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Exploring achievement gamification on online medical quality based on machine learning and empirical analysis
(Work-in-Progress)

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ABSTRACT

How to improve online medical quality is an important challenge for practitioners of digital health platforms. Gamification creates new opportunities to deal with the problem persistent in online health services. To better understand the role of gamification in online health services context, this study intends to use the research method of machine learning and natural experiment to explore the impact of achievement gamification on online medical quality in online health services, as well as the moderating effects of doctors' personality and image. Theoretically, this study will expand the application of game strategy in the field of healthcare, and make up for the deficiency of the effects of gamification on online medical quality. Practically, it provides guidance for promoting doctors' online participation behavior, improves the quality of online health services, and suggests ways for optimizing the rational allocation of online health resources.

Keywords: Digital health, achievement gamification, online medical quality, machine learning and natural experiment.

INTRODUCTION

As a major product in the era of digital economy, digital health has brought subversive changes to health services. It not only facilitates patients' medical treatment, but also enables doctors to obtain more value by providing online services for patients. Furthermore, the emergence of online health services has also promoted the online flow of medical resources. Especially during the period of COVID-19, the popularity of online health services and public awareness have been greatly improved. At the same time, it has also cultivated the habit of people accepting online health services, thus promoting the development of online health services.

Regardless of offline health services or online health services, medical quality has always been the top priority of healthcare services. The medical quality directly affects the health status of patients. However, due to the seriousness and dryness of health services, doctors are often tired of offline health services, and lacked energy for online health services. In addition, it is difficult for doctors to actively participate in online health services because of the uncertainty and unawareness of online health services. This makes online medical quality more difficult to guarantee.

The emergence of gamification provides more possibilities to alleviate the above problems in online health services. As a new concept in recent years, gamification has attracted extensive attention in the fields of education (Santhanam et al., 2016), health (J. Liu et al., 2020; Yang & Li, 2021b), marketing (D. Liu et al., 2017; Tobon et al., 2020) and so on. It is a new way to guide user interaction, increase participation and system interest. Medical gamification refers to the application of gamification elements and mechanisms to scenarios in the healthcare field. The characteristics of game entertainment and immersion make doctors' serious and boring work more interesting, increase the interest of doctors' online services and clarify goals, so as to increase doctors' sense of participation, achievement and value in online health services. This is also a possible solution for doctors who are keen to devote more leisure energy to online health services, and provide higher quality of online services for patients.

Previous studies have explored the impact of gamification on doctors' online participation behavior. Game elements such as badges and ranking are added to the online health services to stimulate the game experience and improve the participation of doctors (J. Liu et al., 2020). At the same time, the online contribution of doctors is stimulated by awarding the title of good doctor of the year. In addition, gamification in online health services introduces competition as a challenge incentive to encourage doctors to actively participate (Harwood & Garry, 2015). However, most of the previous studies explored the impact of gamification on doctors' online participation from the perspective of quantity, while the research on the quality of online participation is insufficient. And gamification is likely to lead doctors to blindly pursue quantity and ignore quality,

resulting in worse online medical quality. Achievement gamification design increases the sense of achievement after doctors' efforts. Will this promote doctors to provide higher quality online health services? These mechanisms are unclear and lack of effective causal evidence. Therefore, this study explores the impact of achievement gamification on online medical quality.

Medical quality includes both medical technology quality and medical service quality. Previous studies mostly measure medical quality from the perspective of patients. For example, patients' satisfaction with doctors' service quality and service attitude, and few studies explore medical quality by mining doctors' own generated information from the perspective of doctors. Therefore, this study will use supervised machine learning method to extract medical technology support and medical service support from the text information generated by doctors' online services for patients, and use these two variables to measure medical technology quality and medical service quality, respectively.

Therefore, based on the above discussion, this study raises the following research questions: how does achievement gamification affect online medical quality (medical technology quality and medical service quality) provided by doctors to patients? In addition, the medical technology quality and medical service quality provided by doctors may be related to their own characteristics. Therefore, the second research question is raised: is the moderator role of doctors' personality traits and doctors' image?

THEORETICAL BACKGROUND AND HYPOTHESES

Gamification on the Online Health Services

In recent years, gamification has gradually penetrated into the field of healthcare. Gamification is not only a method, but also a way of thinking. The essence of gamification is to use game-thinking to solve non-game problems, users can experience the feeling of game and immerse themselves in the experience of gamification, so as to encourage users to actively participate in behavior and motivation. The gamification design in online health services aims to stimulate the game experience and improve doctors' participation by adding game elements to the environment (Yin et al., 2022). It can make doctors actively participate in online health services by adding badges and ranking, which is obvious to other doctors and patients (Liu et al., 2011). At the same time, giving doctors the title of good doctor of the year can reflect their professional knowledge and contribution in the past, which provides a basis for patients to evaluate the credibility of doctors and the reliability of their treatment before choosing online health services. In addition, gamification in online health services introduces competition as a challenge and incentive to encourage doctors to actively participate (Harwood & Garry, 2015). According to the motivation theory of gamification mechanism, excepting intrinsic motivation, extrinsic motivation such as economic return is also an important motivation, which may increase doctors' participation in online health services (Zhou et al., 2019). The achievement gamification design in online health services increases the participation of doctors and makes them keen to compete with others in the process of online services (Liu et al., 2011). The result of this competition among doctors makes the economic returns unequal. The basic principle is that the economic return obtained by doctors from online health services mainly comes from the consulting fees paid by patients, and the level of economic return is positively affected by the number of patients (Guo et al., 2017). Therefore, in online health services, gamification is also closely related to the financial return of doctors.

Gamification in patient health management is considered to be an effective solution that can change health behavior and improve health management performance (Wouters et al., 2013; Sardi et al., 2017; Sola et al., 2015). Gamification can effectively promote individuals' enjoyment of health management and meet their internal needs for health management (Sailer et al., 2017). The main manifestations are as follows: ① Gamification improves the performance ability of individual health management. For example, Allam et al. found that gamification-intervention has a positive impact on patients with rheumatoid arthritis and effectively improves the health management performance of patients with chronic diseases (Allam et al., 2015). ② Gamification promotes changes in personal health behavior. Hamari compared the impact of game design and non-game design on individual physical activities (Hamari, 2017). ③ Gamification increases the willingness of individuals to continuously use health information technology. Yang et al. found that gamification-intervention can improve individuals' perceived usefulness of mHealth, promote their willingness to use mHealth and increase their frequency of use (Yang & Li, 2021b).

Achievement Gamification on Online Medical Quality

The online medical quality is an important part of online health services, which directly affects patient satisfaction, diagnosis and treatment effect, health status and so on (Chen et al., 2020). According to 3Q service quality theory, the online medical quality could be divided into technology quality, system quality and service quality (Xu et al., 2013). Prior literature illustrated that service quality at different stages is an important driver of patient compliments (Wu et al., 2020). Yan et al. posited that the information and emotional are the major type of social support that patients can exchange in online patient-patient interactions, furthermore the companionship support has a positive impact on the peer-patient health status (Yan & Tan, 2014). Mein Goh J et al. (Goh et al., 2016) also confirmed that patients living in rural areas can obtain more benefits by exchanging information with the outside world through the online health services, helping to alleviate regional health disparities between rural and urban users. Therefore, in the online doctor-patient health services, online technology quality and service quality are the major types of online medical quality that doctors and patients exchange in their online interactions.

In previous studies, many scholars have studied the external factors affecting doctors' online service quality from the perspective of motivation theory, including patients' active participation (Chen et al., 2020), the number of patients' gifts (Zhao et al., 2017), thank-you letters and so on (Wiering et al., 2017; X. Zhang et al., 2020). While it also remains unclear what are the internal factors for doctors to provide online health service. Liu et al. (X. Liu et al., 2016) have shown that doctors' online reputation and offline reputation are important determinants affecting doctors' performance. The achievement elements in gamification could make users get more sense of achievement and satisfaction (Xi & Hamari, 2019; Yin et al., 2022). Therefore, we infer that achievement gamification could promote the doctor to provide higher quality of online service. Thus, we hypothesize that:

H1: Achievement gamification has a positive effect on online medical quality (H1a: medical technology quality, H1b: medical service quality).

Moderating Effects of Doctors' Personality and Images

Beyond that, the service quality theory indicates that in different situations, individuals have different expectations in the process of services. Specifically, some scholars have shown that users with different personality traits have different levels of sensitivity to their own behavior (Bansal et al., 2010). Doctors' external behavior stems from their real internal personality. With that in mind, we posit that a doctor's online performance is the true reflection of their internal personality. Thus, it is worth to explore the moderator effect of doctors' personality. Hence, we hypothesize that:

H2: Doctor's personality has a moderator effect on between achievement gamification and online medical quality (H2a: medical technology quality, H2b: medical service quality).

Furthermore, the doctor's images, similar to a brand image, is also a symbol of a person's status or reputation. Prior study has indicated the brand image increases trust and purchase intention, the brand image may moderate the potential negative effects of that text length on trust and purchase intent (Agmeka et al., 2019). And in the field of sharing economy, the Airbnb property demand changed after the acquisition of verified images, properties with verified images had 8.98% higher occupancy than properties without verified images (S. Zhang et al., 2021). On this basis, it can be inferred that doctors with high-quality doctor image are willing to pay more efforts than those with low-quality doctor image. Thus, we also assume:

H3: Doctor's image has a moderator effect on between achievement gamification and online medical quality (H3a: medical technology quality, H3b: medical service quality).

Figure 1. The Theoretical Research Model
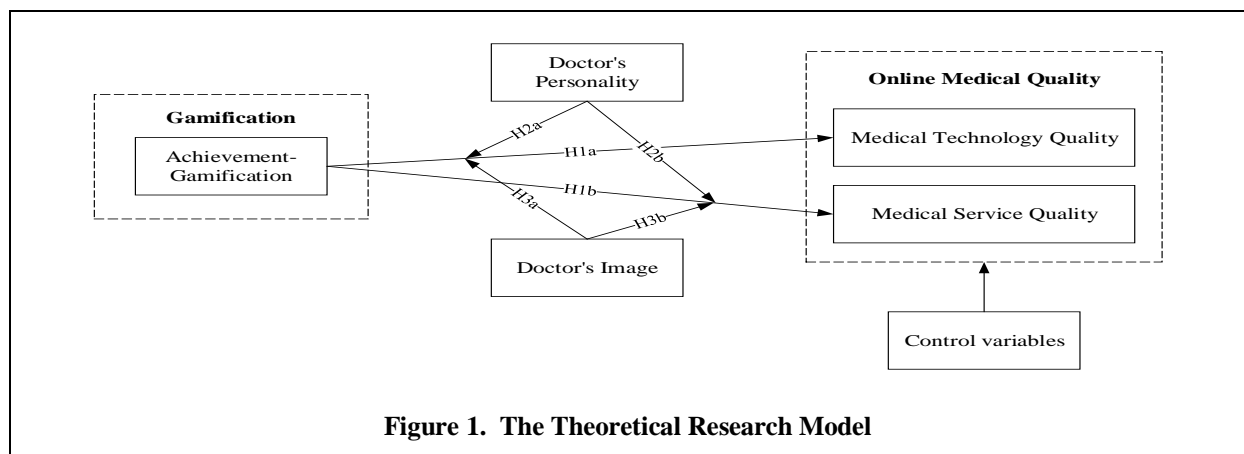
RESEARCH METHODOLOGY

Research Context

Our study focuses on the online health community: haodf.com, which comprises the greatest quantity and quality of authoritative doctors in China. The haodf.com portal was founded in 2006 and is a leading Internet medical platform in China. In fact, haodf.com includes about 790,000 physicians from more than 10,000 different hospitals in large cities providing online appointments and patient management services. It not only generates a large number of structured data, unstructured text and image data, but also provides a game design environment, which provides a good research context for this study. The research context is shown in Figure 2.

Figure 2. The Research Context

Study measures

The dataset will be selected through a python crawler to collect historical data for doctors and their attributed data from Haodf.com with a monthly panel dataset. The definitions and descriptions of the major variables are provided in Table 1.

Table 1. The Description of Variables

Variables	Definition & Measure
Dependent Variable	
Achievement Gamification	A dummy variable indicating whether the doctor have obtained achievement gamification. 1 represents that the doctor has obtained achievement gamification; 0 represents that the doctor did not obtain achievement gamification
Independent Variable (*Online Medical Quality*)	
Medical Technology Quality	In the process of online health services, the average value of doctors providing help to patients from professional and technical aspects in a month
Medical Service Quality	In the process of online health services, the average value of doctors providing help to patients from the aspects of humanistic care such as emotion and attitude in a month
Moderate Variable	
Doctor's Personality	The scores of the openness, conscientiousness, extroversion, agreeableness and neuroticism personality trait of a doctor. The value is in the range of 0-100
Doctor's Image	The doctor's image information classification. 1 for positive emotion; 0 is neutral or negative emotion
Control Variable	
LogTotalPatients	The number of online patients in a month
RecomHeat	Online recommendations from patients. The value is in the range of 3-5
LogThanksLetter	The number of online letters from patients in a month
LogGiftNum	The number of online gifts from patients in a month
LogTotalPapers	The number of online papers that doctors have published in a month
LogPatVotes	The number of online votes from patients in a month

Research Procedures

This study is expected to use machine learning and natural experiment methods to verify the research hypotheses. Machine learning method mainly extracts the required dependent variables and moderator variables from unstructured text data and image data. The natural experiment method is to verify the causal effect of achievement gamification on online medical quality (medical technology quality and medical service quality).

① Machine learning process

The machine learning process includes three parts: First, extracting online medical quality (medical technology quality and medical service quality) from the text information of online doctor-patient interaction by using supervised machine learning method. Second, classifying doctors from their images by image recognition. Thirdly, based on the doctor's multidimensional data, the unsupervised text analysis method is used to extract the doctor's personality trait. The process of machine learning process includes data collection, data pre-processing, database, variables extracting (supervised machine learning, unsupervised text mining, image recognition), then the dependent variables and moderator variables of this study are obtained.

② Natural experiment design

Natural experiment design is mainly through the game design of online health platform to form a natural experiment. The treatment group is the doctors who get the achievement gamification, the doctors who did not obtain the achievement gamification were taken as the control group (Table 2). In the process of doctors and patients participating in online health services, a large number of observable structured data and unstructured text or picture data are generated. By compiling Python web crawler, this study obtains the panel data generated by doctors in online health services, and uses natural experimental

methods to explore the causal effect of achievement gamification on online medical quality (medical technology quality and medical service quality). In particular, whether individual doctors participate in gamification is affected by their own characteristics (such as personality traits or image), and in order to make the research results closer to the causal effect, need to be eliminate the endogenous and selective bias. Therefore, this study will use PSM method to match the samples, and then use DID to analyze the causal effect of gamification. The equations are presented as follows.

Table 2. The Nature Experiment Design

	Before	After
Treatment Group	O	X
Control Group	O	O

The causal effect model of achievement gamification on online medical quality (medical technology quality and medical service quality) is as follows:

$$OnlineMedicalQuality_{it} = \beta_0 + \beta_1 Gamification_{it}$$
$$\beta_2 A_i + \beta_3 B_t + \varepsilon_{it}$$

The moderator effect model of doctors' personality and image is as follows:

$$OnlineMedicalQuality_{it} = \beta_0 + \beta_1 Gamification_{it}$$
$$+ \beta_2 Gamification_{it} * Personality_i + \beta_3 Gamification_{it} * Image_i + \beta_4 A_i$$
$$+ \beta_5 B_t + \varepsilon_{it}$$

Where, *i* represents a doctor, and *OnlineMedicalQuality*$_{it}$ represents to online medical quality (medical technology quality and medical service quality); *Gamification*$_i$ is a dummy variable of the experimental group, and the control group was the baseline; *Personality*$_i$ is the individual personality trait of doctor *i*; *Image*$_i$ is the doctor's image information, and A_i represents the individual fixed effect; B_t represents time fixed effect; ε_{it} is a random error term.

CONCLUSIONS AND OUTLOOK

This study expects to verify the causal effect of achievement gamification on online medical quality (medical technology quality and medical service quality) through machine learning and natural experiment based on service quality theory. Theoretically, the research results will expand the application of game strategy in the field of healthcare, furthermore, it makes up for the deficiency of the gamification on online medical quality from the theoretical level. Meanwhile, it would provide theoretical guidance for improving the medical game design system. Practically, it provides theoretical and practical guidance for medical platform managers to design reasonable game strategies to promote the effective operation of online health services. Furthermore, for patients, it can also increase the good medical experience of patients and help patients' online decision-making behavior.

While the conceptual model of this study is grounded in empirical work and literature, it is still in its infancy. The follow-up work of the conceptual model will include an extended literature review to improve the understanding of each hypothesis. Further work will also include more detailed presentations of the methodology, empirical analysis and discussions introduced in this paper. Finally, in the robustness test section, this study will eliminate the endogenous problem of whether doctors choose gamification through the method of instrumental variables. As a prospect of this study, it can be concluded that the further potential of this study lies in extending the research model to include grouping experiments. Furthermore, it is important to consider the different sub-dimensions of gamification design in this study. Further to this, it is also important to consider the impact of multi-gamification integration strategies on the comprehensive benefits and heterogeneity, such as achievement, immersion and sociality elements.

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