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Study on the Adoption of Remote ECG Monitoring Based on Protective Motivation Theory and TPB Theory

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Abstract

Objective: To construct the adoption behavior model of remote Electrocardiograph (ECG) monitoring by integrating the theory of planned behavior and protective motivation, in order to explain the influencing mechanism of use intention to adopt the remote ECG monitoring. **Methods:** 364 questionnaires were collected, 336 valid questionnaires were obtained. The structural equation model was constructed to analyze the results. **Result:** The structural equation test supported proposed hypotheses: compatibility, subjective normative, perceived disease susceptibility, response efficacy and self-efficacy could positively influence the use intention to adopt remote ECG monitoring; response-efficacy and self-efficacy has the most positive influence on behavior intention, while response cost has the most significant negative effect on use intention. **Conclusion:** The improvement of response-efficacy and self-efficacy could promote the adoption of remote ECG monitoring service, while response cost could probably fail the adoption of remote ECG monitoring service. The service provider and the developers, could promote effective service to the target users, to guarantee a better experience in order to enhance the response-efficacy and self-efficacy. They could also strengthen the training and guidance for users, to reduce the response cost, and promote the adoption of services.

Keywords

Remote Electrocardiograph Monitoring, Structural Equation Model, Protection Motivation Theory, Theory of Planned Behavior

1. Introduction

Remote ECG monitoring consists of ECG monitoring mobile terminal, hospital monitoring center server and network communication support. ECG monitoring terminal collects, processes and analyzes human ECG signals, automatically identifies and distinguishes normal and abnormal ECG signals, provides pre-diagnosis, assessment and classification, timely captures abnormalities, provides alarm, and realizes timely treatment. The ECG signal fragment is transmitted to the monitoring center, and the monitoring center will send the diagnosis result and corresponding treatment measures to the ECG mobile monitoring terminal through the network in the form of SMS, so as to achieve real-time cardiac monitoring. As the aging trend intensifies, subhealthy people and high-risk cardiovascular groups keep growing, cardiovascular diseases not only need hospital diagnosis and treatment, but also need remote ECG monitoring services based on wearable devices, which will reduce the pressure of medical staff and improve the

success rate of cardiovascular disease prevention and first aid. Existing researches focus more on intelligent information processing methods [1] and health monitoring system technology [2], a few on the adoption of medical wearable devices [3], and less on the adoption of information technology for high-incidence diseases. The research model was constructed by combining the theory of planned behavior and the theory of protective motivation to explore the mechanism affecting the adoption behavior of tele-ECG monitoring, so as to provide a reference for patient behavioral intervention and the design and promotion of health service products.

2. Literature Review

The theory of planned behavior is applied to the prediction and intervention of population health behavior [4], including: Drug taking and withdrawal behavior [5, 6], eating behavior [7], clinical treatment and testing behavior [8], etc. In terms of cardiovascular disease, study on the theory of planned behavior includes exercise intention of patients with coronary heart disease [9], interpretation and prediction of patients' participation in stage II cardiac rehabilitation behavior [10], and development of psychosocial determinants scale for measuring physical activity behavior of patients with coronary heart disease [11]. A study of participation in the fourth stage of community cardiac rehabilitation [12].

According to the protective motivation theory, individual threat assessment and behavioral ability to cope with health threats determine the behavioral intention to protect health and affect the health behavior [13]. Mobile health service adoption behavior is explored from the perspective of health behavior to deal with potential health threats [14]. In foreign studies, the main applications of protective motivation theory include: verifying the effect of training on controlling blood sugar in diabetic patients [15]; Protection and promotion of cardiac rehabilitation exercise for patients [16]. Domestic studies include: control of sexual disease transmission [17]; Nursing intervention to promote self-management behavior after coronary intervention [18]; To provide community nursing interventions for patients with diabetes to improve glycemic control [19].

This research proves that the protective motivation theory and the planned behavior theory are effective in analyzing and predicting health behavior, and the combination of them could improve the explanation. Therefore, the theory of planned behavior and the theory of protective motivation are applied on the adoption of information technology related to cardiovascular diseases, to understand the internal cognitive process and interaction mechanism that promote the change of individual behavioral intention and behavior itself, so as to lay a foundation for further intervention, and provide a valuable theoretical framework and application tools for chronic disease prevention and health care, improve the compliance of healthy behaviors.

3. Research models and hypotheses

3.1 Conceptual Model

A conceptual model is proposed by combining the theory of planned behavior and the theory of protective motivation. Among the endogenous variables: behavioral intention is the outcome variable while innovativeness is the intermediary variable. Exogenous variables include perceived disease susceptibility, response effectiveness, response cost, and self-efficacy which are independent variables, as Figure 1.

3.2 Research Hypothesis

3.2.1 Protection motivation theory

(1) Hypotheses related to perceived disease susceptibility. Perceived susceptibility refers to an individual's probability assessment of exposure to adverse threats [20], which significantly affects an individual's intention of self-examination for diseases. The higher the possibility of perceived health problems are, the greater the perceived disease susceptibility is. For remote monitoring devices that require information technology innovativeness, the more likely they are to be adopted by groups with better innovativeness. If the perceived susceptibility is strong but the innovativeness is weak, other non-information technology methods such as diet adjustment and traditional Chinese medicine conditioning would be adopted to reduce the health risk. Perceived disease susceptibility might influence the willingness to adopt remote ECG monitoring through innovativeness. Therefore, we get H1: Perceived disease susceptibility positively affects the innovativeness of users in adopting remote ECG monitoring.

(2) Hypotheses related to innovativeness. Innovativeness could be defined as the degree to which an individual is willing to try an innovative product, technology or to accept an innovative product, which has a significant impact on

doctors' perceived ease of use in mobile health care [21]. Innovativeness could lead to greater willingness of adopting remote ECG monitoring, among individuals with a higher potential risk of getting cardiovascular disease. Therefore, we make the hypothesis H2: Innovativeness positively affects users' willingness to adopt remote ECG monitoring.

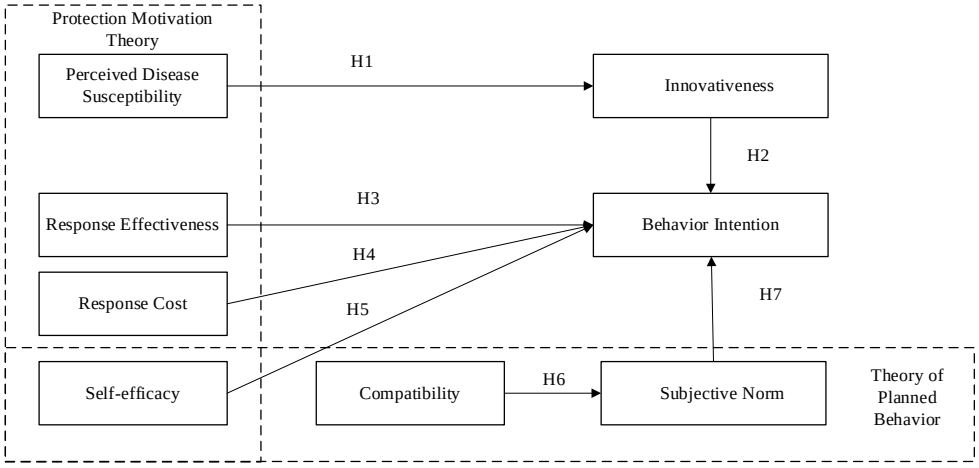

Figure 1. The proposed model.

(3) Hypothesis related to response effectiveness. Response effectiveness refers to the effectiveness of individual evaluation of coping behaviors in reducing threats [22]. Response effectiveness refers to an individual's perception of the role of remote ECG monitoring. If they believe that remote ECG monitoring could help improve cardiovascular health, its use rate increases. Therefore, the hypothesis is as follows: H3: Response effectiveness positively affects users' behavioral willingness to adopt remote ECG monitoring.

(4) Response cost related hypothesis. Reaction cost measures the perceived cost of protective behavior [22], which reduces users' behavioral intention. If the response cost is high, individuals usually hesitate to take the behavior [23]. The response cost refers to the time and money required by individuals to adopt remote ECG monitoring. If the more money and effort it costs, the lower willingness individuals have to use it. Otherwise, they are willing to adopt this measure [24]. Therefore, we get the hypothesis: H4: Response cost negatively affects users' behavioral intention to adopt remote ECG monitoring.

(5) Self-efficacy related hypothesis. Self-efficacy focuses on the assessment of individual's internal ability, which refers to the perception of protective behavioral ability, with a significant impact on the willingness to adopt information systems [24]. If users have more confidence in the services, they are more willing to adopt it. Therefore, we get hypothesis: H5: Self-efficacy positively affects users' behavioral willingness to adopt remote ECG monitoring.

3.2.2 Theory of planned behavior

Compatibility and subjective norm related hypothesis. Compatibility refers to the technology's compatibility degree with other existing products' technical functions, users' demands and lifestyles [25]. The technical compatibility between remote ECG monitoring and existing devices (such as smart phones, personal computers and wireless sensor networks) is considered to measure the extent to which the monitored information could be transmitted to remote devices, significantly affecting the adoption behavior, reflecting the compatibility between life style and ECG monitoring terminal. Subjective norms refer to the social pressure brought by the external environment when taking behaviors, which are obtained by individuals through consulting others or observing their behaviors [26]. The better the compatibility is, the more likely one is to take the initiative to consult related services with others to improve the feasibility of adoption through the influence of external environment. The external environment also positively encourages the adoption due to the compatibility. Therefore, the hypothesis is as follows: H6: Compatibility positively affects the subjective norm for users to adopt remote ECG monitoring. Subjective norms have a significant impact on the adoption of mhealth services by medical staff [27]. Therefore, we get the hypothesis: H7: subjective norms positively affect users' behavioral willingness to adopt remote ECG monitoring.

In the theory of planned behavior, in accordance with research context and research object, perceived behavior control is regarded as self-efficacy, while attitude and perceived severity are replaced by compatibility and innovativeness respectively.

4. Research objects and methods

4.1 Research design and analysis

In order to understand the factors influencing the willingness to adopt tele-ECG monitoring, a questionnaire survey was conducted on potential users of remote ECG monitoring in October 2021. Users should have a knowledge of telemedicine and ECG monitoring, and volunteer to participate.

4.2 Questionnaire design

The questionnaire was designed by referring to the existing literature and reliable scale, including the basic information of potential users and the influencing factors of the willingness to adopt remote ECG monitoring. The online questionnaire was prepared by Wenjuanxing (https://www.wjx.cn/) and distributed through WeChat and QQ.

4.3 Data processing and analysis

SPSS26.0 was used to conduct descriptive, reliability and validity tests. AMOS26.0 was used to validate the model and hypothesis.

5. Results

5.1 Demographic analysis

In this study, 364 questionnaires were collected, among which 336 questionnaires are valid after deletion of the homogenized questionnaires, with an effective rate of 90.31%. Among the participants, the ratio of male to female is close, the age mainly distributed between 26 and 55, education degree mostly bachelor's degree and master's degree, annual income mostly less than 150,000 yuan. Most participants have full-time jobs and a mate, who live with their families, with experience of Internet medical services less than 3 years.

According to the report of cardiovascular diseases in China, 10.3% of residents in China have a high incidence of cardiovascular diseases. Among the 7 regions in mainland of China, the prevalence of high-risk diseases is higher in Northeast China and North China, while lower in South China. The standardized rate of high-risk cardiovascular disease groups in Northeast was 12.6%, 11.4% in North China, and only 8.0% in South China [28]. The survey population mainly covers Northeast and North China, which can reflect the current situation of influencing factors for the adoption of remote ECG monitoring. The geographical distribution and percentage of samples are shown in Table 1.

Table 1. Sample distribution and percentage

Region	Province	Provincial Sample	Regional Sample	Regional Percentage
Northeast	Heilongjiang	167	192	57.14%
	Liaoning	25		
North China	Beijing	79	86	25.60%
	Hebei	7		
Central China	Henan	2	8	2.38%
	Hubei	5		
	Hunan	1		
East China	Shanghai	7	25	7.44%
	Jiangsu	6		
	Zhejiang	3		
	Shandong	5		
	Anhui	3		
	Fujian	1		
South China	Guangdong	8	11	3.27%
	Guangxi	1		
	Hainan	2		
Southwest	Sichuan	3	8	2.38%
	Guizhou	2		
	Chongqing	3		
Northwest	Shanxi	1	1	0.30%
Abroad	UK/US	5	5	1.49%

5.2 Scale construction and reliability & validity analysis

The questionnaire scale and sources are as Table 2:

Table 2. Scale and source

Variable	Item connotation	Reference
Perceived Disease Susceptibility	I might be susceptible to cardiovascular disease	Wang [29], Guo [30], Huang [31]
Response Effectiveness	The possibility that the remote ECG monitoring can improve cardiovascular health.	Wang [29], Guo [30], Huang [31]
Response Cost	The time, money and energy that the use of remote ECG monitoring is considered to cost	Wang [29], Guo [30], Huang [31]
Self-efficacy	The ability I can use remote ECG monitoring to improve cardiovascular health	Wang [29], Guo [30], Huang [31]
Innovativeness	Innovation in the application of personal information technology products.	Liu [32], Wu [33]
Compatibility	The compatibility between remote ECG monitoring and life	Li [34]
Subjective Norm	Influence from environment or family and friends on the adoption of remote ECG monitoring	Deng [35]
Behavior Intention	Intention to adopt remote ECG monitoring	Deng [35]

The scale was constructed as Table 2. By SPSS26.0 software, we got the KMO value of the model as 0.974, and the significance p value of Bartlett's sphericity test 0.000, indicating that the results passed the test, being suitable for validity test. Cronbach's Alpha value and its standardized value of all items were greater than 0.7, factor load greater than 0.7 and significant at the 0.001 level, AVE value greater than 0.5, and composite reliability value greater than 0.7, indicating good reliability and validity of the scale.

5.3 Model construction and verification

By applying maximum likelihood estimation method of the proposed model in AMOS26.0, the analysis was done by bootstrappML method with 5000 subsamples run. Under the 95% confidence interval of bias correction, the hypothesis testing results were obtained as Figure 2, the fitting results in Table 3, with the standardized effect values of the structural equation model in Table 4.

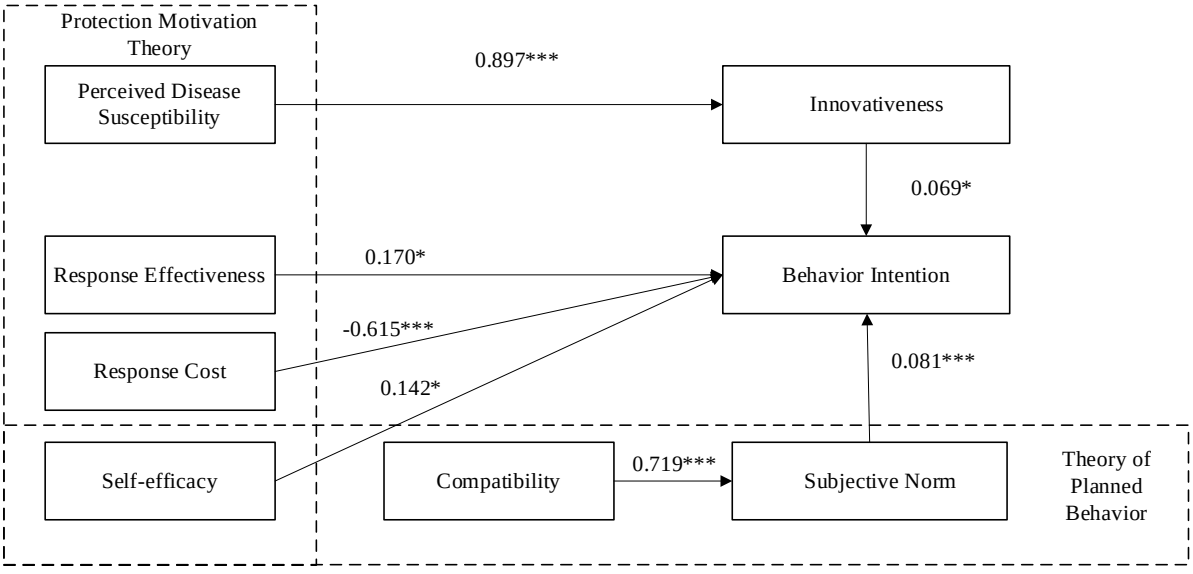

Figure 2. Schematic diagram of Hypothesis test results.

Table 3. Fitting index results of structural equation model

Index	χ^2	df	χ^2/ df	RMSEA	CFI	TLI	NFI
Evaluation Criterion	-	-	2.0-5.0	<1.0	>0.8	>0.8	>0.8
Model-fit Result	939.396	282	3.331	0.083	0.943	0.934	0.921

Table 4. Normalized effect values for structural equation models

	Total Effect	Direct Effect	Indirect Effect	Direct Effect Proportion	Direct Effect P Value	Indirect Effect Proportion	Indirect Effect P Value
Perceived Disease Susceptibility Behavior Intention	0.061	0	0.061	0.00%	-	100.00%	0.038*
Innovativeness Behavior Intention	0.069	0.069	0	100.00%	0.039*	0.00%	-
Response Effectiveness Behavior Intention	0.170	0.170	0	100.00%	0.047*	0.00%	-
Response Cost Behavior Intention	-0.615	-0.615	0	100.00%	0.001**	0.00%	-
Self-efficacy Behavior Intention	0.142	0.142	0	100.00%	0.039*	0.00%	-
Compatibility Behavior Intention	0.058	0.058	0	100.00%	-	0.00%	0.000***
Subjective Norm Behavior Intention	0.081	0.081	0	100.00%	0.000***	0.00%	-

As Figure 2, the original hypothesis was supported. As Table 3, the fitting indexes of the model satisfy the evaluation criteria. After the specification search test, the fitting effect and hypothesis test results of the model significantly got worse after adding or deleting any path, which proved that the model could reflect the influence mechanism of the adoption of remote ECG monitoring better. As Table 4, response efficacy and self-efficacy have the largest positive influence on the intention to use, indicating that the perception of remote ECG monitoring on the improvement of cardiovascular conditions, as well as the self-use of ECG monitoring to improve their own cardiovascular conditions, have a major positive influence on the intention to use. Compatibility, subjective norm, innovativeness, and perceived disease susceptibility have a weak positive effect, which indicated that they are not the main factors affecting the intention to use. Compatibility and subjective norm have the strongest influence on the intention to use, indicating that although compatibility and subjective norms have weak but stable influence. The negative effect of response cost on the willingness to use is much greater than the positive effect of other factors, indicating that remote ECG monitoring should pay more attention to the learning time cost and capital expenditure of users, reducing the reaction cost, so as to be more likely to be adopted by the demander.

6. Discussion

The adoption model of remote ECG monitoring verified the effects of planned behavior theory and protective motivation theory on users' intention to use remote ECG monitoring. The results showed that response efficacy and self-efficacy had mainly positive effects, response cost mainly negative effects. Compatibility, subjective norms, personal innovation, and perceived disease susceptibility had little effect on users' intention to use remote ECG monitoring.

Service providers and developers could promote more services, strengthen training and guidance, improve response efficiency and self-efficacy, to promote service adoption. At the same time, attempts to reduce the time cost and capital expenditure of user adoption could improve the service adoption rate. The results of this study can provide reference for the personnel who plan to use remote ECG monitoring for patient tracking, help the medical institutions and developers who have the conditions to popularize remote ECG monitoring or similar health monitoring services.

In order to improve the user's acceptance of remote ECG monitoring, the equipment needs to provide useful information and services (response effectiveness), and provide medical services in a way that pleases consumers and

arouses their favor (self-efficacy). In addition, special attention should be paid to reducing the use of time and capital expenditure through training, reducing unnecessary functions, prices and other ways. Eventually, healthcare institutions and policymakers could seek guidelines from the study results, for instance, by providing the public with training, infrastructure (such as WiFi connectivity), and community-based technical support services (such as IT specialists), to help them recognize resource availability when using remote ECG monitoring to manage their health conditions.

7. Conclusion

Based on the theory of protective motivation and the theory of planned behavior, the structural equation model of the willingness to adopt remote ECG monitoring was constructed, verified by online questionnaire survey, with relevant suggestions put forward according to the research results, in order to provide reference for the promotion of remote ECG monitoring and the improvement of more efficient medical resource allocation. There are certain limitations and deficiencies in the study, such as insufficient samples and limited theoretical variables. Other theories (such as social cognitive theory) or other scenario-related factors (such as perceived risk) would be considered in the future, to explore remote health monitoring services for other diseases, and the latest implementation of the technology.

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