0.598***	0.552***	0.552***	0.578***
Topic6	0.547***	0.593***	0.543***	0.562***	0.599***
Moderating effect					
Age		−0.063***			−0.063***
Smile			0.016***		0.020***
Glass				−0.024***	−0.021***
Topic1 × Age		0.049***			−0.044***
Topic2 × Age		0.018***			0.019***
Topic3 × Age		0.020***			0.020***
Topic4 × Age		0.029***			0.028***
Topic5 × Age		0.016**			0.011*
Topic6 × Age		–			–
Topic1 × Smile			−0.081***		−0.071***
Topic2 × Smile			−0.045***		−0.049***
Topic3 × Smile			−0.024***		−0.024***
Topic4 × Smile			−0.032***		−0.035***
Topic5 × Smile			−0.019**		0.024***
Topic6 × Smile			–		–
Topic1 × Glass				0.017*	−0.009
Topic2 × Glass				0.052***	0.052***
Topic3 × Glass				0.019***	0.018***
Topic4 × Glass				0.038***	0.039***
Topic5 × Glass				0.041***	0.042***
Topic6 × Glass				–	–
Control Variables					
Title	0.005***	0.005***	0.005***	0.004***	0.004***
Gift	0.000***	0.000***	0.000***	0.000***	0.000***
Observations	746,981	746,981	746,981	746,981	746,981
R-squared	0.816	0.816	0.816	0.818	0.819
F test	0	0	0	0	0
r2_a	0.816	0.816	0.816	0.818	0.819
F	414482	236918	237011	240478	129593

Notes: ***p < 0.01; **p < 0.05; *p < 0.1.

an interaction term to test whether physician age significantly affects these relationships. The modified model is as follows:

$$PDM = \sum_{k=1}^{K} A_i^k \cdot Topic_i^k + B_1 \cdot Age_i + \sum_{k=1}^{K} C^k \cdot \left(Topic_i^k \times Age_i\right) + D \cdot T_i + E \cdot G_i + \delta + \varepsilon_i \tag{3}$$

Where B_1 is the corresponding coefficient of Age_i, which denotes the age of each doctor, and C^k is the corresponding coefficient of the interaction term $Topic_i^k \times Age_i$, $k \in [1, 2, 3, 4, 5, 6]$. D and E are the corresponding coefficients of the control variables T_i and G_i, respectively.

Second, the smile variable was added as a moderating variable to the main effect in order to explore the moderating effect of doctors' smiles. The model was modified as follows:

$$PDM = \sum_{k=1}^{K} A_i^k \cdot Topic_i^k + B_2 \cdot Smile_i + \sum_{k=1}^{K} C^k \cdot \left(Topic_i^k \times Age_i\right) + D \cdot T_i + E \cdot G_i + \delta + \varepsilon_i \tag{4}$$

Where B_2 is the corresponding coefficient of $Smile_i$, which indicates whether each doctor smiles or not, and C^k is the corresponding coefficient of the interaction term $Topic_i^k \times smile_i$, $k \in [1,2,3,4,5,6]$. D and E are the corresponding coefficients of the control variables T_i and G_i, respectively.

Finally, the spectacle variable was added to the main effect as a moderating variable to explore the moderating effect of doctors' smiles. The model was modified as follows:

$$PDM = \sum_{k=1}^{K} A_i^k \cdot Topic_i^k + B_3 \cdot Glass_i + \sum_{k=1}^{K} C^k \cdot \left(Topic_i^k \times Age_i\right) + D \cdot T_i + E \cdot G_i + \delta + \varepsilon_i \tag{5}$$

Where B_3 is the corresponding coefficient of $Glass_i$, which indicates whether each doctor wears glasses, and C^k is the corresponding coefficient of the interaction term $Topic_i^k \times Glass_i$, $k \in [1,2,3,4,5,6]$. D and E are the corresponding coefficients of the control variables T_i and G_i.

First, as shown in Table 2, including the moderator variable Age significantly and positively moderates the effect of patients' perceived physician warmth and perceived competence on PDM. By adding the moderating variable of Age, we can see that when the physician's age increases, patients pay more attention to the physician's professional competence and experience. This suggests that patients perceive more experienced older physicians to be more cautious and accurate in dealing with their illnesses and therefore trust their medical advice and treatment plans more. Age can also affect communication and trust between physicians and patients. Patients may perceive that older physicians may be more patient and better able to understand patients' needs and provide effective treatment options. Therefore, patients may be more likely to choose an older physician as their primary care physician.

Second, including the moderator variable Smile has a significant negative moderating effect on each theme, which contradicts our hypothesis. We can see that a physician's Smile diminishes the positive effects of perceived physician warmth and competence on patient choice. This suggests that although smiling can convey positive emotions and trust, too much smiling may be interpreted by patients as the physician not being severe enough or too casual. When choosing a physician, patients consider the physician's professionalism and trustworthiness. While a smile can convey warmth and friendly feelings, excessive smiling in healthcare may raise suspicions in patients' minds. Patients may perceive a physician as overly cordial, leading them to question their professionalism, which may affect PDM. Therefore, in physician-patient communication, physicians' smiles should be moderate to create a favorable physician-patient relationship and atmosphere.

Finally, including the moderator variable Glass had a significant positive moderating effect on each theme. An avatar of a physician wearing eyeglasses may make it easier for patients to associate it with the image of a medical professional, conveying professionalism and recognition of the physician. Eyeglasses are often perceived as a symbol of professional image and may trigger patients' feelings of respect and trust in their physicians. Eyeglasses may alter a physician's appearance, making him or her seem more approachable, warm, and gracious. Eyeglasses may soften a physician's facial features and make him or her appear friendlier, which can help build trust and closeness in the physician-patient relationship.

5. Conclusion and discussion

5.1. Research conclusions

Based on user-generated content (patient post-diagnosis evaluations), this study aimed to capture and summarize the mechanism of patient concerns on PDM based on the two dimensions of the Stereotype Content Model. Further, it analyzed the relationship between stoic stereotypes of doctors and PDM and the role of doctor image moderation. The results of hypothesis testing through empirical analysis and multiple regression modeling are summarized in Table 3, and the results of the study show that:

Patient stereotypes have a significant impact on PDM. Not only do patients pay attention to the doctor's expertise and competence, but also to the doctor's attitude, communication skills, and feedback from other patients. Patients' perceived physician warmth and competence both significantly influence PDM.

There was a moderating effect of physician age, smile, and whether or not they wore eyeglasses on the relationship between

physician image characteristics and PDM. Older physicians were more trusted by patients in terms of professional competence and experience. A moderate smile can convey warmth and friendly feelings, but an excessive smile may be misinterpreted as not serious enough. Doctors wearing eyeglasses can increase professionalism and closeness and improve patient trust in doctors.

This section discusses the mechanisms by which patient attention influences PDM and the moderating role of physician image, explaining the mechanisms as follows:

First, we explain the mechanisms of the main effect of patient attention on PDM. (1) Patient perceptions of physician competence significantly and positively influence PDM. This can be explained as follows: when patients have positive perceptions of a doctor's competence, they are more confident in accepting the doctor's advice and decision-making because they believe that the doctor has the professional knowledge and experience to make the correct diagnosis and treatment recommendations [39], and thus more and more people will choose that doctor to provide services for them. Suppose patients feel that their doctors need to be more competent and professional. In that case, they may be skeptical of the medical results and resistant to their doctors' advice or even choose to seek other doctors' advice or treatment options. This situation may lead to tensions in the doctor-patient relationship or even medical disputes [64,65], thus reducing the doctor's reputation and affecting patients' choice of online health advice.

(2) Patients' perceived physician warmth significantly and positively influences PDM. This suggests doctors' interpersonal relationships and emotional expression are crucial in medical care. In the doctor-patient relationship, doctors' warmth and care can ease patients' anxiety and fear and enhance patients' trust in medical decision-making. Research data show that patients' trust and satisfaction with their doctors are often closely related to their interpersonal skills. Doctors who can listen to patients' needs and give patient explanations are recommended and chosen by more patients. This trust-based doctor-patient relationship also provides a better working environment for the healthcare team, making the medical process smoother and more efficient [43,44,66]. In addition, patients' perceived physician warmth also positively affects the reputation of healthcare platforms and patient loyalty. Patients often share their healthcare experiences and recommend doctors who have given them warmth and care to their friends and family. This word-of-mouth communication helps healthcare platforms build a favorable reputation, attract more patients, and promote long-term patient loyalty.

Second, we explained the mechanism of the moderating effect influence of physician image. (1) Physician age positively moderates the relationship between patient perception and PDM. This suggests older physicians have more authority and trust in patients' minds. On the one hand, a doctor's age and experience tend to be positively correlated, and patients perceive that older doctors have more medical knowledge and clinical experience and are, therefore, more able to provide professional medical advice. On the other hand, more senior physicians usually demonstrate excellent steadiness and patience when communicating with patients, which increases patients' trust in them and thus positively influences the relationship between patients' perceived physician warmth and PDM [52].

(2) Physician smiles negatively moderated the relationship between patient perceptions and decision-making. This is contrary to our hypothesis. In previous studies, physician smiling positively affects patients' trust and satisfaction, motivating them to be more inclined to choose that physician for their consultation [67]. However, our findings suggest that this is different. This unexpected finding may stem from several reasons. First, patients may pay more attention to the doctor's professionalism and clinical experience when choosing a doctor rather than relying solely on a superficial smile. Second, some patients may perceive a doctor's smile as a professional performance rather than a direct indication of medical competence. Thus, they may use it as a minor factor in their decision-making. The most crucial reason for a smile's moderating effect depends on the profession. For a utilitarian-oriented industry like healthcare, the role of smiles may need to be more robust [53,54].

(3) The wearing of eyeglasses by doctors positively moderates the influential relationship between patient perception and PDM. This suggests that eyeglasses, as a professional symbol of doctors, carry the responsibility and professionalism of doctors to patients. Patients tend to develop a sense of trust when they see doctors wearing eyeglasses because eyeglasses not only represent the doctor's level of knowledge but also reflect the doctor's concern for the patient's health. When choosing a doctor, patients tend to consider the doctor's professional ability and personality [68]. Therefore, wearing eyeglasses by doctors enhances the influential relationship between patient perception and PDM.

In summary, this study provides an in-depth analysis of the role of physician image in PDM, revealing the influence of different aspects of physician image characteristics on patient choice and the moderating effect of factors such as age, smile, and glasses on this influence. This has important implications and guidance for the professional development of the medical profession and the establishment of patient-physician relationships.

Table 3
Summary of hypothesis testing results.

Hypotheses		Supported
H1a	Patient perceived physician competence significantly and positively influences PDM.	Yes
H1b	Patient perceived physician warmth significantly and positively influences PDM.	Yes
H2a	Physician age moderates the relationship between patient perception and PDM. And it's positively regulated.	Yes
H2b	The physician smiles the influential relationship between patient perception and PDM. And it's positively regulated.	No
H2c	Whether the physician wears glasses or not has a moderating effect on the influential relationship between patient perception and PDM. And it's positively regulated.	Yes

5.2. Theoretical implications

The theoretical significance of this study is mainly reflected in the following aspects.

First, the feasibility, effectiveness, and superiority of applying unsupervised machine learning methods to unstructured data are verified. This study applies disruptive methods such as text mining and structural topic modeling to help us obtain valuable user insights from a large amount of user-generated content. In addition, the quantification of patient concerns is also achieved through STM output topic occupancy, which breaks the disadvantage of the quantitative limitation of traditional questionnaire data and lays the foundation for further testing the influence of physician image on PDM. This is a valuable attempt to apply big data text analytics to user experience management.

Second, this study extends image-related research to online medical communities. Previous research on the image has mainly focused on tourism and e-commerce. There have been fewer studies on online medical communities and images. This study will contribute to expanding image research and promote a comprehensive understanding of online medical communities.

Third, it expands the application field of stereotype modeling and enriches the connotation of stereotype modeling. Stereotype modeling is mainly used in social psychology, and researchers usually apply it to analyzing stereotypes of race, gender, social groups, and so on. This study introduces the stereotype model into the medical field to analyze the impact of a physician's image on PDM, help the medical industry understand patients' concerns and needs, and improve the doctor-patient relationship. This helps the rational allocation of medical resources and improves patient satisfaction and medical treatment outcomes. It expands the application field of stereotype modeling and provides new ideas and methods for research in different fields. This study enriches and expands the connotation of the stereotype model by analyzing multiple aspects of the image of the physician, such as warmth attitude, professional competence, and communication ability. The study not only focuses on the influence of external factors on stereotypes but also considers internal individual traits and behaviors, providing a more comprehensive understanding of the stereotype model.

Finally, this study analyzes the image characteristics of physicians based on signaling theory, which provides a new perspective for theoretical research. In signaling theory, the reliability of the signal is one of the critical factors. The reliability of a physician's image features as signals will affect whether patients use them as a basis for decision-making. This study shows that the characteristics of a physician's age, smile, and glasses affect PDM in different contexts, further emphasizing the importance of signal reliability in the doctor-patient relationship. However, some interesting findings were obtained in the analysis of moderating effects. Physicians wearing eyeglasses enhanced the effect of patients' perceived impressions of PDM. This suggests that the wearing of eyeglasses by a physician may increase the physician's professional image and sense of authority in the patient's mind. This phenomenon may be because eyeglasses symbolize knowledge, wisdom, and professionalism, making it easier for patients to trust and respect physicians who wear eyeglasses. Unexpectedly, the primary effect influence was weakened by physician smiles, which are often considered positive nonverbal signal that conveys feelings of friendliness, trust, and pleasantness. However, patients may interpret physician smiles as a gesture of friendliness and cordiality rather than an image of seriousness and professionalism. Patients may perceive a physician's smile as implying that the physician is not severe or focused enough, thus lowering their assessment of the physician's competence and attitude.

5.3. Practical implications

Meanwhile, this study possesses crucial practical significance, as it could significantly contribute to creating a fairer environment for patients by reducing biases influenced by doctor images.

For physicians, the study sheds light on various aspects that patients consider when choosing a healthcare provider, including medical ethics, communication skills, and professional expertise. Armed with this understanding, physicians can adjust their image and communication strategies to better align with patient expectations, fostering positive doctor-patient relationships. Furthermore, insight into patients' perceptions of physical characteristics, such as the degree of smiling and wearing eyeglasses, enables physicians to make more appropriate choices in their appearance presentation. Studies have indicated that patients tend to trust older physicians, attributing reliability to their expertise and experience. Older physicians can leverage this perception by highlighting their wealth of experience and expertise, potentially earning greater trust from patients.

For patients, the study provides clear criteria for making informed decisions when selecting a physician. This enables patients to focus more precisely on aspects such as ethics, communication skills, and professional expertise. In the context of Patient Decision-Making (PDM), patients can weigh these aspects more rationally, ultimately choosing a healthcare provider that better aligns with their needs. Notably, the study reveals that a physician's warm image and good communication skills positively impact PDM, instilling confidence in patients and improving the overall doctor-patient relationship, thereby enhancing the consultation experience.

For online healthcare service platforms, the findings of this study offer valuable insights. Platforms can target physicians' images and characteristics more precisely for display and promotion. Emphasizing characteristics related to professional ethics, communication skills, and professional expertise can provide patients with comprehensive information, enabling more informed choices. By recommending physicians that better align with patients' expectations through matching algorithms based on physician image characteristics, online healthcare platforms can significantly improve patient satisfaction and increase user engagement and loyalty to the platform.

5.4. Managerial implications

This study also provides some management insights. It can be applied to image management and service delivery in healthcare

organizations, online healthcare platforms, and individual physicians.

Healthcare organizations can provide training for physicians to strengthen their communication skills and interpersonal relationship management capabilities. Training can help physicians better communicate with patients, build trust, and enhance the doctor-patient relationship; promote physician teamwork and emphasize multidisciplinary collaboration to provide more integrated, high-quality healthcare services. The professional competence and cooperation of the team will affect patients' satisfaction and choice of healthcare services; collaborate with physicians to shape their image and emphasize their professionalism, warmth, and communication skills. This helps improve the hospital's reputation and attract patients to the clinic.

Online medical platforms can utilize data on physician image characteristics to enable matching and recommendation through intelligent algorithms to help patients choose the correct physician better. The platform can recommend physicians with appropriate characteristics based on patient's needs and preferences. Optimize the display of physician information, highlighting the physician's professional ethics, communication skills, professional skills, and other characteristics. Provide more comprehensive information about the physician through the clear display of information to help patients make informed PDMs.

Physicians can emphasize their professional skills and experience in their promotional materials and convey their professionalism and competence to patients through case presentations and other means; show friendliness and cordiality in their communication with patients and build up their trust and comfort through good communication; and pay attention to their outward appearance and image, smile moderately and wear glasses reasonably to show confidence and professionalism.

5.5. Limitations

This study still has some limitations and needs further improvement in future research. First, this study only selected Chinese review data from a single healthcare service platform. It did not collect review information in other languages, such as English, which resulted in sample companies and sample data needing to be more homogeneous. In future studies, we consider collecting multi-language comment data from multiple third-party online platforms to validate the generalizability of the study. Additionally, the reliance on patient reviews as a sole measure of decision-making introduces potential biases, as only a subset of patients may contribute reviews. The study lacks a definitive solution to this issue. To address this limitation, future research should explore alternative methodologies to mitigate biases related to patient reviews, enhancing the robustness of findings and providing a more comprehensive understanding of the relationship between patient decision-making and online reviews. Second, this study mainly obtained user insights from surface user-generated content but could not deeply analyze the deeper motivations and psychological factors behind patients. These deep motives may impact physician image and PDM, and the findings can be enriched by combining other research methods in subsequent work.

Data availability statement

The data supporting the findings of this study are not publicly available due to privacy and ethical concerns. The datasets contain sensitive information that could compromise research participant privacy and confidentiality. Despite these restrictions, interested researchers can contact the corresponding author for inquiries regarding the data under specific conditions that ensure compliance with ethical standards and participant consent.

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CRediT authorship contribution statement

Shizhen Bai: Project administration, Funding acquisition, Conceptualization. **Yongbo Tan:** Writing – review & editing, Validation, Software, Methodology, Conceptualization. **Jiayuan Zhao:** Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Dingyao Yu:** Writing – review & editing, Methodology. **Jing Zhang:** Supervision. **Qiutong Li:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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