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A comparative analysis of digital health usage intentions towards the adoption of virtual reality in telerehabilitation

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ABSTRACT

Background: With the rapid development of the metaverse and the problem of non-attendance in traditional rehabilitation, virtual reality in telerehabilitation has become increasingly vital in modern medicine. However, research on determining predictors that influence the public's behavioral intention to adopt VR-based telerehabilitation has not been extensively studied.
Objective: This study aims to propose a new research model with a comparative analysis on understanding factors affecting the public's behavioral intention to adopt VR in telerehabilitation for different user groups.
Methods: A total of 215 respondents from the general public completed an online questionnaire to validate the proposed research model. The collected data was analyzed using SPSS and AMOS. The proposed model was additionally validated using CFA and multiple linear regression.
Results: This study found that effort expectancy, threat appraisals, and trust had a positive significant influence on the public's behavioral intention to adopt VR in telerehabilitation. However, performance expectancy and facilitating conditions had no significant relationship with behavioral intention. Notably, the average of the primary factors for older adults was generally higher than for younger adults.
Conclusions: The present study confirms the applicability of the proposed research model. Our findings contribute up-to-date insights for related stakeholders to minimize implementation failures and develop successful adoption strategies for the future expansion of telerehabilitation.

1. Introduction

Recently, an increase in the global elderly population, an unhealthy lifestyle, and a rise in the prevalence of disability have been the key factors driving the demand for rehabilitation services. However, limited appointment times, inconvenient travel distances, and declining motivation pose a challenge to the participation rate in rehabilitation treatments. Additionally, the COVID-19 epidemic has prompted worldwide healthcare organizations to consider alternative digital approaches for delivering medical services remotely.

Meanwhile, due to the latest technological advances in digital health and medicine, various approaches have been developed to improve patients' participation in rehabilitation programs. Recently, the applications of a metaverse in medicine have become increasingly important in the healthcare industry [1]. Metaverse in medicine refers to the medical Internet of Things (MIoT) accessed via a combination of virtual reality (VR), augmented reality (AR), and mixed reality (MR) technology, which can deliver medical services via 3D avatars [2–4]. Of those, telerehabilitation with virtual reality is one of the promising treatments that use information and communications technology to deliver rehabilitation services to patients remotely [5]. Previous literature examined that VR in telerehabilitation has been widely adopted in digital health [6–9]. This cutting-edge technology can save time, transportation fees, and medical expenses while enhancing access to rehabilitation programs [10–12]. Using VR in telerehabilitation, healthcare providers can offer conventional rehabilitation services like evaluation, diagnosis, treatment, and education via the Internet [13]. Telerehabilitation with VR also offers patients prescribed goal-oriented exergames and task-based exercises in virtual settings to improve balance, gait, and motivation in treatment [12,14,15]. With the rising applications of VR platforms in digital medicine, the global telerehabilitation market is projected to grow significantly at a Compound Annual Growth Rate (CAGR) of 15%

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between 2020 and 2027 [16].

Although VR-based telerehabilitation is a growing trend in digital health, telehealth initiatives fail 75% of the time globally and 90% in developing countries [17]. The public's acceptance of virtual environments in telerehabilitation is seen as a long-term challenge that requires further investigation. To further popularize the use of VR in telerehabilitation, behavioral intention is considered a vital factor affecting the success rate of digital health. However, previous research mainly focused on the technological, feasible, safe, and effective aspects of telerehabilitation. The existing literature lacks comprehensive insights to support future decision-making on VR in telerehabilitation [18]. There is still much to explore regarding the variables influencing the public's behavioral intention to use VR in telerehabilitation. Therefore, healthcare organizations and service developers need to understand the behavioral intention to use VR-based telerehabilitation to comprehend patients' needs and reduce implementation failure [19].

Despite the rising number of potential applications for telerehabilitation using virtual reality, research regarding the public's usage intentions is still in its infancy. The use of VR-based telerehabilitation is viewed not only as a technological acceptance behavior but also as a health-promoting action that assists patients in preventing health threats [20,21]. However, prior research primarily applied the technology acceptance model (TAM) or the unified theory of acceptance and use of technology (UTAUT) model to analyze user behavior in the context of VR in telerehabilitation [14,22,23]. Recently, the protection motivation theory (PMT) has been widely adopted to explain protective behavior in the telehealth field [24–27]. There is still a lack of research on examining the usage intentions of telerehabilitation with the combination of the UTAUT and PMT. Additionally, previous studies have not shed light on comparing user intentions across different age groups using a comprehensive analysis. Determining the public's perceptions of VR-based telerehabilitation regarding different age groups is essential for healthcare organizations and service developers to understand the actual needs and drawbacks of the currently used VR technologies. However, there is still much investigation needed to examine the user's needs with a multi-group analysis.

Thus, this study proposes to understand factors affecting the public's behavioral intentions to adopt VR in telerehabilitation. Additionally, a multi-group analysis will be conducted to analyze age differences. Notably, this study focuses on the following two contributions:

To propose a new research model that integrates existing theories to indentify key predictors of behavioral intentions to adopt digital health technology.

To advance the knowledge of VR in telerehabilitation by comparing behavioral intentions between different age groups through a comparative analysis.

2. Methods

2.1. Proposed research model

This study proposes a new research model based on previous literature [20,25,26,28–38]. The proposed theoretical framework is illustrated in Fig. 1. Five hypotheses are proposed as follows: H1: Performance expectancy positively affects behavioral intention in using VR in telerehabilitation [39–41]. H2: Effort expectancy positively affects behavioral intention in using VR in telerehabilitation [42–44]. H3: Facilitating conditions affect behavioral intention in using VR in telerehabilitation [38,45,46]. H4: Threat appraisals positively affect behavioral intention in using VR in telerehabilitation [20,24,39]. H5: Trust positively affects behavioral intention in using VR in telerehabilitation [31–33].

2.2. Questionnaire design

In the first section, 24 items were used to measure the five constructs shown in the proposed research model (Fig. 1). All questions were measured using a 7-point Likert scale. The second section contained basic demographic questions about participant characteristics. The instruments included in the proposed research model were developed from the previous literature. Among the 24 items, 4 items were adopted to determine performance expectancy [25,30,47], 5 items were adopted to determine effort expectancy [48–50], 3 items were adopted to determine facilitating conditions [20,51,52], 4 items were adopted to determine threat appraisals [28,53], 4 items were adopted to determine trust [31,50,54], and 4 items were adopted to determine behavioral intention [22,55]. Details on the factors and measurement items are summarized in Appendix A. Informed consent was obtained for experimentation with human subjects. All procedures were performed in compliance with institutional guidelines and conducted with the

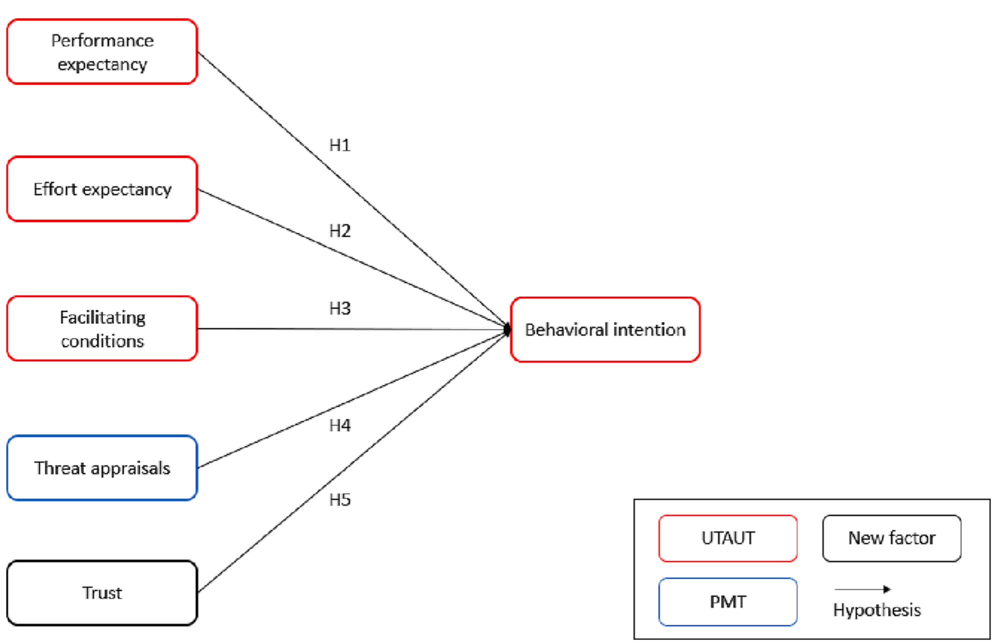

Fig. 1. Proposed research model.

approval of the Human Subjects Ethics Sub-Committee of the Hong Kong Polytechnic University.

2.3. Participants and procedures

An online survey was conducted with the population who have received rehabilitation services in the last 12 months and are aged 18 or above in Hong Kong. The reasoning is that potential telerehabilitation users include not only those over the age of 60 but also adolescents and adults, particularly employees who require repetitive movements that pose a risk of injury. In Hong Kong, 14,299 people received rehabilitation treatments in the last 12 months. The sample arose from the database of the Hong Kong Society for Rehabilitation [56]. A simple random sampling method was adopted to select 225 participants as respondents, which was in line with previous telehealth-related research [57–59]. A detailed explanation of related definitions and key terminology was provided to the participants before the survey. A total of 215 valid samples were received via Google Forms with the support of a rehabilitation center in Hong Kong. The method was also in line with recent research [60,61]. Detailed explanatory information and the letter of invitation are summarized in Appendix B.

2.4. Data analysis

IBM SPSS Statistics 26 and IBM SPSS Amos 26 Graphics were utilized to analyze all the collected data. First, the CFA was applied to test the proposed model's reliability, and convergent and discriminant validity. The thresholds of Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE) were set to 0.6, 0.7, and 0.5, respectively. [62–65]. Additionally, the heterotrait-monotrait ratio of correlations (HTMT) was used to evaluate the discriminant validity of the model [66]. The value of HTMT is calculated by comparing the correlations of the indicators on the other constructs with the correlations of indicators inside the same construct [66]. An acceptable value of HTMT should be less than 0.85, 0.9, or between confidence intervals of −1 and 1, respectively [66–68]. In addition, chi-square to degrees of freedom, root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), and comparative fit index (CFI), were applied to determine the model fitness. This study adopted the recommended values of $\chi^2/df < 5$, RMSEA < 1, SRMR < 0.08, and CFI > 0.9 [65,69]. Further, the age differences were determined using Welch's ANOVA test. An alpha level of 0.05 was applied in the current study. In addition, multiple regression analysis was used to test and validate the relationship between the model parameters using SPSS [70]. The values of R, R-Square, adjusted R-Square, beta coefficient (β), p-value, and t-value were also determined in the analysis.

3. Results

3.1. Demographic characteristics

A total of 225 questionnaires were distributed to the target population via email. In total, 215 responses were received, yielding a 95.6% response rate. Table 1 revealed that males accounted for 33.5% (n = 72) and females accounted for 66.5% (n = 143) of the participants. Moreover, the largest age group of respondents was 18 to 24 years old (n = 101), followed by 25 to 34 years old (n = 46). Besides, most participants were married, accounting for 67.4% (n = 145) of the total. Additionally, 45.1% (n = 97) of the total respondents had a university degree. Students were the largest industry group among respondents (n = 99), followed by those working in the wholesale, retail, import, and export trades, restaurants, and hotel industries (n = 35).

Furthermore, most participants (n = 205) had no previous experience with VR in telerehabilitation. In addition, about 60.5% (n = 130) of participants had never heard of telerehabilitation before.

Table 1
Demographic characteristics.

	Classification	n	%
Gender	Male	72	33.5
	Female	143	66.5
Age	18 – 24 years	101	47
	25 – 34 years	46	21.4
	35 – 44 years	18	8.4
	45 – 54 years	24	11.2
	55 – 64 years	15	7
	65 or above	11	5.1
Marital status	Married	145	67.4
	Single	67	31.2
	Divorced	3	1.4
Education level	Junior high school or below	4	1.9
	Senior high school (Including vocational)	45	20.9
	Diploma/Sub-degree	12	5.6
	University degree	97	45.1
	Post-graduate or above	57	26.5
Industry	Manufacturing	20	9.3
	Construction Industry	8	3.7
	Wholesale, Retail, Import and Export trades, Restaurants and Hotels Industry	35	16.3
	Transport, Warehousing, and Communication Industry	9	4.2
	Financing, Insurance, Real Estate, Professional and Business Services	15	7
	Community, Social and Personal services	29	13.5
	Student	99	46
Monthly income	HKD 10,000 or below	117	54.4
	HKD 10,001–20,000	62	28.8
	HKD 20,001–30,000	22	10.2
	HKD 30,001–40,000	8	3.7
	HKD 40,001–50,000	2	0.9
	HKD 50,001 or above	4	1.9
Have you ever used telerehabilitation services before?	Yes	10	4.7
	No	205	95.3
Do you know any information on telerehabilitation services before conducting this survey?	Yes	85	39.5
	No	130	60.5

3.2. Descriptive analysis

As shown in Table 2, the overall mean score was 5.55 (SD = 1.14), and the means of each item ranged from 5.00 to 6.17. This result implied that the overall responses could be viewed as positive. Moreover, the SD of each item ranged from 0.844 to 1.749, meaning that the collected data were clustered around the mean. Additionally, this study accepted the recommended values of ± 2.0 and ± 7.0 for skewness and kurtosis, respectively [65,71,72]. According to Table 2, the skewness values ranged from −1.498 to −0.438, and the kurtosis values ranged from −0.113 to 2.794, meaning that the collected data were normally distributed and appropriate for data analysis.

3.3. Reliability and validity analysis

3.3.1. Reliability analysis

To measure the internal reliability, Cronbach's alpha (α) was calculated against the cut-off value of 0.6 [62,63]. The overall Cronbach's alpha was 0.933. According to Table 2, five constructs ranged from 0.692 to 0.890, which were higher than the recommended thresholds. The results indicated favorable internal reliability of the measurement model.

Table 2
Results of descriptive analysis, standardized factor loadings, internal consistency, and convergent validity.

Factors/Items	Mean	SD	Factor Loadings	Skewness	Kurtosis	Cronbach's α	CR	AVE
Performance expectancy	**5.74**	**0.978**				0.739	0.743	0.420
PE1	5.75	0.981	0.715	−1.107	2.794			
PE2	5.95	0.844	0.766	−0.750	0.699			
PE3	5.73	1.032	0.761	−0.763	0.387			
PE4	5.53	1.054	0.762	−0.830	1.236			
Effort expectancy	**5.76**	**0.990**				0.855	0.858	0.548
EE1	5.80	1.000	0.817	−0.931	1.266			
EE2	5.78	0.920	0.839	−0.812	1.012			
EE3	5.91	0.960	0.813	−1.100	2.094			
EE4	5.60	1.031	0.727	−1.020	2.186			
EE5	5.73	1.038	0.789	−0.859	0.628			
Facilitating conditions	**5.59**	**1.146**				0.692	0.702	0.441
FC1	5.20	1.235	0.793	−0.808	0.648			
FC2	5.39	1.194	0.866	−0.966	1.070			
FC3	6.17	1.009	0.693	−1.498	2.617			
Threat appraisals	**5.31**	**1.481**				0.799	0.815	0.534
TA1	5.00	1.749	0.680	−0.939	−0.100			
TA2	5.51	1.427	0.829	−1.110	0.843			
TA3	5.44	1.262	0.842	−0.670	−0.113			
TA4	5.29	1.485	0.843	−0.921	0.400			
Trust	**5.34**	**1.125**				0.890	0.894	0.680
T1	5.40	1.071	0.852	−0.497	−0.074			
T2	5.25	1.235	0.832	−0.669	0.139			
T3	5.33	1.150	0.909	−0.607	−0.060			
T4	5.36	1.044	0.884	−0.438	0.064			
Behavioral intention	**5.52**	**1.148**				0.878	0.882	0.652
BI1	5.53	1.118	0.850	−0.645	0.123			
BI2	5.65	1.044	0.871	−0.818	0.776			
BI3	5.59	1.106	0.888	−0.890	0.710			
BI4	5.30	1.324	0.829	−0.758	0.434			
Overall mean and SD	**5.55**	**1.14**				**0.933**		

3.3.2. *Convergent validity analysis*

As shown in Table 2, the composite reliability (CR) varied in the range of 0.702 to 0.894, which was greater than the suggested threshold of 0.7 [67]. Besides, if the CR was>0.6, the convergent validity could still be viewed as acceptable even though the AVE was<0.5 [73]. In the study, the values of AVE ranged from 0.420 to 0.680, however, all the measured CRs were higher than 0.6. Thus, this study can still accept the construct of performance expectancy (AVE = 0.420). In addition, all item loadings were higher than the recommended threshold of 0.5 [65]. The factor loadings ranged from 0.715 to 0.766 for *PE*; 0.727 to 0.839 for *EE*; 0.693 to 0.866 for *FC*; 0.680 to 0.843 for *TA*; 0.832 to 0.909 for *T;* and 0.829 to 0.888 for *BI*. Thus, the results indicated satisfactory convergent validity of constructs.

3.3.3. *Discriminant validity analysis*

Discriminant validity was assessed using the HTMT. According to Table 3, the HTMT criterion of each pair ranged from 0.398 to 0.955. It was found that thirteen pairs of constructs were smaller than the $\text{HTMT}_{0.85}$ criterion, fourteen pairs of constructs were smaller than the $\text{HTMT}_{0.9}$ criterion, and one pair (trust and behavioral intention) showed that only the use of $\text{HTMT}_{\text{inference}}$ established discriminant validity [66,68]. Thus, the results revealed that the discriminant validity of the model has been determined based on the $\text{HTMT}_{\text{inference}}$ criterion.

3.4. *Model fit*

In the study, $\chi^2/\text{df} = 2.133 < 5$, RMSEA = 0.073 < 1, SRMR = 0.059 < 0.08 and CFI = 0.909 > 0.9. All the above fit indices reached the thresholds, demonstrating a favorable model fit measurement for confirmatory factor analysis [65,69].

3.5. *Comparison between different age groups*

As shown in Table 4, Welch's ANOVA test was used to determine the age differences in the public's behavioral intentions to adopt VR in telerehabilitation. There were statistically significant differences between age groups and performance expectancy ($p < 0.05$), facilitating conditions ($p < 0.05$), threat appraisals ($p < 0.001$), trust ($p < 0.001$), and behavioral intention ($p < 0.001$). Additionally, the mean scores of PE, EE, TA, T, and BI for older adults were generally higher than for younger adults. Besides, the mean scores of facilitating conditions for older adults were generally larger than for younger adults, except for older people aged 65 or above. Remarkably, the elderly aged 65 or older had the largest mean score for the average behavioral intention, indicating that they were more likely to adopt VR-based telerehabilitation in the future. Lastly, by applying Games-Howell post hoc tests, the results revealed that older people aged 65 or above had significant differences

Table 3
Discriminant validity - The HTMT results.

Discriminant validity - The HTMT results.

Items	PE	EE	FC	TA	T	BI
1. Performance expectancy						
2. Effort expectancy	0.875					
3. Facilitating conditions	0.812	0.846				
4. Threats appraisals	0.471	0.445	0.398			
5. Trust	0.670	0.637	0.689	0.550		
6. Behavioral intention	0.720	0.701	0.686	0.581	0.955	

Table 4
ANOVA results for the age differences.

ANOVA results for the age differences.

Variables	Age Group						Welch's F.	Sig.	Games-Howell Post Hoc Test
	18-24	25-34	35-44	45-54	55-64	≥ 65			
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)			
Performance expectancy	5.62 (0.74)	5.67 (0.73)	5.90 (0.88)	6.04 (0.62)	5.85 (0.67)	**6.11 (0.42)**	3.291	0.012*	⑥ > ①*
Effort expectancy	5.65 (0.84)	5.74 (0.73)	5.79 (0.97)	6.00 (0.70)	6.15 (0.63)	5.87 (0.35)	2.011	0.093	
Facilitating conditions	5.51 (0.89)	5.58 (1.03)	5.35 (1.24)	**5.96 (0.58)**	5.93 (0.54)	5.33 (0.54)	3.465	0.009*	④ > ①*
Threat appraisals	5.14 (1.12)	5.02 (1.10)	4.81 (1.51)	6.02 (0.99)	**6.25 (0.86)**	6.07 (0.57)	9.849	0.000**	④ > ①*; ⑤ > ①*; ⑥ > ①*; ④ > ②*; ⑤ > ②*; ⑥ > ②*; ⑤ > ③*; ⑥ > ③*
Trust	5.14 (0.97)	5.13 (1.03)	5.49 (1.02)	**5.96 (0.75)**	5.73 (0.87)	5.82 (0.34)	7.618	0.000**	④ > ①*; ⑥ > ①**; ④ > ②*; ⑥ > ②*
Behavioral intention	5.28 (0.98)	5.38 (0.87)	5.64 (1.07)	6.07 (0.86)	5.93 (1.06)	**6.30 (0.43)**	9.565	0.000**	④ > ①*; ⑥ > ①**; ④ > ②*; ⑥ > ②**

*refers to a p-value < 0.05; **refers to a p-value < 0.001; the shaded cells are the highest mean scores among age groups.

from young adults aged 18 to 24 in most of the measured variables, including performance expectancy, threat appraisal, trust, and behavioral intention.

3.6. Predictability

In the study, a correlation coefficient (R) of 0.868 demonstrated a satisfactory level of prediction. Additionally, the R-squared = 0.754 indicated that the proposed model explained 75.4% of the variance in the behavioral intention to use VR-based telerehabilitation. Furthermore, the adjusted R-squared = 0.748 revealed that 74.8% of the variation was explained by only the predictors that influenced the BI. In addition, the independent variables significantly predicted behavioral intention, $F (5, 209) = 127.940$, $p = 0.000 < 0.001$, denoting that the five predictors had a significant impact on behavioral intention. Therefore, the regression model had strong explanatory power for the response variable.

3.7. Multiple regression analysis

The results of the multiple regression analysis are summarized in Table 5. The final testing results are illustrated in Fig. 2.

4. Discussion

4.1. Age differences

Older adults perceived a higher intention to adopt VR in telerehabilitation as they were more likely to experience functional decline and be hospitalized [74]. They also have relatively lower sensitivity toward privacy concerns than younger generations [75]. Furthermore, older people are less capable than young adults of using electronic devices such as game-based telerehabilitation platforms and mobile applications [38]. Therefore, service developers should offer timely online support to end-users, especially with concise electronic instruction manuals, assistance, and guidelines for older users to understand the use of VR-based telerehabilitation applications [38,44].

Table 5
Results of the Multiple Regression Analysis.

Results of the Multiple Regression Analysis.

Hypothesis	Regression Weights	Beta Coefficient (β)	t	P-value	Results
H1	PE → BI	0.085	1.673	0.096	Rejected
H2	EE → BI	0.132	2.463	0.015*	Accepted
H3	FC → BI	0.003	0.063	0.950	Rejected
H4	TA → BI	0.099	2.516	0.013*	Accepted
H5	T → BI	0.679	14.626	0.000**	Accepted

*refers to a p-value < 0.05; **refers to a p-value < 0.001; the colored cells refer to the accepted hypothesis testing.

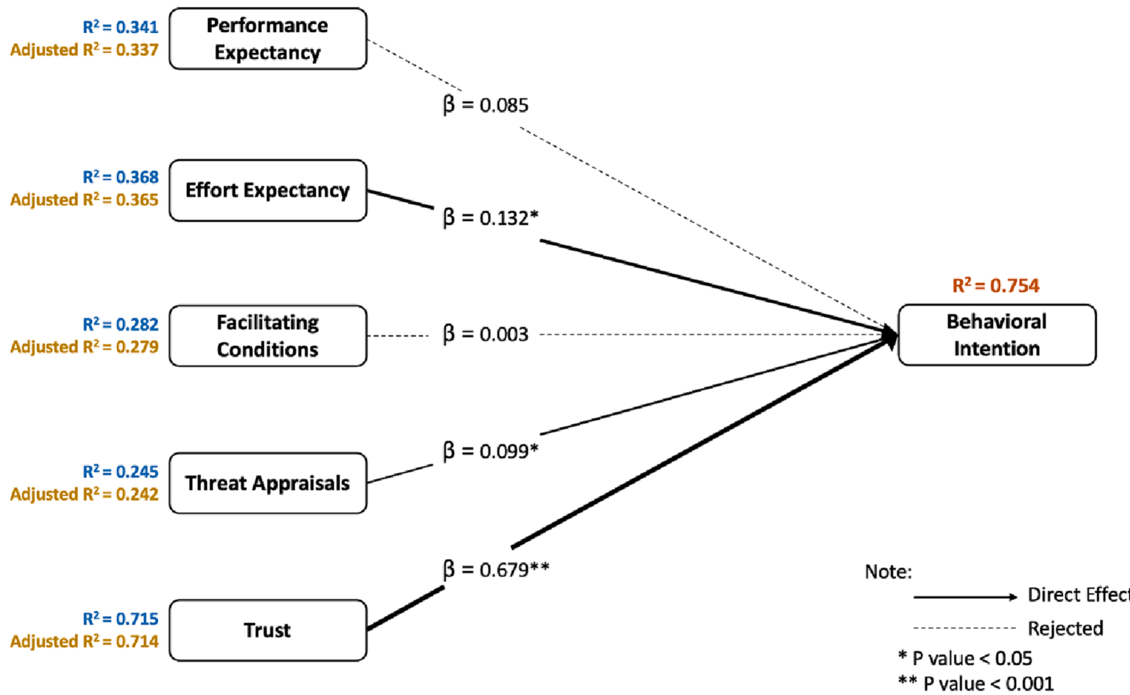

Fig. 2. Results of the Multiple Regression Analysis.

4.2. Performance expectancy (PE)

Performance expectancy was rejected as having a significant impact on the usage intention. Our respondents seem to be the late majority of new technology adopters, who tend to adopt an innovation after it is widely accepted by the public and acknowledge its related benefits. Further, the lack of hands-on experience in operating technologies such as AI-powered medical devices and IoT automation systems is another vital reason [76]. Thus, it is suggested to enhance promotional campaigns via traditional and digital channels. Service providers can offer a trial version to the public for free. The government can also invest more resources in educating the public on core competencies related to AI, IoT, VR, and cloud-based technology.

4.3. Effort expectancy (EE)

Effort expectancy was the second strongest predictor affecting usage intention. Owing to the high potential risk of COVID-19 inflection [60,77], people are more willing to receive treatment via the Internet [34,78]. Additionally, greater schedule flexibility regarding appointment time and treatment duration is another reason [79,80]. Thus, developers should improve the user interface with well-established guidelines, simple data visualization, multiple languages, and adjustable icons and fonts [38,81,82]. Besides, developers should also focus on the ergonomics of the head-mounted display, handheld controllers, and wearable sensors [83,84].

4.4. Facilitating conditions (FC)

Facilitating conditions proved to have no significant influence on the usage intention. People from Generation Z are viewed as “self-learners”, meaning that they are more technologically sophisticated and are likely to solve problems by browsing the Internet [85]. Additionally, owing to the omicron outbreak, we do not have a chance to visit in-person rehabilitation centers. Thus, our respondents were mainly from Generation Z and Y, who are familiar with using the Internet to solve technical problems. Consequently, it is advised to add an exclusive Q&A section plus a search bar feature for users to search for desired answers using keywords [86,87].

4.5. Threat appraisals (TA)

Threat appraisals were positively influencing the usage intention. During the pandemic, people became more aware of COVID-19 diseases and related sequelae [88–90]. Besides, an increase in the sufferers of musculoskeletal conditions could be another reason [91]. As younger employees always require repetitive movements with prolonged sitting gestures, they are at a relatively higher risk of suffering joint pain [92]. Further, aging problems also cause acute and chronic musculoskeletal pain in the elderly [93]. Thus, it is suggested that marketers should target both older adults and workers who require repetitive movements in the global telerehabilitation market [20,94].

4.6. Trust (T)

Trust was the strongest predictor that positively affects the usage intention. The possible reason can result from the raising of confidence in healthcare providers who have clinical expertise in telehealth [95,96]. The public perceives less uncertainty as providers can offer a high climate of trust with various data protection practices. Accordingly, providers should indicate service reliability by offering evidence-based research papers and a detailed explanation of the currently used cloud-based storage platform on their website [41,97]. Besides, developers can display the obtained safety certifications, like CE marking, fulfillment of regulations, and ISO standards, as well as employee profiles on the website [98].

5. Conclusions

This study proposed a new research model that integrates the UTAUT and PMT to explain the factors affecting usage intentions toward adopting VR in telerehabilitation. A comparative analysis is also conducted to determine the age differences. The results reveal that EE, TA, and trust are key determinants that significantly affect usage intentions toward VR in telerehabilitation. Further, the results also indicate that PE and FC had no significant relationship with BI. In terms of age categories, older generations have higher averages for PE, EE, TA, T, and BI than younger adults. Practical implications for developers are summarized as follows: (i) Establish promotional campaigns for VR technologies; (ii) Improve an easy-to-use user interface with detailed guidelines, simple data visualization, multiple languages, adjustable icons, and fonts; (iii) Target both older generations and workers who require repetitive movements; (iv) Build trust through sufficient data protection measures and communication strategies. Thus, our findings offer valuable insights for stakeholders to develop well-established user adoption strategies for VR-based telerehabilitation in the future.

6. Summary table

What is already known on the topic:

- The UTAUT and the PMT are widely used models for determining technology acceptance and health behavior, respectively.
- Behavioral intention is a vital factor influencing the success rate of the implementation of virtual reality in telerehabilitation.
- Applications for VR-based telerehabilitation are becoming increasingly vital in digital health; however, research on determining the public's behavioral intentions based on a multi-group analysis and a new research model is still not well studied.

What has this study added to the body of knowledge?

- A new research model that integrates the UTAUT and the PMT, along with trust as an additional factor, was able to explain the public's behavioral intentions to adopt virtual reality in telerehabilitation through a survey of 215 respondents from the general public.
- A multi-group analysis determined the age differences in behavioral intentions and found that the average of performance expectancy, effort expectancy, threat appraisals, trust, and behavioral intention for older generations were higher than for younger generations.
- Among factors, trust explained the highest amount of variance in the public's usage intentions to adopt VR in telerehabilitation.

CRediT authorship contribution statement

Yee Kiu Chan: Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. **Yuk Ming Tang:** Conceptualization, Resources, Validation, Writing – review & editing, Supervision, Funding acquisition. **Long Teng:** Writing – review & editing, Funding acquisition.

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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Appendix A

Measurement items for the behavioral intention to use VR in telerehabilitation services

Constructs	Items	Description	References
Performance expectancy (PE)	PE1	Using the AI Analysis System can enhance the effectiveness of VR in telerehabilitation services.	
	PE2	Using the Automated IoT System makes VR in telerehabilitation more convenient.	
	PE3	I think that using immersive VR technology will be useful for practicing telerehabilitation services.	
	PE4	If I use non-immersive VR Technology, I will improve my performance on telerehabilitation services.	[25,30,47]
Effort expectancy (EE)	EE1	By displaying my health data in a simple graphic form weekly or monthly, I would find VR in telerehabilitation easy to use.	
	EE2	With easy-to-wear VR hardware that includes a head-mounted display, handheld controllers, and wearable sensors, my interaction with telerehabilitation services would be clear and understandable.	
	EE3	I think the VR-based telerehabilitation platforms will be easy to use if they provide a user-friendly interface in terms of language, instructions, and guidelines.	
	EE4	I think the VR-based telerehabilitation service is easy to use using a 5G-enabled network.	[48–50]
	EE5	I do not need high effort to use VR in telerehabilitation based on the convenient location and flexible schedule.	
Facilitating conditions (FC)	FC1	I have the capability to use VR in telerehabilitation services.	
	FC2	I think I can get help from the organization when I have technical difficulties in using VR in telerehabilitation services.	
	FC3	It is important to have online support for technical difficulties while using VR-based telerehabilitation services.	[20,51]
Threat appraisals (TA)		Please answer the following questions regarding these health problems: (1) Upper extremity pain; (2) Lower extremity pain; (3) Low back pain	
	TA1	It is possible for me to suffer from the stated health problems.	[28,53]
	TA2	I will worry about the stated health problems.	
	TA3	If I suffered the stated health problems, it would be serious.	
	TA4	If I get the stated health illness, it will change my whole life.	
Trust (T)	T1	VR-based telerehabilitation services would be trustworthy for improving my health conditions.	
	T2	I do not doubt the honesty of VR-based telerehabilitation services.	
	T3	VR in telerehabilitation would be reliable in conducting rehabilitation services.	[31,50,54]
	T4	I feel confident that I will be able to rely on the advantages provided by VR-based telerehabilitation services.	
Behavioral intention (BI)	BI1	I feel positive about using VR in telerehabilitation services.	
	BI2	Assuming that I have a chance to access VR in telerehabilitation services, I intend to use it.	

(*continued on next page*)

(*continued*)

Constructs	Items	Description	References
	BI3	Whenever I would require rehabilitation services from therapists, I would gladly adopt VR in telerehabilitation services.	
	BI4	I plan to use VR-based telerehabilitation services in the future.	[22,55]

Appendix B

Detailed explanatory information and the letter of invitation

- **Explanatory information**

Telerehabilitation uses information and communications technology to deliver rehabilitation services like evaluation, diagnosis, therapy, and education to patients via the Internet. Virtual reality in telerehabilitation also provides goal-oriented exergames and task-based exercises to improve patients' balance, gait, and motivation toward rehabilitation.

Benefits: Save time, minimize therapy spending, and transportation fees, and improve access to rehabilitation services under the COVID-19 circumstances.

Connection methods: Video-conferencing platforms, smartphones, wearable sensors, Virtual Reality, and Robotics.

Key terminology

– The AI Analysis System provides diagnostic clues, identifies error causes, and develops a better treatment plan for patients.
– The automated IoT system allows the collection of patient information such as their body position and range of movement. Patients can track their health information and receive real-time feedback from the IoT-based vision.
– Immersive VR technology refers to the use of VR headsets, hand controllers, data gloves, or bodysuits to interact with a virtual environment. It enables patients to visualize the rehabilitation process through an immersive computer display.
– Non-immersive VR technology uses a computer or television screen to create a two-dimensional environment that does not require any additional immersive equipment. Goal-oriented games allow real-time feedback and utilize motion-tracking sensors to exemplify the required ranges of motion for patients to improve.

- **The Letter of Invitation**

This survey aims to collect your opinions on the behavioral intentions to use virtual reality in telerehabilitation. Your participation is entirely voluntary. Your responses will be highly appreciated and valuable for the telerehabilitation system developer and healthcare organizations in planning and developing an advanced system to enhance users' participation in rehabilitation programs.

You are required to fulfill the following requirement before conducting this survey.

*Aged 18 or above.

*Obtained any rehabilitation treatments in the past 12 months.

It will take you about 10 min to complete this survey. Please be assured that all information provided in this survey will be kept strictly confidential. Results and findings will be reported in aggregated form only. If you have any questions about the survey, you may contact our research team.

We truly appreciate your participation in this questionnaire.

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