Heliyon 8 (2022) e08765

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Elderly's intention to use technologies: A systematic literature review

Yee-Yann Yap, Siow-Hooi Tan *, Shay-Wei Choon

Faculty of Management, Multimedia University, Persiaran Multimedia, 63100 Cyberjaya, Selangor, Malaysia

ARTICLE INFO

Keywords:
Elderly
Technology adoption
Systematic literature review
Older adults
Behavioral intention
Aging

ABSTRACT

The population aging and an increased life expectancy are widely recognized social changes. Technologies are believed to improve the elderly's daily lives and maintain their health efficiently. Despite the advantage of adopting technologies, the elderly are slower to adopt new technologies compared to younger adults. This paper presents a Systematic Literature Review (SLR) to identify the different antecedents prevailing in the literature on elderly technology adoption. The SLR classifies and analyzes 26 relevant articles on elderly's technology adoption. Our findings revealed that quantitative approach and cross-sectional studies predominate in this field, building fundamentally upon the technology-driven theories. We identify seven categories of antecedents influencing elderly's use of technology, namely, technology, psychological, social, personal, cost, behavior, and environment antecedents. A conceptual framework for elderly's technology adoption and recommendations were presented. Particular attention is given to the need for in depth study for the antecedents, development of new measurement scales and investigation on the effectiveness of the proposed benefits after technology adoption.

1. Introduction

According to the United Nations [1], 703 million people aged over 65 years in the worldwide population in the year 2019, and it is expected to double to over 1.5 billion in 2050. This increase in the aging population will bring a significant impact on society and healthcare systems. When the elderly get older, their cognitive, physical and sensory impairments will increase; hence more health-related issues will occur [2, 3, 4]. Moreover, most elderly prefer to age in place independently for as long as possible. The need to travel for regular medical treatment will be difficult for the elderly with limited mobility [5]. With that, technologies have emerged to provide innovative and efficient ways to assist the elderly in their daily life and maintain their health.

Many different types of technologies have been introduced to provide the elderly assistance in daily activities, such as computers [6], the internet [7], digital healthcare technology [8] and others. Hence, technology is believed to resolve the gap between the elderly's wishes and their needs to have great potential to assist and prolong elderly independent living, improve mental and physical health, and increase well-being. Despite the advantage of adopting technologies, the elderly are slower to adopt new technologies compared to younger adults [9]. Therefore, understanding the factors that will influence their intention to use new technologies is vital to increase the elderly's technology adoption. Since 2010, the context of elderly technology adoption has been frequently studied in a variety of technologies setting such as healthcare and assistive technology [8, 10, 11], social networking technology [12, 13, 14], online shopping [15, 16], Internet [17, 7], computer [6], online public service [18] and entertainment [19, 20].

While the literature on technology adoption among the elderly has grown rapidly, a thorough, systematic literature review will be helpful to discuss and critically identify the gaps of what is already known and unknown regarding the antecedents impacting the technology adoption. Hence, this paper provides a comprehensive systematic literature review that aims to analyze the present state of the literature about elderly's technology adoption; subsequently, the research gaps are identified, and recommendations for the future research are proposed.

2. Method

This paper presents a comprehensive systematic literature review by identifying, appraising, and synthesizing all relevant studies that fulfill the pre-identified inclusion criteria based on the predetermined and explicit technique to answer the specified research questions [21, 22]. The following four research objectives were developed in order to present a comprehensive report on the current studies:

(1) To compare the similarities and differences of the elderly's technology adoption literature over time, countries, research methods and topics;

* Corresponding author.
E-mail address: shtan@mmu.edu.my (S.-H. Tan).

https://doi.org/10.1016/j.heliyon.2022.e08765
Received 11 September 2021; Received in revised form 6 December 2021; Accepted 11 January 2022

(2) To determine the frameworks/theories/models that constitute the most prominent structure in the elderly adoption of technologies;
(3) To identify the antecedents affecting the elderly's technology adoption;
(4) To propose multiple directions that can open new avenues for future research based on the identified knowledge gaps.

This systematic literature review aims to locate research focusing on the elderly adoption of technology tools. The search keyword(s) and the database(s) to search were identified in the review phase. For the search, this study used an online database which is ScienceDirect. Hence, the following keywords were used to search for related articles: technology, elderly, older, aging[1], adoption, behavior[2] intention and intention. The search was conducted using the following expression: "Technology" AND ["elderly" OR "elder" OR "aging" OR "senior" OR "older"] AND ["adoption" OR "behavior intention" OR "intention"]. The search centered on 2010 to April 2021 studies to see the trend of the studies. By using the pre-identified keywords, the results show 1385 articles. After refining the results with inclusion criteria, results were reduced to 586 articles. After screening the title and abstract of articles with the exclusion criteria (see Table 1), 50 articles remained for full-text articles accessed for eligibility.

It is noteworthy that the definition of the "elderly" is different in chronological age in different countries and contexts. Those studies without specifying the age range of the elderly respondent were not included in this review. Figure 1 summarizes the procedure of finding and choosing suitable articles. A total of 26 articles were retained and reviewed. Table 2 illustrates the list of journals that published the chosen articles.

The research objective (1) was addressed in Section 3, in which the similarities and differences of the elderly's technology adoption literature over time, countries, research methods and topics are identified. Following this, frameworks/theories/models adopted in the elderly's technology adoption studies are being discussed in Section 4. More specifically, a descriptive analysis of the 26 articles was first undertaken, mainly frequency tables and graphs, and descriptive measurement, to provide an overview on each study's years and countries, age range of elderly, type of technology, methodology and theories used in technology adoption for the elderly. Section 5 answered the research objective (3), which is about the identification of key antecedents. In particular, details of each selected study were extracted and their findings were analyzed to identify the influencing antecedents of technology adoption for the elderly. Section 6 echoed the research objective (4) by identifying the gaps in the existing literature and providing recommendations for future research.

3. Categorization of literature on elderly's technology adoption

3.1. Categorization of studies: years and countries

From the 26 articles which were retained, it is worth noting that the number of elderly's technology adoption studies grew from 2013 onwards as shown in Figure 2. The year 2019 (8 publications) was the one in which the greatest number of publications were observed. The average year of publication is 2017, which shows that this is an emerging research field. The results show that research on the subject began to be published more frequently from 2017 onwards. Apart from that, out of the 26 studies, only one study conducted cross-countries research. In general, most studies were conducted in China (13 articles) and United States (4 articles), while research on Southeast Asia countries is scant (see Table 3).

[1] The ScienceDirect database supported both English and American spelling variants, for instance, a search for "ageing" returns "aging" and vice-versa.
[2] A search for "behaviour" returns "behavior" and vice-versa.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• Review articles and research articles written in English; • Articles published between the years 2010 to April 2021; • Qualitative, quantitative or mixed methods research; • Research in which participants are older aged above 50. (This is to reflect the attitudes and experiences of younger older adults (the 'young old') as well as those past retirement ages and older); • Research aimed at investigating factors that influence the elderly's adoption/ intention to use/or the actual use of electronic technology.	• Studies published before 2010 or after April 2021; • Review articles and research articles which written not in English; • Research in which participants are below 50 years old; • Articles published in books, book chapters, Ph.D. or Masters' thesis; • Articles that were lecture notes in conferences, theoretical papers, narrative reviews, meta-analysis, systematic literature review, and other types of literature review; • The article types are encyclopedia, book chapters, conference abstracts, book reviews, and case; • Articles did not provide enough information for categorizing the article (e.g., description of participants).

The widespread acceptance and use by elderly of these technology products could be seen as a driver for the increased number of studies. In the studies by [13, 23, 16, 24, 7, 14], and [25] targeted elderly aged 50 and above in their studies. Besides, seven studies defined the elderly with a chronological age of 55 and above, such as studies by [26, 10, 6, 15, 27, 28]. Eleven studies targeted at elderly aged 60 and above, including studies by [12, 29, 30, 31, 32, 33, 18, 8, 19, 19, 20, 11]. Out of 26 studies, only two studies [30, 34], compare the elderly population with the younger generation in their studies.

3.2. Categorization of technologies

In order to systematize the selected articles, technologies are be categorized as follows: 1) *Healthcare & Assistive technology*, which technologies are related to healthcare or assisting the elderly; 2) *online shopping,* which includes the usage of online technologies to purchase or sell goods; 3) *social networking technology,* which includes online social networking sites such as Facebook or WeChat; 4) *Internet*, 5) *computer/ smartphone/tablet*, 6) *e-service*, focus on providing services through an online platform such as online public service. 7) *Online entertainment*, referring to technologies or online platforms that focus on entertainment such as exergaming. Table 4 relates the studies and types of technologies under investigation. The majority of the existing studies focus on the elderly's adoption of healthcare & assistive technology (9 studies) such as health monitoring, wearable technology, E-health, followed by social networking technology (6 studies) such as Facebook, social robot and more. Studies relevant to the elderly adoption of online shopping and e-service are still minimal.

3.3. Methodology employed

Quantitative studies predominate in the elderly's technology adoption literature. Three studies adopted a mixed-method approach [29, 24, 20] and only one study implemented both experimental and quantitative methods [32]. [32] assess the technology acceptance by using randomized control trials based on an ABAD withdrawal experimental design with a control group and lasting for a time frame of 32 weeks. Then, questionnaire surveys were taken before and after the elderly were exposed to technology to measure belief and attitude towards the technology.

Among the quantitative approach studies, all of the studies conducted cross-sectional studies, and none of the quantitative approach studies carried out the longitudinal studies. It is reasonable for behavioral intention studies to conduct a cross-sectional study as the behavioral intention is defined as "an individual subjective and probability that he

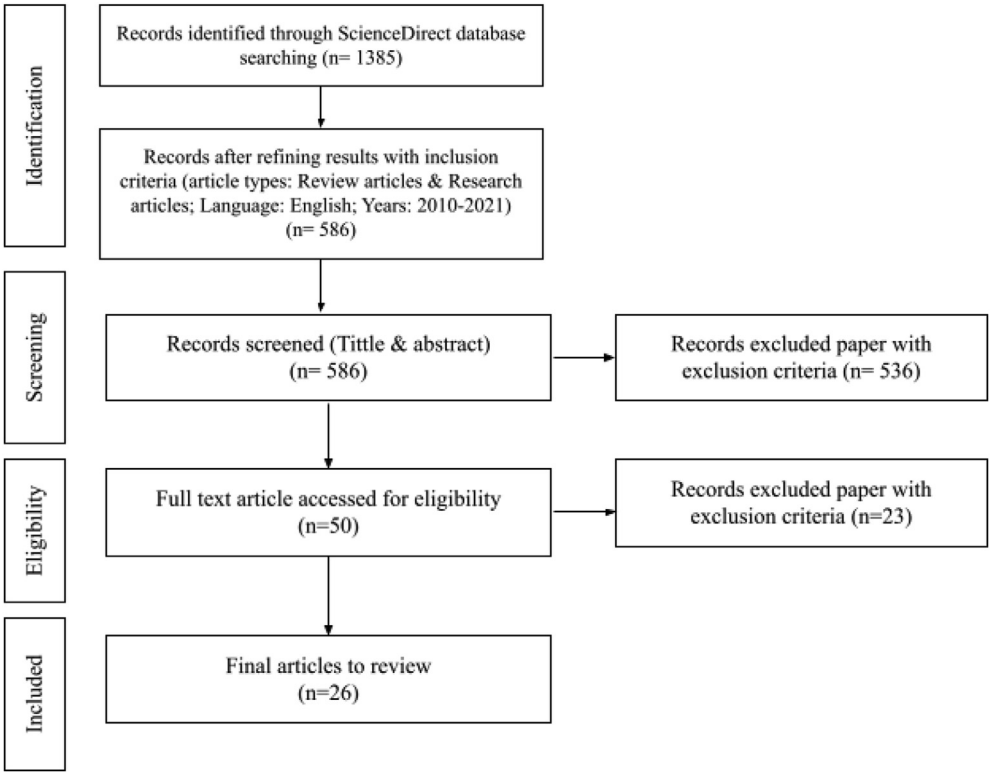


Figure 1. Article selection and retention process.

Table 2. List of journals.

Name of journals	Number of articles allocated (n = 26)
Applied Ergonomics	3
Asia Pacific Management Review	1
Computers in Human Behavior	8
Entertainment Computing	1
International Journal of Medical Informatics	4
Preventive Medicine Reports	1
Technological Forecasting & Social Change	3
Technology in Society	1
Technovation	1
Telematics and Informatics	2
Transportation Research Part F	1

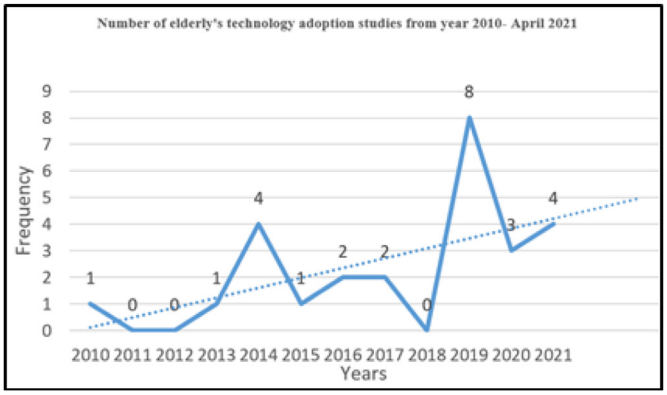


Figure 2. Number of studies by years.

Table 3. List of countries and number of studies.

Country	Number of articles (26)
China	13
Bangladesh	1
Finland	1
Korea	1
Netherland	2
Portugal	1
United Kingdom*	2
Japan*	1
United States	4
India	1

* Shirahada et al. [18] examined technology adoption in two different countries.

will perform some behavior in future" [35]; hence longitudinal study is unnecessary. However, when the study examines the actual adoption of technology, a longitudinal study will be required to better observe the elderly's actual use of the technology.

A few studies have been conducted in non-English as the primary language countries, such as China studies; hence, translation of the

Table 4. Type of technologies and related studies.

Type of technologies	Studies
Healthcare & Assistive technology	[8, 10, 11, 24, 25, 28, 30, 31, 33]
Social networking technology	[12, 13, 14, 23, 26, 32]
Online shopping	[15, 16]
Internet	[7, 17]
Computer/smartphone/tablet	[6, 17, 27, 29, 34]
E-service	[18]
Entertainment	[15, 19, 20]

measurement scales is required [17, 7] have used backward translation methods to translate the measurement scales from English to Portuguese and Mandarin. The natives or experts were also involved in the translation process, such as [10, 6, 31, 8, 11]. However, most of the translated versions of scale measurements were not reported, which will lead to construct validity problems as reporting translations are vital for establishing construct validity because they can enable comparison between studies [36].

4. Theories of technology adoption

Technology Adoption Model (TAM) and Unified Theory of Acceptance & Use of Theory (UTAUT) are the two most commonly used theories for technology adoption studies. TAM was initially developed by [37] to examine the possibility of a new information system or technology adoption within an organization, which predicts the perceived ease of use and perceived usefulness of technology on attitude towards technology. The original TAM has gradually evolved over the years. Besides, UTAUT, developed by [38], which built on the root constructs of TAM, was another most often employed theory based on the literature review on elderly technology adoption. UTAUT has four predictors of users' behavioral intention, performance expectancy, effort expectancy, social influence and facilitating conditions. In addition, the UTAUT model also included four moderators, including gender, age, experience and voluntariness of use. Table 5 illustrates the theories or models being adopted in the elderly's technology adoption studies.

The majority of the technology adoption studies focused on behavioral intention (BI) or can be known as intention to adopt/use a technology. BI refers to 'the degree to which an individual has formulated conscious plans to perform or not perform some specified behavior in future' [39]. Previous evidence has proved that a person who intends to use technology will positively affect their actual usage of technology, meaning that if a person has a high intention to use technology; it is very high possibility that the person will use it [38]. Hence, 23 out of the 26 studies focused on elderly intention to use technology rather than actual technology usage. Studies examined the consequences of actual behavior, and usage behavior were limited, such as healthcare technology [10, 31], computer [6] and online public services [18]. Besides, the study by [13] investigated on elderly's behavioral intention and continuous intention to use social networking sites in the United Kingdom. Table 6 demonstrates the measures of technology adoption used in the elderly studies.

Table 5. Theories/models for elderly's technology adoption studies.

Theories/models		Number of papers
IT-related theories	Technology Acceptance Model (TAM)	12
	Unified Theory of Acceptance & Use of Theory (UTAUT)	10
	Unified Theory of Acceptance & Use of Theory 2 (UTAUT2)	2
	Use & Gratification Theory (UGT)	1
	Media Richness Theory	2
	Senior Technology Acceptance Model (STAM)	1
	Theory of Planned Behavior (TPB)	2
	E-services Adoption Model	1
	Decomposed Theory of Planned Behavior (DTPB)	1
	Model of Adoption of Technology in Households	1
	Model of Online Social Networks (MOSN)	1
	Innovation Diffusion Theory	1
	Innovation Resistance Theory	1
	Technology Readiness Index (TRI)	1
Psychology/social-psychological theories	Life Course	1
	Capabilities Approach	1
	Socio-emotional Selectivity Theory	1
	Selective Optimization with Compensation	1
	Life-span Theory of Control	1
	Value Attitude Behavior Model (VAB)	1

5. Antecedents of elderly's technology adoption

The antecedents in the elderly's technology adoption studies in this systematic literature review are categorized into a total of 7 major categories to simplify for analysis and comparison: *technology, social, psychological, personal, cost, behavior, and environment.* According to a systematic literature review, a conceptual model of the antecedents, moderator, mediator of elderly technology adoption is developed (see Figure 3). The conceptual model also reflects the number of papers included in the respective antecedents. In the following section, antecedents that were frequently used in the relevant groups (e.g., technology factors) are discussed. Tables 7, 8, 9, 10, 11, 12, 13 provide a complete list of the antecedents of elderly's technology adoption, while Table 14 includes a summary of all the studies considered in this literature review.

5.1. Antecedents-technology factors

Technology factors emphasize the attitude, perception and interaction between human and technology [40]. Many available technology acceptance theories focus on the technology factors such as the Technology Acceptance Model (TAM), Unified Theory of Acceptance & Use of Theory (UTAUT) and many more. The two most popular and widely investigated technology factors are the perceived ease of use and perceived usefulness, both of the variables are from TAM.

5.1.1. Perceived ease of use (PEOU)

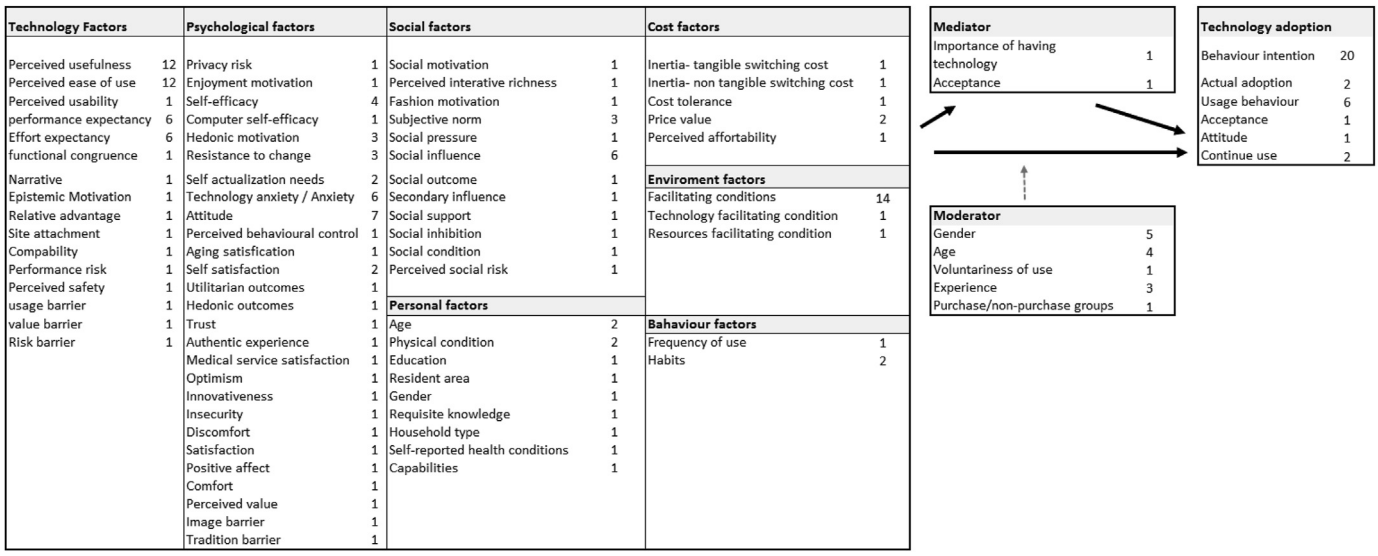
PEOU was defined as the degree to which an individual believes that using a given system will be free of effort [37]. PEOU is believed to directly or indirectly influence technology adoption. The effect of the PEOU on technology adoption varies across different types of digital technology studies. For instance, studies related to Internet adoption [7], digital gameplay technology [19], telehealth [11], stair mobility assistive technology [25] and automation driving technology [28] are found to have a significant direct relationship with technology actual adoption or intention to adopt/use. However, some studies found that the PEOU does not significantly affect technology adoption [12, 10, 33, 27]. Besides, the indirect effect of PEOU and technology's adoption also showed, such as mediated by perceived usefulness [19], acceptance [11].

5.1.2. Perceived usefulness (PU)

Within the TAM framework, PU is "the degree to which an individual believes that using a particular system would enhance their job performance [41]. Based on this systematic literature review, most studies found a significant direct relationship of PU on technology adoption [12, 33, 28, 7, 25, 19, 11]. However, by applying a mixed-method approach in investigating the elderly acceptance of tablets [29], in their recent study,

Table 6. Measures of technology adoption.

Technology adoption measures	Studies
Adoption/Actual usage	[7, 14, 18]
Intention to use/behavior intention to use/intention	[6, 7, 8, 11, 12, 13, 15, 16, 17, 19, 20, 24, 27, 28, 29, 30, 31, 33, 34]
Acceptance	[32]
Usage behavior	[6, 10, 18, 31]
Continuous intention	[13]



Technology Factors		Psychological factors		Social factors		Cost factors	
Perceived usefulness	12	Privacy risk	1	Social motivation	1	Inertia- tangible switching cost	1
Perceived ease of use	12	Enjoyment motivation	1	Perceived interative richness	1	Inertia- non tangible switching cost	1
Perceived usability	1	Self-efficacy	4	Fashion motivation	1	Cost tolerance	1
performance expectancy	6	Computer self-efficacy	1	Subjective norm	3	Price value	2
Effort expectancy	6	Hedonic motivation	3	Social pressure	1	Perceived affortability	1
functional congruence	1	Resistance to change	3	Social influence	6		
Narrative	1	Self actualization needs	2	Social outcome	1	**Enviroment factors**	
Epistemic Motivation	1	Technology anxiety / Anxiety	6	Secondary influence	1	Facilitating conditions	14
Relative advantage	1	Attitude	7	Social support	1	Technology facilitating condition	1
Site attachment	1	Perceived behavioural control	1	Social inhibition	1	Resources facilitating condition	1
Compability	1	Aging satisfication	1	Social condition	1		
Performance risk	1	Self satisfaction	2	Perceived social risk	1		
Perceived safety	1	Utilitarian outcomes	1				
usage barrier	1	Hedonic outcomes	1	**Personal factors**			
value barrier	1	Trust	1	Age	2	**Bahaviour factors**	
Risk barrier	1	Authentic experience	1	Physical condition	2	Frequency of use	1
		Medical service satisfaction	1	Education	1	Habits	2
		Optimism	1	Resident area	1		
		Innovativeness	1	Gender	1		
		Insecurity	1	Requisite knowledge	1		
		Discomfort	1	Household type	1		
		Satisfaction	1	Self-reported health conditions	1		
		Positive affect	1	Capabilities	1		
		Comfort	1				
		Perceived value	1				
		Image barrier	1				
		Tradition barrier	1				

Figure 3. Conceptual model of the antecedents, moderators, and mediators of technology adoption based on the SLR. The numbers reveal the amount of articles supporting/rejecting those antecedents, moderators, and mediators affecting technology adoption.

found that the PU does not have high predictive power in predicting the elderly adoption of technology.

Another two frequently used variables from the Unified Theory of Acceptance & Use of Theory (UTAUT) are performance expectancy and effort expectancy; both have a similar definition as PU and PEOU. Performance expectancy and effort expectancy were also found to affect the elderly's technology adoption directly. A study by [31] indicated that performance expectancy and effort expectancy significantly positively affect the elderly's mHealth adoption in Bangladesh. However [16, 8], found that effort expectancy does not significantly affect technology adoption of the elderly. Besides, scholars also found that other technological factors will affect the technology adoption, such as perceived usability [25], performance risk [33] and others. Table 7 presents the list of the technological factors that influence the elderly's adoption of technologies.

5.2. Antecedents- psychological factors

Psychological factors are the most identified predictors of the elderly's technology adoption based on the systematic literature review. According to [42], psychological factors are related to individual-level cognitive and experience processes, including feelings, beliefs and thoughts that affect the user's behavior (see Table 8).

5.2.1. Attitude

Attitude can be defined as "an individual's positive or negative feelings (evaluative effect) about performing the target behavior" [35]. The significant effect of attitude on elderly technology adoption was found in studies such as mobile health services [30], stair mobility assistive technology [25] and tablet usage [29]. These showed that the elderly who have a higher positive attitude toward the technology tend to use the technology. However, in the study by [10], the attitude was not significant towards technology usage, which shows that elderly might not intend to use telecare technology although they have a positive attitude towards the relevant technology. The insignificant attitude towards technology usage might be due to the elderly already having family support; hence, they do not need telecare technology. Therefore, future investigation on the effect of family support on technology adoption for the elderly is required. Consistent with [10, 27] also found that attitude does not significantly influence the elderly behavior intention to use smartphone technology.

Moreover [6], use three dimensions of attitudes to predict the elderly intention to use technology, including positive affect, satisfaction, and anxiety, unlike the previous studies investigating attitude from a single dimension. Results found that only the positive effect of attitude is significant towards behavioral intention on technology which means that if an elderly liking for the technology were high, they would be interested in using it, vice versa.

5.2.2. Technology anxiety/anxiety (TA)

TA refers to an individual's apprehension when faced with the possibility of using new technology [43]. Besides, TA is also a negative emotional response and relates to the fear or discomfort people experience when they consider using technology [44]. The majority of the studies proved that TA is negatively significant towards technology adoption [8, 10, 29, 30, 31, 32]. However, the study by [30] found that the TA was found to have a significant impact on the behavior intention for the older group (aged above 60) but was insignificant for the middle-aged group (aged 40–60). According to [30], one possible justification is that middle-aged adults are still active in the workforce and have more opportunities to use new technology to support their job tasks. In comparison, the older users have retired and are less familiar with the technology. As a consequence, they will have more substantial technology anxiety. There are some reasons identified that caused technology anxiety of the elderly such as less familiar with new technology [8], little control over technology [10], and afraid of breaking or destroying it [31]. [31], a study about elderly's m-Health technology adoption in Bangladesh, discussed that the digital divide, limited technical skills, traditional culture, and information-seeking behavior are the primary roots of technology anxiety for the elderly when adopting new technologies.

5.3. Antecedents- social factors

Social factors are an "interpersonal relationship and focus on the social structures and social processes that impinge on an individual" [42], including subjective norms, social influences and others (see Table 9).

5.3.1. Subjective norms (SN) & social influences (SI)

Social influence (SI) in the Unified Theory of Acceptance and Use of Technology (UTAUT) is a construct similar to the subjective norm as presented in the Theory of Reasoned Action and Theory of Planned Behavior [35]. Hence, both antecedents are discussed in the same section here. SN/SI was defined as "the person's perception that most people who

Table 7. Technological factors that influence the elderly's adoption of technologies.

Technological factors	Supported for the following online technology:	Rejected for the following online technology:
Perceived usefulness (Supported by 6 studies)	Internet [7]; Social network sites [12]; Telehealth [11]; Stair mobility assistive [25]; Health monitoring wearable technologies [33]; Automation technology [28]	Gerontechnology [10]; Gameplay [19]; Smartphone [27]
Perceived ease of use (Supported by 5 studies)	Internet [7]; Gameplay [19]; Telehealth [11]; Stair mobility assistive [25]; Health monitoring wearable technologies [33]	Gerontechnology [10]; Social network sites [12]; Smartphone [27]; Automation technology [28]
Perceived usability (Supported by 1 study)	Stair mobility assistive [25]	-
Performance expectancy (Supported by 6 studies)	Healthcare technology [8]; Online shopping [16]; Tablet [34]; Mobile health [31]; Computer & Internet [17]; Exergaming [20]	-
Effort expectancy (Supported by 4 studies)	Tablet [34]; Mobile health [31]; Computer & Internet [17]; Exergaming [20]	Healthcare technology [8]; Online shopping [16]
Functional congruence	-	Healthcare technology [8]
Narrative (Supported by 1 study)	Gameplay [19]	-
Epistemic motivation	-	Ubiquitous mobile social service [14]
Relative advantage (Supported by 1 study)	Social network sites [13]	-
Site attachment (Supported by 1 study)	Mobile social network sites [23]	-
Compatibility (COM) (Supported by 1 study)	Health monitoring wearable technologies [33]	-
Performance risk	-	Health monitoring wearable technologies [33]
Perceived safety (Supported by 1 study)	Automation technology [28]	-
Usage barrier	-	Online shopping [16]
Value barrier (Supported by 1 study)	Online shopping [16]	-
Risk barrier (Supported by 1 study)	Online shopping [16]	-

Table 8. Psychological factors that influence the elderly's adoption of technologies.

Psychological factors	Supported for the following online technology:	Rejected for the following online technology:
Privacy risk (Supported by 1 study)	Social network sites [13]	-
Enjoyment motivation (Supported by 1 study)	Ubiquitous mobile social service [14]	-
Self-efficacy (Supported by 3 studies)	Ubiquitous mobile social service [14]; Gerontechnology [10]; Online public service [18]	-
Computer Self-Efficacy	-	Internet [6]
Hedonic motivation (Supported by 3 studies)	Healthcare technology [8]; Computer & Internet [17]; Exergaming [20]	-
Resistance to change (Supported by 2 studies)	Healthcare technology [8]; mobile health [31]	Mobile health services [30]
Self-actualization/self-actualization needs (Supported by 2 studies)	Healthcare technology [8]; Mobile health services [30]	-
Technology anxiety/Anxiety (Supported by 4 studies)	Healthcare technology [8]; Mobile health [31]; Mobile health services [30]; Gerontechnology [10]	Internet [6]; Automation technology [28]
Attitude (Supported by 3 studies)	Gameplay [19]; Mobile health services [30]; Stair mobility assistive [25]	Gerontechnology [10]; Smartphone [27]
Aging satisfaction (Supported by 1 study)	Online public service [18]	-
Self-satisfaction	-	Smartphone [27]
Utilitarian Outcomes (Supported by 1 study)	Social network sites [13]	-
Hedonic Outcomes		Social network sites [13]
Trust (Supported by 1 study)	Social network sites [12]	-
Authentic experience (Supported by 1 study)	Mobile social network sites [23]	-
Medical Service Satisfaction (MSS) (Supported by 1 study)	Telehealth [11]	-
Optimism (Supported by 1 study)	Online public service [18]	-
Innovativeness (Supported by 1 study)	Online public service [18]	-
Insecurity (Supported by 1 study)	Online public service [18]	-
Discomfort (Supported by 1 study)	Online public service [18]	-
Perceived value (Supported by 1 study)	Mobile health services [30]	-
Perceived behavioral control (Supported by 1 study)	Mobile health services [30]	-
Satisfaction	-	Internet [6]
Positive affect (Supported by 1 study)	Internet [6]	-
Comfort (Supported by 1 study)	Internet [6]	-
Image barrier	-	Online shopping [16]
Tradition barrier (Supported by 1 study)	Online shopping [16]	-

Table 9. Social factors that influence the elderly's adoption of technologies.

Social Factors	Supported for the following online technology:	Rejected for the following online technology:
Social motivation (Supported by 1 study)	Ubiquitous mobile social service [14]	-
Perceived interactive richness (Supported by 1 study)	Ubiquitous mobile social service [14]	-
Fashion motivation (Supported by 1 study)	Ubiquitous mobile social service [14]	-
Subjective norm (Supported by 2 studies)	Internet intention & actual adoption [7]; Mobile health services [30]	-
Social pressure (Supported by 1 study)	Social network sites [12]	-
Social influence (Supported by 7 studies)	Healthcare technology [8]; Online shopping [16]; Tablet [34]; Mobile health [31]; Health monitoring wearable technologies [33]; Computer & Internet [17]; Internet [6]	Exergaming [20]
Social outcome (Supported by 1 study)	Social network sites [13]	-
Secondary influence	-	Social network sites [13]
Social support (Supported by 1 study)	Online public service [18]	-
Social inhibition (Supported by 1 study)	Online public service [18]	-
Social interaction (Supported by 1 study)	Gameplay [19]	-
Perceived social risk	-	Health monitoring wearable technologies [33]

Table 10. Cost factors that influence the elderly's adoption of technologies.

Cost factor	Supported for the following online technology:	Rejected for the following online technology:
Inertia- tangible switching cost (Supported by 1 study)	Ubiquitous mobile social service [14]	-
Cost tolerance (Supported by 1 study)	Smartphone [27]	-
Inertia- non tangible switching cost	-	Ubiquitous mobile social service [14]
Perceived affordability (Supported by 1 study)	Stair mobility assistive [25]	-
Price value (Supported by 1 study)	Exergaming [20]	Computer & Internet [17]

Table 12. Personal factors that influence the elderly's adoption of technologies.

Personal Factors	Supported for the following online technology:	Rejected for the following online technology:
Age (Supported by 3 studies)	Social network sites [12]; Online shopping [15]; Entertainment media [15]	-
Physical condition (Supported by 1 study)	Gameplay [19]	Mobile health services [30]
Education (Supported by 1 study)	Online shopping [15]	Entertainment media [15]
Resident area (Supported by 1 study)	Entertainment media [15]	-
Gender (Supported by 1 study)	Entertainment media [15]	Online shopping [15]; Entertainment media [15]
Requisite knowledge	-	Social network sites [13]
Household type (Supported by 1 study)	Online shopping [15]	Entertainment media [15]
Self-reported Health Conditions (Supported by 1 study)	Health monitoring wearable technologies [33]	-
Capabilities (Supported by 1 study)	Digital Healthcare [24]	-

Table 13. Behavior factors that influence the elderly's adoption of technologies.

Behavior factors	Supported for the following online technology:	Rejected for the following online technology:
Frequency of use (Supported by 1 study)	Social network sites [12]	-
Habits (Supported by 2 studies)	Computer & Internet [17]; Exergaming [20]	-

are important to him think he should or should not perform the behavior in question" [35].

Based on the systematic literature review, the majority of the studies proved the significant effect of SN/SI in predicting the various types of technology adoption such as the Internet [7], online shopping [16] and mHealth [31]. In addition [17], found that the direct influence of SN is significant on the elderly intention to use technology. Yet, the non-direct effect of SN on usage behavior was insignificant. Conversely [33], revealed SI was not a significant determinant for elderly intention to use technology but implied that affirmative attitudes or usage of smart wearable systems from others would significantly enhance perceived usefulness among older adults. Similarly [30], revealed that SN from family and friends in the context of using mobile health services was not noticeable. According to the followed-up interview, the elderly explained that mobile health services seemed too distant from the reality of the existing medical environment. Besides, the elderly would prioritize their economic condition over the influence of others since they perceived that the technology would be costly to them. On the other hand [6], observed that the elderly aged 55 to 64 were influenced by friends, but not family. The older age group (60+), however, was not influenced by either. One potential explanation might be that the older age group (60+) has fewer

Table 11. Environment factors that influence the elderly's adoption of technologies.

Environment factor	Supported for the following online technology:	Rejected for the following online technology:
Facilitating condition (Supported by 6 studies)	Internet intention [7]; Gerontechnology [10]; Tablet [34]; Health monitoring wearable technologies [33]; Computer & Internet intention [17]; Exergaming [20]	Internet adoption [7]; Healthcare technology [8]; Online shopping [16]; Smartphone [27]; Mobile health [31]; Computer & Internet use behavior [17]
Technology Facilitating condition (Supported by 1 study)	Social network sites [13]	-
Resources Facilitating condition	-	Social network sites [13]

family or friends nearby. Hence family members have fewer chances to influence the elderly when they are physically separated.

5.4. Antecedents- personal factors

Personal factors can be defined as internal factors which may be an individual personal characteristic such as gender, age, education and others [45].

5.4.1. Physical conditions

The physical condition of the elderly can also act as a predictor for their adoption of technology. It can be defined as "the beliefs of one's physical difficulties of vision, hearing, and motion that may be faced in everyday life using technologies" [30]. The elderly who experience aging will encounter biophysical and psychosocial changes that will affect how they interact and react to the environment [46, 47]. The aging process of the elderly will cause a decline in physical and cognitive capabilities (physical condition) that will affect the elderly to experience troubles when adopting technologies.

Wang et al., [19], who examine the effect of the elderly's physical condition towards adopting gameplay technologies, proved that the relationship to be positively significant. The result showed that the elderly with better physical conditions that exercise regularly would consider digital games a practical new approach for maintaining their health and hence intend to adopt it. However, a study by [30] found that the physical condition of the elderly will not affect their intention to use the technologies. The author explains that this might be because the investigation was conducted outdoors; hence, mostly the respondents who participated in the research mostly had better physical conditions.

Due to limited studies investigating this factor, researchers may scrutinize this factor on different technologies to fill this gap since only two studies illustrate two different results and perspectives. Besides, the physical condition of the elderly was obtained through the respondent's self-rated health condition, which will cause inaccuracy of the result as the elderly might underestimate or overestimate their health condition.

5.4.2. Age

Age is a factor that has little attention to acting as a predictor of technology adoption, as many studies will adopt age as a moderator in the studies. A study by [12] correlates the physical condition with the age factor. The result shows that age would be negatively correlated with the elderly's intention to use Social networking websites (SNS) which might be due to the respondents of the studies being internet users who demonstrate high computer use sophistication. Therefore, age may have acted as less of a barrier in this sample. However, it is recommended that researchers may measure the elderly physical conditions instead of age as age was just purely measured through raw numbers. Measuring the elderly physical condition can provide better insight for the research to understand the possible changes in the aging process of the elderly [46]. On the other hand, another study performed by [15] found that age is one of the best predictors of the elderly's online shopping adoption in a specific life stage such as ages 60 to 64 while ages 70 to 74 stage appears in which the use of online shopping is the lowest among elderly.

Other than physical condition and age, the elderly's technology adoption literature considers other personal factors. For instance, the capabilities to live independently, which can be facilitated by using technology, will also positively affect the elderly intention to use digital healthcare technology [24]. Table 10 presents the list of the personal factors that influence the elderly's adoption of technologies.

5.5. Antecedents- cost factors

Cost factors are those antecedents involving costs, such as consumers' need to trade-off between the perceived benefits and relevant costs such as monetary cost. The identified cost factors include inertia-tangible switching cost, cost tolerance, inertia-non-tangible switching cost, perceived affordability and price value (see Table 11 for details).

5.5.1. Price value (PV)

The price value is one of the key constructs in the Extended Unified Theory of Acceptance and Use of Technology (UTAUT2). PV is the direct determinant of people's intention to use technology. PV is a factor that can address the cost concern of technology usage. PV is defined as a consumer's cognitive trade-off between the perceived benefits of the applications and the monetary cost of using them [48]. Similar to [48, 20] also found that the PV had moderately related with the elderly intention to use Exer-gaming technology in India, which means that the elderly felt that the relevant technology is a value-for-money product.

Conversely, the study by [17] revealed, the direct influence of PV on the elderly intention to use information communication technology (ICT) was not significant; however, the indirect effect of PV on the actual use through behavior intention was significant. One possible interpretation for the insignificant PV might be because the PV is perceived as a barrier only by those elderly who are not ICT users. In addition, another reason for the insignificance of PV might be due to the popularization of ICT adoption globally and the decreasing costs of computers and the internet today [49]; hence, financial concerns (PV) seem to play a minor role for the elderly.

Other cost factors are also being studied in the context of elderly technology adoption, such as cost tolerance [27], perceived affordability [25], inertia switching cost and inertia non-switching cost [14]. Most of the studies mentioned found a significant effect of the relevant cost factors on the elderly adoption of technology. However, the investigation of cost factors in the elderly context of technology adoption is still scarce; hence, further investigation to test the cost effects are still required.

5.6. Antecedents- environment factors

5.6.1. Facilitating conditions (FC)

Facilitating conditions is also one of the key predictors in the UTAUT model, where facilitating conditions can be defined as how a person believes an existing technical infrastructure can support her or his use of the information system. In UTAUT2 (2012), facilitating conditions is hypothesized as having direct effect on use and an indirect effect through behavioral intention. Table 12 presents the list of the environmental factors that influence the elderly's adoption of technologies.

FC has been widely adopted in various type of elderly technology adoption studies such as the internet [7], healthcare technology [8, 31, 33], gerontechnology [10], online shopping [16], Information Communication technology [17, 27, 29, 34], and others.

The effect of the FC on technology adoption for the studies is not consistent. In the context of healthcare technology [33], revealed a significant influence of FC on elderly intention to use wearable healthcare technology and believes that financial aid, technical support and training programs would be important in enabling the use of the technology. At the same time [10], revealed that FC has significant influence on perceived usefulness, perceived ease of use, and elderly technology use behavior respectively which author also concluded that the use of technology by the elderly in Hong Kong are strongly affected by the FC, rather than the technology itself. Besides, studies by [17, 20, 29, 34] also found a significant positive effect of FC on the elderly technology adoption. Nevertheless [7], found that the FC will significantly impact the elderly intention to Internet use only, instead of actual adoption of the internet. In the study of social networking sites (Facebook) adoption by [13], the FC in the study was divided into two types which are Resources Facilitating Condition (RFC) that discuss the availability of time and money while Technology Facilitating Condition (TFC) focused on internet access and internet enabled devices (e.g. smartphone). The result indicated that RFC was not a significant predictor of Facebook adoption for both

Table 14. Overview of articles on elderly's technology adoption.

Author	Technology types	Methodology	Sample size and analysis	Theory	Antecedents (supported)	Rejected	Con-sequences
[14]	Ubiquitous mobile social service	Survey Questionnaires	266 respondents aged 50 and above in Taiwan, data analyzed via PLS-SEM	Use & Gratification Theory, Media Richness Theory	Enjoyment motivation, self-efficacy, social motivation, perceived interactive richness, fashion motivation, Inertia- tangible switching cost	Epistemic motivation, Inertia-non tangible switching cost	Adoption of ubiquitous mobile social service
[7]	Internet	Survey Questionnaires	374 respondents aged 50 and above in China, data analyzed via regression analysis	TAM, UTAUT	Perceived usefulness, perceived ease of use, subjective norm, Facilitating condition (intention)	Facilitating condition (adoption)	Internet use intention and adoption
[8]	Healthcare technology	Survey Questionnaires	325 respondents aged 60 and above in China, data analyzed via PLS-SEM	UTAUT	Performance expectancy, hedonic motivation, resistance to change, self-actualization, technology anxiety, social influence	Effort expectancy, functional congruence, facilitating condition	Behavior intention to use
[10]	Gerontechnology	Survey Questionnaires	1012 respondents aged 55 and above in China, data analyzed via PLS-SEM	TAM, UTAUT	Self-efficacy, anxiety, facilitating condition	Perceived usefulness, perceived ease of use, Attitude	Usage behavior
[12]	Social network websites (Facebook)	Survey Questionnaires	124 respondents aged 60 and above in United States, data analyzed via regression analysis	TAM	Perceived usefulness, trust, social pressure, age, frequency of use	perceived ease of use	Behavior intention to use
[16]	Online shopping	Survey Questionnaires	574 respondents aged 50 and above in Taiwan, data analyzed via PLS-SEM	UTAUT, Innovation Resistance Theory	Performance expectancy, social influence, value barrier, risk barrier, tradition barrier	Effort expectancy, facilitating condition, usage barrier, image barrier	Behavior intention to use
[19]	Gameplay	Survey Questionnaires	534 respondents aged 60 and above in China, data analyzed via regression analysis	TAM	Perceived ease of use, narrative, attitude, social interaction, physical condition	Perceived usefulness	Intention to play
[34]	Tablet	Survey Questionnaires	899 respondents (comparing younger & elderly) in United States, data analyzed via MANOVA, ANOVA, t-test	UTAUT	Performance expectancy, effort expectancy, facilitating condition		Behavior intention to use
[11]	Telehealth technology	Survey Questionnaires	436 respondents aged 60 and above in China, data analyzed via PLS-SEM	TAM	Perceived usefulness, perceived ease of use, medical service satisfaction (MSS)		Behavior intention to use
[15]	Mobile technology for online shopping and entertainment	Survey Questionnaires	322 respondents aged 55 and above in Finland, data analyzed via General linear model	Life Course	Age, education (online shopping), resident area (entertainment media), gender (entertainment media), household type (online shopping)	Education (entertainment media), gender (online shopping), Household type (entertainment media)	Intention to use
[24]	Digital healthcare technology	Survey Questionnaires, interview, focus group	545 respondents aged 50 and above in Netherland, data analyzed via PLS-SEM	Capabilities Approach	Capabilities		Behavior intention to use
[27]	Smartphone	Survey Questionnaires, interview	120 respondents aged 55 and above in China, data analyzed via PLS-SEM.	TAM & UTAUT	Cost tolerance	Perceived usefulness, perceived ease of use, Attitude, self-satisfaction, Facilitating condition,	Behavior intention to use
[13]	Social network websites (Facebook)	Survey Questionnaires	1080 respondents aged 50 and above in United States, data analyzed via PLS-SEM.	E-services Adoption model, Decomposed Theory of Planned Behavior (DTPB), Model of Adoption of Technology in Households Model of Online Social Networks (MOSN)	Relative advantage, privacy risk, utilitarian outcomes, social outcome, technology, facilitating condition	Hedonic outcomes, resources facilitating condition, requisite knowledge	Behavior intention to use and continuous intention

(*continued on next page*)

Table 14 (*continued*)

Author	Technology types	Methodology	Sample size and analysis	Theory	Antecedents (supported)	Rejected	Con-sequences
[32]	Social robot	Survey Questionnaires, ABAB withdrawal experimental design	103 respondents aged 60 and above in Hong Kong, data analyzed via MANOVA & t-test	TAM, UTAUT, Senior Technology Acceptance Model (STAM)	-	-	Acceptance of technology
[26]	Information and communication technologies	interview	35 respondents aged 55 and above in Netherland, data analyzed via qualitative method (Atlas.ti)	TAM, UTAUT, Socio Emotional Selectivity Theory, Selective Optimization with Compensation, Life-span Theory of Control	-	-	ICT use
[23]	Mobile social network sites	Survey Questionnaires	500 respondents aged 50 and above in Korea, data analyzed via PLS-SEM	TAM, Innovation Diffusion Theory	Authentic experience, site attachment	-	Intention to continuous use
[31]	Mobile health	Survey Questionnaires	300 respondents aged 60 and above in Bangladesh, data analyzed via PLS-SEM	UTAUT	Performance expectancy, effort expectancy, resistance to change, technology anxiety, social influence	Facilitating condition	Behavior intention to use & use behavior
[18]	Online public service	Survey Questionnaires	324 respondents aged 60 and above in United Kingdom and Japan, data analyzed via SEM (AMOS)	Technology Readiness Index (TRI)	Self-efficacy, aging satisfaction, social support, social inhibition		Actual usage
[30]	Mobile health services	Survey Questionnaires	424 respondents aged 40 and above in China, data analyzed via PLS-SEM	Value Attitude Behavior Model, Theory of Planned Behavior	Perceived value, perceived behavioral control, subjective norm	Physical condition	Behavioral intention to use
[25]	Stair mobility assistive	Survey Questionnaires	104 respondents aged 50 and above in United States, data analyzed via Regression analysis and qualitative: systematic text condensation (STC)	TAM	Perceived usefulness, perceived ease of use, perceived usability, attitude	-	Attitude and intention to use
[33]	Health monitoring wearable technologies	Survey Questionnaires	146 respondents aged 60 and above in China, data analyzed via SEM (AMOS), ANOVA, Kruskal–Wallis test	TAM, UTAUT	Perceived usefulness, perceived ease of use, compatibility, social influence, facilitating condition, self-reported health conditions	Performance risk	Behavior intention to use
[17]	ICT (computer & internet)	Survey Questionnaires	278 respondents aged 55 and above in Portugal, data analyzed via PLSE-SEM	UTAUT2	Performance expectancy, effort expectancy, social influence, habits	Price value, facilitating condition	Behavior intention to use
[20]	Exergaming	Survey Questionnaires, interview	27 respondents aged 60 and above in India, data analyzed via Spearman's correlation analysis	UTAUT2	Performance expectancy, effort expectancy, price value, facilitating condition, habits	Social influence	Behavior intention to use
[6]	Computer	Survey Questionnaires	246 respondents aged 55 and above in China, data analyzed via PLS-SEM	Theory of Planned Behavior	Positive affect, comfort, social influence	Computer self-efficacy, satisfaction	Behavior Intention to use & usage behavior
[29]	Tablet	Survey Questionnaires, focus group	57 respondents aged 60 and above in China, data analyzed via regression analysis	TAM	-	-	Behavior intention to use
[28]	Automated Driver Assistance Systems (ADASs)	Survey Questionnaires	247 respondents aged 55 and above in United states, data analyzed via path analysis and descriptive analysis	TAM	Perceived usefulness, perceived safety	Perceived ease of use, anxiety	Behavior intention to use

adopter and non-adopter, while TFC was significant only to the adopter of Facebook users.

Conversely, studies by [8, 16, 31] found an insignificant effect of the FC in predicting elderly technology adoption in their studies [31] from Bangladesh and [8] from China found an insignificant effect of FC on the healthcare technology adoption that the author perceived as a reflection on the current socio-technological situations in the developing countries, which need further investigation. Besides, drawing from TPB, it is possible to establish some conceptual parallels between the TPB construct of perceived behavioral control and facilitating conditions considered in UTAUT2 as a driver of intention. As originally theorized, intention is influenced by perceived behavioral control, which shares

aspects of facilitating conditions [50]. This implies that a sense of control over aspects related to technology usage is important to trigger behavioral intention. This inferred explanation may be useful as a recommendation for fostering ICT acceptance among older adults. However, future studies need to substantiate this claim.

5.7. Antecedents- behavior factors

Behavior factors are those factors which involve behaviors such as frequency of behavior, habit, and previous usage behavior with a particular technology [40].

5.7.1. Habits

Habit can be defined as "the act of learning process that become an automatic responses to specific cues and functional in achieving certain goals" [51, 48]. Habit is a vital predictor with moderating, direct and indirect effect through an individual's behavioral intention to use technology. In the literature of computer and internet adoption, the direct and indirect effect of habit on the elderly intention to use the internet and use behavior is all significant, respectively [17]. The study by [20] found the habit has associated moderately with the elderly behavioral intention to use an exergaming technology. The Elderly used the exergaming technology and intended to use it in the future as they felt habituated to use it while exercising. Both of the studies mentioned found a significant effect of habits on technology adoption.

Besides habit, the elderly's technology adoption literature considers other behavioral factors. For instance, For instance, the elderly's internet use frequency will positively impact the elderly's intention to use social network sites [12]. Overall, the behavior factors on the elderly's technology adoption in existing literature are still considered limited compared to other factors commonly studied, such as technology factors and psychological factors (see Table 13 for details). Table 14 includes a summary of all the studies considered in this literature review.

6. Agenda for future research

This systematic literature review reveals seven categories of antecedents, methodology, and different types and nature of technologies to better understand the context of the elderly's technology adoption behavior from previous findings. Hence, this section suggests some recommendations for future research. Table 15 identified future research opportunities.

Table 15. Future research opportunities.

Focus	Research Questions
	• How do antecedents different according to vary type of technologies?
Antecedents	**Psychological factors**
	• To what extent different sub-components of attitude will affect the elderly technology adoption?
	• What are the drivers of technology anxiety have the most influences on elderly technology adoption?
	• To what extent do family supports affect elderly's technology adoption?
	Technology factors
	• What are the specific aspects of the technology that contribute to ease of use and usefulness that affect the elderly's adoption of technologies?
	Behavior/Personal factors
	• How behavior do affects technology adoption among elderly?
	• How an elderly's capabilities (personal factors) can be enhanced by technology will influence the elderly technology adoption?
	• How can objective health status measurement evaluate the elderly adoption behavior?
	Cost factors
	• To what extent do purchasing power or income level will influence elderly adoption behavior?
	• What's the differences of perceived price value between developing and develop countries?
	Social factors
	• How does culture affect elderly's technology adoption?
	• To what extent do living arrangement affect elderly's technology adoption?
	Environment factors
	• How socio-technological settings in developing countries will affect elderly's technology adoption behavior?
	• To what extent different sub-components (e.g. access, cost, or availability of technical support) of facilitating condition will affect the elderly technology adoption?
Consequences	• What is the consequences effect (e.g. enhance well-being) after adopting the technology among the elderly?

6.1. Research methodology

6.1.1. Qualitative approach studies in future

Based on SLR, quantitative approaches and cross-sectional studies predominate in the elderly's technology adoption literature. Qualitative studies by adopting a holistic perspective such as in-depth analysis are still rarely available in technology adoption studies. According to an analysis, up to 90% of the existing studies successfully published in the leading information system journals (e.g. ISR) commonly apply a quantitative approach in their studies [52]. According to [53], most studies frequently adopt a quantitative approach instead of a qualitative approach because the researcher in the field does not have good training and guidance provided; hence, most of the researchers tend to follow the footsteps of previous information systems studies.

Studies on the elderly based on qualitative approaches such as observation, interviews, and focus groups are still scarce. Future research may consider using a qualitative approach to provide an in-depth understanding and potentially explore new antecedents of the elderly's perception of technology adoption, since the elderly segment is a relatively understudied group. The use of the qualitative approach in studies can provide a rich investigation of the interpretation, experience and consideration of the interview members and provide an in-depth understanding of the ICT use of the elderly [26]. In addition, the qualitative stance can also explore new potential antecedents of technology adoption as the elderly's behavior can be understood thoroughly with the use of the qualitative method. For instance, by conducting an observation and qualitative analysis [20], merely use UTAUT to explore the elderly's response towards a tailored exergaming and find the key constructs when considering using the technology in India. Besides, study by [26] conducted qualitative semi-structured interviews with elderly with cognitive impairments to examine the ICT usage by adopting classical theories on technology adoption and gerontological theories on social and emotional aging. Unlike the typical studies which only found the predictors (e.g. perceived usefulness) of technology adoption [26], found that the elderly perceive ICTs as useful when these contribute to the satisfaction of social and emotional needs in terms of relationships, hobbies or daily activities. Therefore, the qualitative approach can be considered a more helpful alternative to determine deeper information with smaller number respondents. Rather than only using a single method, researchers are suggested to use triangulation methods to discover more decadent and profound results [54, 55]. For instance [7], recommended that future research adopt a qualitative stance to unveil the elderly's in-depth thoughts on the topics and explore other factors' impact.

6.1.2. Longitudinal studies

Typically, most studies reviewed were cross-sectional studies instead of longitudinal studies in nature [56] pointed out the significance of the longitudinal approach, specifying that users' expectations might change after they familiarize themselves with IS technology, and what was previously acceptable may no longer be acceptable. For instance, the TAM, which was proposed by [41], measures the usefulness and ease of

use of an electronic mail system, their intention to use, and their 15 weeks later were measured in longitudinal studies. However, we can notice that some of the studies such as [31, 7] who adopted the TAM tend to measure the intention to use and actual adoption by using a cross-sectional method instead of longitudinal method, which might be inappropriate when it involves changeable environment and human behavior [31] also pointed out those studies with cross-sectional design unable to validate the contingent and causality effects of the elderly's degree of experiences before and after the technology adoption. Studies such as [23, 34, 8] also recommended that longitudinal studies are highly required in the upcoming research to gain a greater understanding of the relationship between antecedents and consequences over the time.

6.1.3. New measurement scales

Based on systematic literature review, it is noticeable that quantitative approach studies, especially studies that used survey questionnaires as data collection methods, heavily rely on the existing well-established measurement scales and constructs such as adopting the constructs and measurement dimensions from [38] or [41]. It is understandable that the well-established and popular scales are more reliable and validated in many studies with different technologies. Hence, the researchers are more confident with the constructs. However, the contribution of these studies may be limited as the scales, and theory development may be hindered. Moreover, some scales that developed years ago might not fit the current situation with emerging technologies anymore. Hence, qualitative research may be a typical first step to discover new insights and, therefore, develop new measurement scales. For instance [24], carried out sequences of mixed-method approaches in order to understand in what way digital technologies can help elderly live their lives in a valuable way, instead of considering how technologies help to execute predefined tasks. With the information obtained from the interviews with the elderly [24], developed new constructs and measurement scales that provide a new insight for the technology adoption context from a different perspective rather than just adopting the well-established technology acceptance theory (e.g. TAM) in the studies.

6.1.4. Exploring different type of technologies

Besides, existing studies focus on the elderly's adoption of healthcare technology and social networking technology but how the elderly perceive online shopping and e-services remain unclear. In light of the recent COVID-19 outbreak, researchers are urged to investigate these domains as the COVID-19 outbreak causes the increase in online activities (such as shopping, services). This could have a long-term impact on how people interact with technology. Indeed, technologies will become more pervasive in the elderly's daily lives, and the COVID-19 pandemic may accelerate their growth and adoption in a variety of previously peripheral domains.

6.1.5. Exploring elderly's technology adoption in different regions

Based on the SLR, it was found that most studies were conducted in China, followed by the United States. Due to technological advancements and cultural diversity, it is probable that the perception of the elderly varies across countries. It's still uncertain whether the findings can be generalized to other countries. The behavior of the elderly in other countries, particularly in Southeast Asian countries, is unknown and requires further investigation.

6.2. Antecedents

6.2.1. Psychological factors

Based on the systematic literature review, psychological factors have obtained the most attention among other factors. Psychological factors such as attitude and technology anxiety were the two factors that were studied the most. However, the inconsistent nature of the results reflects that further investigations are still needed. For example, researchers may look into what the different dimensions of attitude will contribute to the elderly technology adoption? For example, the attitude factors can be divided into three dimensions: positive affect, satisfaction and anxiety to predict elderly's technology use intention [6]. In addition, most previous studies measure the elderly's attitude towards technology adoption, such as TAM and UTAUT. The measurement items for the models are mainly focused on the positive aspect of a technology [18]. However, researchers should acknowledge that the emerging technologies (e.g., healthcare technology) are new to the elderly as they are unavailable during their younger years. The elderly may often have difficulties and skepticism about technologies. Therefore, researchers can further investigate and include the examination of the opposing sides of technologies to obtain a complete picture of the elderly's perceptions towards technology. For instance, technology readiness can be further investigated in the context of the elderly's technology adoption because technology readiness includes both positive (Optimism and Innovativeness) and negative views (Discomfort and Insecurity) of technology.

Similarly, the technology anxiety (TA) factor can also be further investigated in detail where for instance [31], identified that the digital divide, practicing traditional culture, limited technical skills, and information-seeking behavior would surge the technology anxiety in elderly to adopt new technologies. Hence, borrowing from the concept from these studies, future research may also look into the actual factors that lead to TA that will affect technology adoption, instead of measuring TA or attitude at a surface level. Besides, how family support will influence the elderly's attitude towards technology adoption still remains unknown, hence further investigation is needed.

6.2.2. Technological factors

Technological factors also received much attention in the existing studies, among which perceived ease of use and perceived usefulness have been widely explored. Having established the importance of perceived ease of use and usefulness, researchers may study these factors in-depth as the present technological environment varies compared to those theories such as TAM or UTAUT were established. Besides, the usage of the technology of those core theories (e.g. TAM developed by [41]) might be different from the recent studies where the recent technologies might be more complex and advanced. Hence, recent studies that applied the theories developed years ago might lack specification and accuracy. Therefore, it is recommended that researchers should investigate in depth on how the specific factors will contribute to the adoption. For instance, which specific dimension of technology will influence the elderly to perceive a specific technology to be useful that can be investigated in detail? For example, is a tablet perceived as easy to use if the technology can help the elderly save effort, or the elderly will think that tablet may be useful if the tablet can provide them enjoyment features, social interaction, or learning features? Specification on what factors will affect elderly's perception of a technology to be useful or easy to use are important as it can provide technology developers in a better position to develop proactive and corrective strategies that increase elderly's technology adoption. Hence, future research can examine the specific aspects of the technology that contribute to ease of use and usefulness that affect the elderly's adoption of technologies. Besides, the indicators of technologies constructs tend to be mostly presented in a reflective approach where the questions being asked in the questionnaire construct overlap between interchangeable indicators. Therefore, the future study may also utilize formative approach items in the technological constructs to obtain different insights.

Next, the majority of studies build fundamentally upon technology-driven theories such as the Technology Acceptance Model (TAM). However, the elderly do not always make decisions to adopt technology based on the characteristics of the technology; rather, they consider how the technology allows them to live their lives in ways that are valuable to them [24]. Hence, instead of subsuming under the technology-driven perspectives (e.g., TAM), how the adoption of technology can enhance the elderly's capabilities to achieve the life they desire (e.g., living independently) should be further investigated.

6.2.3. Behavior factors & personal factors

Although some papers discuss the influence of behavior factors on the elderly technology adoption, its coverage is relatively limited. Future research may explore more on several behavior and personal aspects. Firstly, researchers may take into account the characteristics of technology, which can enable a better conceptualization of user's behavior and explore how it affects the adoption. For example, goal-oriented virtual games are more likely to lead to addictive behavior compared to experience-oriented games [57]. Besides, personal factors such as the capabilities factor that is proposed by [24] can be further investigated in different types of technologies. This capabilities factor provides a relatively new perspective to the technology adoption field by discussing how an elderly's capabilities (personal factor) provided by technology can influence the elderly intention to use technology, instead of only limited to the technology perspective like ease of use.

On the other hand, behavior data (e.g. frequency of use), or personal data (e.g. health condition & physical condition), were employed commonly through self-assessment of the participants, which may be subjective in nature. Hence, biased and inaccurate evaluation outcomes might be incurred. In addition, individuals always tend to underestimate or overestimate their behavior [58]. Therefore, future research can employ an objective health status measurement approach for the respondents when evaluating their health condition. Besides, to accurately measure the technology usage frequency of elderly, experimental manipulation of the technology product on the spot can be executed [33].

6.2.4. Cost factors

Technology such as healthcare technology was traditionally viewed as an expensive innovation product for the elderly. Financial constraint is especially pertinent to the elderly population, as the majorities are retired and on fixed incomes [59]. However, cost factors in the elderly's technology adoption context remain uncertain as this factor has not gained much attention in the research. Further research to determine the cost factors is necessary. Future research may explore the respondents' purchasing power or income level, which might also influence the cost factors. For instance, the elderly who has higher purchasing power or financially stable might perceive that the price of technology is reasonable and value for money as they can afford the price of it, hence they will have the intention to use it, but for the elderly who does not have purchasing power might think that the cost of technology may be too expensive for them. Besides, researchers may also conduct cross-countries studies between developed and developing countries to determine whether a country's status will also become one of the possible factors that will affect how the respondents perceive the price values.

6.2.5. Social factors

Existing studies on technology adoption tend to frequently implement the subjective norms or social influences from the UTAUT, TRA and TPB when examining factors from a social perspective. However, the majority of studies only emphasize the influences of friends and family towards the elderly. It is still unclear how culture will influence elderly technology adoption. For instance, due to the local culture, the elderly in Bangladesh usually use mobile phones for making typical phone calls only. Using a mobile phone for receiving health care advice is still a relatively new concept for the elderly [31]. According to [60], the elderly would prefer to continue to engage in similar activities, behaviors, and relationships as they did throughout their previous experiences. The cultural influence on elderly's behaviors and practices during the elderly's earlier life will affect them to continue to engage in similar ways, which will affect their intention to use new technology. However, further investigation is still required to validate the influence of culture on the elderly's technology adoption.

Other than that, it was found that the elderly were living away with friends and family; hence the social influences might be affected as they have lesser chances to influence elders when physically separated [6]. Hence, researchers can also explore the possibility of living arrangement on subjective norms of the elderly, which will consequently lead to technology adoption.

6.2.6. Environment factors

The facilitating condition had been studied frequently in the technology adoption context. Since the elderly themselves are heterogeneous and may have different resources, researchers may investigate in-depth by figure out which dimensions for instance, access, cost, or availability of technical support of the facilitating condition were the key impact on the elderly's technology adoption. With more specific findings, the studies are able to provide more impact to the field. Moreover, the insignificant outcome of FC on the elderly technology adoption studies (e.g. [31, 8]) might be a reflection on the current socio-technological settings in developing countries. The social environment for developed and developing countries might not be similar. For instance, the accessibility of technology and an individual's purchasing power might vary. Hence, further investigation on the differences of facilitating conditions between the developed and developing countries can be conducted. With that, practitioners or authorities can provide the technological products that fit the elderly's conditions in the respective countries.

6.3. Consequences

Most of the studies only aim to investigate the elderly intention to use or actual adoption behavior towards technology. However, studies that discuss the consequent effects such as benefits or drawbacks after adopting the technologies are limited. Proposed benefits of elderly technology adoption include ICT able to improve quality of life [34], gameplay can enrich elderly's life [19], communication technologies can improve social interactivity, decrease depression and improve cognitive skills [7], gerontechnology can provide elderly more independent and healthier lifestyle [10]. However, existing studies seldom further investigate the effectiveness of the proposed benefits after adopting a technology. It is vital to recognize the consequences obtained by the users after the actual adoption of a technology. Compared to perception-based studies, investigation of the actual consequences experienced by the user can provide a more realistic experience and feedback for the researchers. For instance, the feedback regarding the benefits, drawbacks, or effectiveness of a technology is very beneficial for practitioners to implement or invent a technology that fulfils the elderly's actual needs. Hence, future research should also validate and further explore the consequences (e.g. improve in well-being) obtained after the technologies adoption.

6.4. Moderator and mediator

It can be noticed that the existing studies tend to investigate the demographic criteria such as gender or age as moderator the studies. The influences of mediators on technology adoption studies are generally underplayed in the existing literature. The process of technology adoption should not be considered as a one-off choice like mainstream adoption models (e.g. TAM), as the adoption of technology is an extensive process from trying out towards routinizing the use of technologies. For instance, even though a technology can provide benefits (e.g. usefulness) to the elderly, however, elderly will only have an intention to it only when their needs arise. An important implication for adoption studies in future is that the consequences of having technology available (e.g. the usefulness) may not be readily observable by the elderly. Therefore, adoption models should consider the perceived importance of having a technology available as a mediator between outcome expectations and intentions to use [24].

7. Conclusion

This paper analyzes the topic of the elderly's technology adoption, by conducting a systematic literature review based on 26 related studies.

This paper classifies the literatures in terms of years, countries, age range of elderly, categorization of technologies, methodology, theories and model, and findings. This paper categorized antecedents into seven major groups, namely: *technology, social, psychological, personal, cost, behavior, and environment,* then discussed on few most frequently used factors in every category and also the consequences of adoption. A conceptual framework for the elderly's adoption of technology and an agenda for further research is established. The agenda for future research includes the research methods and recommendations for each category of antecedents. Particular attention is given to the need for more in-depth, dimensional, qualitative based research.

Nevertheless, this systematic literature review also has some limitations. This paper collected articles from a single database, namely ScienceDirect, but research on elderly's technology adoption may be published in outlets not covered by the database. As a result, this paper might shortly address the gaps identified in the literature. Despite this, we hope this systematic literature review and identified limitations and recommendations can provide researchers with some valuable guidelines and insights.

Declarations

Author contribution statement

Yee-Yann Yap, Siow-Hooi Tan, Shay-Wei Choon: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by Ministry of Higher Education, Malaysia (FRGS/1/2019/SS06/MMU/02/3).

Data availability statement

No data was used for the research described in the article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors thank the anonymous referees and editor for useful comments and suggestions.

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