Assistant technologies for aged care: comparative literature survey on the effectiveness of theories for supportive and empowering technologies
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Abstract

**Purpose:** One may categorize assistive technologies for aged care into two types, namely supportive (helping the elderly with their everyday activities) and empowering (obtaining physical or educational training to help seniors to maintain their capabilities). This paper looks at the impact of this perspective in the adoption of technologies that are used to aid already declined functions in comparison with technologies that are used to empower an elderly person’s capabilities. The article aims to extract the factors that influence adoption of assistive technologies among seniors and the theories used in this context.

**Methodology:** A systematic literature review was conducted on relevant peer reviewed papers. A preliminary exploratory search was conducted to identify keywords and online databases for the search. A total 104 papers published since 2000 were analysed after title, abstract and full text filtering.

**Findings:** The study summarizes and categorizes the factors impacting the adoption of assistive technologies among seniors. The paper analyses the theoretical support utilized by literature and maps the empirical evidence for supportive and empowering technologies.

**Originality:** It was found that existing adoption theories are able to handle supportive technology adoption mainly because of the direct link between usage and improved functionalities. However due to the indirect effect of empowering technologies, elderlies lag in benefit realization for empowering technologies. This opens avenues of research and requires future work and utilization of new theoretical approaches in this area. The paper indicates propositions, claims and suggested questions for future research in both supportive and empowering technologies.
1. Introduction

The world’s population is ageing rapidly and the cost of caring for older people is also rising (Mariño et al., 2016). In 2012, 6.9% of the world population was more than 65 years old, and this is estimated to increase to around 20% by 2050 (OECD, 2012). This has resulted in a push to develop innovative approaches in the aged care sector in order to reduce the cost of care (Magnusson et al., 2004). One approach could be the use of assistive technologies to provide efficiencies in patient care and to lower costs. There are two main arguments for this approach. First, seniors traditionally like to live independently and preferably in their own homes (Leeson et al., 2004; Magnusson et al., 2004; Porteus and Brownse, 2000). Second, it is commonly believed that the healthcare system, particularly the aged care sector, will soon face a huge shortage in qualified workers (Australian Nursing Federation, 2012; OECD, 2012; Yusif et al., 2016). In addition, in remote and regional areas, even basic healthcare services require patients to travel long distances to get treatment and this is further exacerbated as the elderly often have transport issues such as restricted movement and an inability to drive (Khosravi and Ghapanchi, 2016). Recent advancements in Information Technology (IT) have resulted in low-cost off-the-shelf products that have the potential to assist older people in their daily life activities at their home (Leeson et al., 2004). These products have been categorized as assistive technologies as they are designed to assist older people in their normal living.

One may take two approaches to define assistive technologies for aged care related purposes:

- **Supportive Technologies**: The traditional approach defines an assistive technology as a technological product that aids older persons to perform their daily activities that they would not be able to do without the functional support of the technology. For instance, the Department of Veteran Affairs in the USA (Broekens et al., 2009; Department of Veterans Affairs, 2009) defines assistive technologies in the context of aged care as “any service or tool that helps the elderly perform their everyday activities that they have always performed, but must now do differently”. The above definition focuses on supportive technologies that aid elderly in their daily activities in an attempt to overcome their functional disabilities, i.e. cognitive, physical, visual or communicational.

- **Empowering Technologies**: Recent research in this area has enhanced the concept of assistive technologies to technological products that train and empower seniors to improve their functional capabilities, thus improving some of their capabilities that are required to maintain independent living (S. Vichitvanichphong et al., 2014). Empowerment in this context means to obtain physical or educational training that helps older people to maintain their capabilities with respect to their daily activities and accordingly be able to live independently. This definition has extended the use of assistive technologies to the products that facilitate seniors in their daily life activities through training. Some examples of empowerment can be seen in literature (Gamberini et al., 2008; Tu et al., 2006).

While one may believe that the above-mentioned definitions may not be the dominant view in the literature, they do provide an interesting perspective in the differentiation of adopting assistive technologies for the following two purposes; namely adopting a technology to help (1) with already declined functional capabilities, and (2) with empowering functional capabilities to maintain them. This difference leads us to investigate the literature that supports the adoption of each of these two types of assistive technologies.

The healthcare framework introduced by World Health Organization (WHO) (Wilkinson and Marmot, 2003) highlights the significant role of assistive technologies in the area of aged care. The report puts an emphasis on the adoption of technologies by seniors. Should seniors take up the benefits of technological advancements, it is crucial for supporting organizations to understand the factors impacting on the adoption of assistive technologies among seniors.

Although there has been a growing body of literature on the adoption of assistive technologies in aged care, a more comprehensive picture covering the overarching importance of the research in this area is...
Table 1 presents a comparison of previous literature reviews that have been conducted on the topic of assistive technologies for seniors. While the comprehension and inclusiveness for some of these studies may not be as systematic as our study, they are arguably very useful in many aspects. However, many of these reviews did not target the problem of adoption in a relevant context. Another drawback of existing reviews is that fact that some of them are attached to specific technologies or a particular application of a technology. Some of these reviews are outdated and the fast pace of changes in the technologies and people attitudes may impact on the results of these studies. In addition and more importantly, none of these studies have looked at the theoretical aspects of technology adoption in aged care and related them to the factors supported by the empirical results.

### Table 1 Previous Literature Reviews in Assistive Technologies for Seniors

<table>
<thead>
<tr>
<th></th>
<th>(Magnusson et al., 2004)</th>
<th>(Leist, 2013)</th>
<th>(Or and Karsh, 2009)</th>
<th>(Broekens et al., 2009)</th>
<th>(Peek et al., 2014)</th>
<th>(Khosravi and Ghapanchi, 2016)</th>
<th>(Mostaghel, 2016)</th>
<th>(Yusif et al., 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number reviewed papers</td>
<td>84</td>
<td>n/a</td>
<td>52</td>
<td>43</td>
<td>16</td>
<td>41</td>
<td>18</td>
<td>44</td>
</tr>
<tr>
<td>Number of searched databases</td>
<td>7</td>
<td>n/a</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Is the review systematic?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Has adoption concept been considered?</td>
<td>No</td>
<td>No</td>
<td>Yes, Factors investigated.</td>
<td>No</td>
<td>Yes, Factors investigated</td>
<td>No</td>
<td>Yes but only from Impact and Cost perspective.</td>
<td>Yes but only barriers of adoption</td>
</tr>
<tr>
<td>Have theories been identified?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Specific Technologies</td>
<td>Remote care</td>
<td>Social media</td>
<td>Online health information and remote care</td>
<td>Robots</td>
<td>General</td>
<td>General</td>
<td>General</td>
<td>General</td>
</tr>
<tr>
<td>Specific Application Contexts</td>
<td>Independent living</td>
<td>Independent living</td>
<td>Independent living and mental health</td>
<td>Independent Living</td>
<td>Independent Living</td>
<td>Independent Living but only in Sweden.</td>
<td>Independent Living</td>
<td></td>
</tr>
</tbody>
</table>

Despite the review papers (Broekens et al., 2009; Leist, 2013; Magnusson et al., 2004; Mostaghel, 2016; Or and Karsh, 2009; Peek et al., 2014; Yusif et al., 2016) that have been published in this area, a comprehensive and updated model of antecedents of adoption covering various technologies and different application contexts in relation to the theoretical aspects has not been uncovered. The theoretical aspects of
adoption have not been addressed in these reviews. In addition, the literature in this area has not compared the differences in adopting supportive and empowering technologies among seniors.

To this end, the current study systematically searches the literature in this area and aims to investigate the factors that influence the adoption of technologies among seniors. The paper also looks at the theoretical support used to justify the empirical evidence for these factors. This study answers to the following research questions (RQ):

- **RQ1**: What are the antecedents of adoption of supportive and empowering technologies for seniors in the literature?
- **RQ2**: What are the theoretical perspectives that have been used in the literature for adoption of assistive technologies among seniors?
- **RQ3**: What are the differences between supportive and empowering technologies in terms of justifying the empirical evidence by utilizing the available theories?

Conventionally, “elderly” has been defined as a chronological age of 65 years old and greater (OECD, 2012). Orimo et al (Orimo et al., 2006) have discussed the differences between those from 65 through 85 years old, referred to as “early elderly” and those over 85 years old as “late elderly” or “oldest old”. For the purpose of this work, we treat the term elderly as people who are over 65 years of age.

The rest of this paper is organized in the following way: Section 2 presents a literature review of previous papers associated with the Adoption of Assistive Technologies among Seniors and highlights the differences between the current study and the previous reviews. Section 3 presents the method of searching and analyzing the papers used in this study. Section 4 presents the theoretical perspectives in adoption of assistive technologies among seniors. Section V presents the antecedents of adoption and section 5 discusses the findings and limitations of the current work and opens new avenues for future studies.

### 2. Methods

In our work we have customized the guidelines for systematic review laid down by (Keele, 2007). These have been extensively used by researchers such as (Vichitvanichphong et al., 2013b, 2013a). The systematic method proposes four main steps to carry out a literature review, namely; (1) An exploratory background search to identify the relevant keywords and databases, (2) a search for the initial list of studies, (3) a relevance appraisal, and finally (4) data extraction and analysis.

#### 2.1. Exploratory background search: identifying search key and databases

The first step towards searching appropriate articles was to identify the relevant keywords and databases that need to be searched. To do this end, we conducted a background survey (Vichitvanichphong et al., 2013b). An initial list of journals related to the topic was chosen from the journal classification list proposed by the Excellence in Research for Australia (ERA, 2012). The journals with an impact factor of less than one were omitted. From this initial search, we came up with 14 journals. From these journals, we found 31 papers, in the last five years, which were relevant to the topic. In order to identify the relevant keywords and related online databases, we applied the experimental method proposed by (Dieste et al., 2009) to the above-mentioned 31 papers and we identified the most popular online databases indexing these 31 articles. The method took the set 31 papers and using a frequency analysis in an ANOVA for the terms used in the papers generated the most relevant keywords to be searched. A similar method was adopted to find out the most relevant databases to search. These databases are listed in Table 2.

Having analyzed the 31 papers, we created our search key including a term for each of the following groups
• Technology
AND
• aged care” OR “aged” OR “aging” OR “senior” OR “old” OR “elderly” OR “elder” OR “older”
AND
• “adoption” OR “acceptance” OR “use” OR “behavioural intention” OR “behavioural intention” OR “attitude” OR “believe” OR “belief” OR “usefulness” OR “diffusion” OR “user”

2.2. Searching for initial list of studies

Eight popular databases were searched using the above search key. The search considered titles, keywords, abstracts and full texts of papers published since 2000, inclusive and returned 723,944 articles. The distribution of papers in each database is presented in Table 2.

Due to the large number of papers, only the publications after 2000 inclusive have been targeted to ensure timeliness of the results. We also found some of the papers were indexed by multiple databases, see Table 2.

<table>
<thead>
<tr>
<th>Name of Database</th>
<th>Initial list of papers</th>
<th>Filtered by titles</th>
<th>Filtered by abstract</th>
<th>Filtered by text</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of found articles</td>
<td>Number of duplicated articles</td>
<td>Number of found articles</td>
<td>Number of duplicated articles</td>
</tr>
<tr>
<td>Springer</td>
<td>16,539</td>
<td>213</td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>Wiley InterScience</td>
<td>453,537</td>
<td>99</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>ScienceDirect</td>
<td>11,442</td>
<td>49</td>
<td>18</td>
<td>38</td>
</tr>
<tr>
<td>IEEE Xplor</td>
<td>69,690</td>
<td>30</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>ACM Digital Library</td>
<td>560</td>
<td>21</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Scirus</td>
<td>94,487</td>
<td>27</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>PubMed</td>
<td>10,989</td>
<td>33</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Google Scholar</td>
<td>66,700</td>
<td>160</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>723,944</td>
<td>632</td>
<td>212</td>
<td>213</td>
</tr>
<tr>
<td>Relevant papers by deducting the duplicated articles</td>
<td>420</td>
<td>138</td>
<td>104</td>
<td></td>
</tr>
</tbody>
</table>

2.3. Selection of studies

In this step, the objective was to filter the relevant papers from the initial list and exclude the ones which are not related to our study. This process was carried out by excluding papers based on titles, keywords, abstracts and full texts; see Figure 1. Articles that have one of the following exclusion criteria were removed:
• Did not focus on assistive technologies for aged care.
• Did not have any empirical evidence.
• The definition of elderly does not fall into 65 years old or greater
• Were in languages other than English.
• Were not in the relevant fields or could not be applied to relevant fields.
• Were not peer reviewed.
• Were not available online.

Among 723,944 papers indexed in the databases and searched by the keywords, 420 papers remained after title filtering, 138 articles remained after abstract filtering and 104 papers were identified as final list of
relevant papers after reading the full texts (Figure 1). The final list of the relevant papers can be found in (Suchada Vichitvanichphong et al., 2014).

### 2.4. Extracting and analysis of data

Figure 2 presents the data extraction and analysis process. In the data extraction stage, key details from the selected papers were obtained. Data were collected from each paper, namely: (1) Technology and its type being supportive or empowering, (2) Utilized adoption theories, if available, and (3) Factors impacting on adoption of assistive technologies. In order to ensure the reliability of the results, the standard critical review forms for quantitative (Law et al., 1998a) and qualitative studies (Law et al., 1998b) were used. For mixed-method studies, both forms were completed. An initial list of factors impacting the adoption as well as initial categories that contains these factors were created from the completed forms.
2.5. Evaluating findings by experts

A peer review of the findings was then undertaken. Five experts from North America, Australia, Europe, Asia and Middle East were invited to code the impacting factors of adoption into different categories. These nationalities were chosen based on the checklist provided in (Owens et al., 2010). This incorporate the global coverage of different perspectives that may apply to different healthcare systems geographically located in different parts of the world. The experts were chosen based on their academic knowledge and practical experience in the topic. The experts were given an instruction sheet including the description of all the items as well as an answer sheet in which they were asked to map the items into the proposed initial categories. A reliability test was then undertaken based on proportional reduction in loss (PRL) reliability indicator introduced by (Rust and Cooli, 1994). PRL is used to assess the consensus between judges who are invited to code a number of elements into exclusive categories. Inter-judge agreement was measured by dividing the total pair-wise agreements by the total pair-wise decisions. Having five judges on board; in assigning each item into a category, a total number of 10 pair-wise decisions were made. The consensus of assigning an item to a category was the most frequently selected choice by the five judges. The reliability for each contribution was calculated based on the value of Inter-judge agreement. According to the data presented in Table 3 and based on (Rust and Cooli, 1994), the reliabilities of contributions proposed in this paper are acceptable.

| Table 3 Results of the reliability test |
|-----------------|-----------------|------------------|-----------------|------------------|
| Pair-wise agreements | Pair-wise decisions | Inter-judge agreement value | Reliability value | Is it reliable? |
| 327 | 520 | 0.63 | 80% | Yes |

3. Theoretical Perspectives

The major theories used to research the adoption of assist technologies among seniors as shown in the literature are listed below (note that appropriate referencing to the theory itself is also shown);

- Technology Adoption Model (TAM) (Davis et al., 1989), (Davis, 1989)
- Diffusion of Innovation (DoI) (Rogers, 1962)
- Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003).

Other theories have attracted less attention and these include; the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1980), Theory of Planned Behavior (TPB) (Ajzen, 1991), Seniors’ Technology Acceptance Model (STAM) (Renaud and van Biljon, 2008), Motivation Theory (MT) (Cofer and Appley, 1964), Learning Theory (LT) (Illeris, 2004), Activity Theory (AT) (Bedny and Meister, 1997), Theory of Disengagement (ToD) (Cumming and Henry, 1961), Parsimonious Technology Acceptance Model (pTAM) (Sharp, 2006), Ubiquitous Computing-service Acceptance Model (UCAM) (Shin, 2010), Attribute of Technology (AoT) (Jaspars et al., 1983); See Figure 3.

Learning theory (LT) (Illeris, 2004) has been identified as one that is relevant to the context in question, this theory describes how information is absorbed, processed, and retained during learning or trying a new technology. LT introduces three dimensions influencing the adoption of new technology, namely; emotional and cognitive abilities of individuals as well as the social context involved in the use of the technology. TAM is still the predominate theory used and there have been few modification of TAM when applied to technology adoption amongst seniors. Some examples of modifications include, pTAM (Sharp, 2006) which suggests that perceived usefulness and perceived ease of use directly impacts on a person’s intention to use and as such pTAM has removed the attitude construct from the original version of TAM.
Ubiquitous computing acceptance model (UCAM) (Shin, 2010) indicates that cognitive and affective attitudes are potentially the primary factors of technology acceptance or intention to use. Seniors’ Technology Acceptance Model is a modified version of TAM that suggests technology adoption among seniors begins with behavioral intention and that this is influenced by social context and perceived usefulness. The seniors’ behavioral intention can be converted to actual use and, if usefulness is confirmed, it can be related directly to adoption. Another theory of adoption that has been specifically developed for seniors is the theory of disengagement, this theory claims that some elderly people will disengage themselves from the intervention due to concerns about their own mortality and whether a long term intervention is worth all the effort.

3.1. Lack of Theoretical Perspective

It was found that most of the papers in adoption of assistive technologies among seniors have not used any theories to frame the research or elucidate their results. This could demonstrate a need for more attention to be paid with respect to theoretical support for the studies and to improve the reliability of the results. In a closer look at the theories and their utilization in empowering and supporting technologies, it is seen that the application of adoption theories in researching empowering technologies is even poorer than that of supportive technologies; See Figure 4.

The review found that there is no overwhelming widespread model for adoption of assistive technologies among seniors but rather it was noted that the adoption theories have not been effective in the context of aged care (62 papers did not mention any theory at all). As there is very limited use of theoretical perspectives in the adoption of empowering technologies in the literature (25% used theories while 75% avoided), we infer that there must be a degree of disillusionment in the theories available and (based on the systematic review undertaken here) this appears to have resulted in a large amount of research (almost 51% in Supportive technologies and 25% in empowering technologies) being conducted devoid of any theory.

In order to ascertain the implications of this, the review looked at the effectiveness of these theories in the studies that have used theoretical foundations. The review sought to assess the empirical evidence and the antecedents that can be explained by theories used in research associated with the adoption of assistive technologies among seniors. The review also aims at comparing theoretical background for adoption of supportive versus empowering technologies.
4. Taxonomy of Factors Influencing Adoption of Assistive Technologies among Seniors: Theoretical Support for Empowering versus Supportive Technologies

Our findings suggest that adoption of assistive technologies among seniors is a complex issue and is influenced by a variety of factors as shown in Figure 5. After arriving at 48 distinguishable determinants, this paper has classified them into the six main categories of Individual, Psychological, Technology, Environmental, Intervention, Support and Training Factors.

4.1. Individual Factors

Individual factors refer to human being’s capacities, strengths and limitations based on different demographics, abilities and interests. These influence the rejection or adoption of technologies, particularly among seniors. The Level of Innovativeness refers to the degree in which an individual is ready or willing to try new technologies and has a significant impact on adoption of assistive technologies among seniors. For instance, it was shown in (Mahoney, 2010) that seniors with a higher level of innovativeness would adopt remote monitoring technologies much more easily. Rogers (Rogers, 1962) in Diffusion of Innovation (DoI) defines five categories of adopters and this relates to the level of innovativeness or willingness to adopt by
individuals, these categories are: (1) innovators who take risk, initiative and time to try something new, (2) early adopters that take the lead to adopt a technology if they realize the technology would potentially solve a problem, (3) early majority that do not want to take risk, or time but would adopt a technology if they are sure that the technology solves a problem, (4) late majority that are very persistent against change and they are very hard to change without influence, and (5) laggards who need pressure to adopt a technology.

The level of technology learnability has been shown as an effective antecedent for adoption. For example it was shown to be a significant factor in the adoption of interactive TV among seniors (Stojmenova et al., 2013). In this study (Stojmenova et al., 2013), it was found that elderly who live alone adopt home telecare technology more easily because they realize the benefits of the telecare solution and these benefits are more visible in comparison with seniors who do not live alone (Peeters et al., 2012). A The level of social isolation is the degree in which seniors spend less time associating with friends and do not want to interact with people (Boyd et al., 2014). It was found that the more socially isolated the elderly are, the less time they spend on the Internet (Sum et al., 2008). The level of income or seniors’ buying power has shown to have a significant impact on adoption of technologies; for example elderly with higher level of incomes will be more likely to use the Internet for their daily needs. It was suggested by (Sum et al., 2009) that the better educated seniors adopt internet services for their everyday lives more easily. As discussed earlier, seniors of 65 to 85 years of age are referred to as “early elderly” and those over 85 years old are called “late elderly”. Early elderly in many cases have considerably different needs, and have different abilities and competencies. For example they adopt mobile information services much more readily than late elderly (Wilkowska and Ziefle, 2009). A barrier for seniors to adopt technologies is the fact that a significant number of them are facing some sort of decline in their physical and cognitive abilities (Yusif et al., 2016), which would directly impact on their ability to learn and the skills needed to use the technologies. For instance, many seniors are unable to touch the mobile phone buttons properly (Xue et al., 2012), or some elderly cannot remember how to use electronic emails to communicate with their carers (Singh et al., 2009). In other cases, adoption could be related to context whereby a person with chronic disease may enthusiastically adopt a specific technology to help manage their condition. If a person is suffering from a chronic disease (for example diabetes), they will be much more open to the adoption and use of social media sites where they can discuss how to manage their condition with others (Braun, 2013).

4.1.1. Theoretical Support: Empowering vs Supportive
Theoretical background of adoption supports several antecedents for this group such as the level of innovativeness, the level of technical learnability, educational background or income level. However, some of the antecedents categorized in this group may highlight the contextual settings related to ageing. For example, living alone is very much related to many seniors’ desire to live independently (Leeson et al., 2004; Porteus and Browse, 2000). It was shown that seniors who live alone can realize the contributions that of technologies can give to their independent lifestyle. Clark et al. (Clark et al., 2011) found that older adults can adopt technological or lifestyle interventions that enhance their independent living (Kolkowska et al., 2016). The concept can be utilized in both supportive technologies and empowering technologies. In the case of supportive technologies, the elderly person who has functional difficulties would appreciate the role of technologies that assist them in continuing their independent living. However, in the case of empowering technologies, the older individual adopts a technology to maintain or improve their functional abilities and as such is able to continue their independent lifestyle longer.

The level of social isolation characterizes an issue in that is problematic in the life of many of seniors and the theory of disengagement supports this. This theory suggests that because many elderly see their death as being very close, they often disengage themselves from their social roles and do not get involved with any of...
interventions associated with social connections that are often facilitated by the Internet. Although adoption theories such as TAM categorize the contextual antecedents such as living alone and social isolation as external factors influencing perceived usefulness, they fail to explain the cognitive process in which these contextual factors would be converted to a mental state that believes the technology would be useful i.e. perceived usefulness. This theoretical process may differ from the adoption of supportive technologies to those of empowering technologies. For example, the key to perceiving that empowering technologies are useful can be the demonstration of training of functional abilities to help support living alone. However, to perceive a supportive technology as useful, the technology needs to be seen as helpful to an elderly person who has difficulties in living alone.

Age is another individual factor that defines the seniors’ cohort into early and late elderly. While these two age groups can be different with respect to their abilities and needs, they also show different behaviors in the adoption of supporting and empowering technologies. For example, it is expected that the late elderlies will develop more chronic diseases, which lead them to adopt supportive technologies to manage their conditions e.g. (Braun, 2013). However, this is in conflict with theory of disengagement when by having more chronic diseases they are supposed to see themselves closer to the death and avoid engaging with the technologies. In addition, later elderlies are expected to develop more physical and cognitive difficulties that may be considered a barrier in adoption of many technologies that require these abilities to operate.

4.2. Psychological Factors: Attitudinal Factors

People of various backgrounds often have different belief and value systems, which gives a rise to dissimilar attitudes, particularly while adopting a technology. Au and Enderwick (Au and Enderwick, 2000) define the attitude towards technology as a cognitive process which depicts positive or negative individual affection about using a technology. Theory of Planned Behavior (Ajzen, 1991) suggests that individual attitudes towards adoption of a technology are determined by relevant internal factors. Our reviews have identified these factors as attitude towards learning, technological confidence, technology anxiety, intervention preference and lack of interest.

Barnard et al (Barnard et al., 2013) have studies older adults who use the Samsung Galaxy Tab handheld touchscreen tablet with a seven inch screen to support their walking. They found older people who have prior experiences with learning new things show better attitude to adopt the assistive walk technology. They also suggest that seniors who have ideas about how difficult it would be to learn a given new technology would more readily learn the technology and adopt it. Aula (Aula, 2005) has looked at how older adults adopt web technologies and in particular search engines. He found the seniors who have self-confidence in using technologies would have better attitudes towards adoption of technology. Technology preference refers to the degree in which technology can be a choice, not a must. For example, it was found that seniors who have chosen Nintendo Wii Fit as an alternative therapy has adopted the intervention easier. However, the elderly who have been pushed to use the Nintendo Wii Fit therapy program have given up after a while (Laver et al., 2011). Technology anxiety and Lack of interest were found as attitudinal barriers of adopting assistive technologies among seniors. Technology anxiety defines a cognitive factor for the fear of using technologies. Czaja et al (Czaja et al., 2006) has adopted wireless sensors to monitor health conditions of elderly. They found the majority of the participants are terrified by the fact that computer systems are hard to understand and that scares them. They expressed their stress on what would happen if they press the wrong button. Another attitudinal barrier in adoption of technologies among seniors refers to the lack of interest among elderly to put effort and attempt to use the technologies. Morris et al (Morris et al., 2007) found that many elderly think that they are too old to be bothered to use Internet. They believe that is too much effort.
4.2.1. Theoretical Support: Empowering vs Supportive

There has been considerable amount of attention in different theories on attitudinal factors. Most of the factors discussed in this category are theoretically well explained. It was found that providing technology as an alternative option, i.e. Technology preference, has more impact on successful adoption of technologies among seniors. This lacks a theoretical explanation and it is notable that this cannot be applied for supportive technologies, where using the technology is to support the age-related functional declines and this usually does not come as an option. However, it is indeed a very good fit for empowering technologies where elders choose a technology to empower them for living independently longer.

4.3. Psychological Factors: Perception Factors

Perceived antecedents of adoption are subjective judgment of technology users of what contributes on their decisions to adopt or reject the use of a technology (Lin and Hsieh, 2006). In contrast to the actual value of antecedents, perceived antecedents are the result of a cognitive process (Kim, 2008). Perceived independency refers to seniors’ perception about their ability of living alone. Kiel (Kiel, 2005) believes that using technologies enhances seniors’ perceived independency as they can now shop, pay bills, bank, learn and engage in chat groups. Perceived quality of life has been defined as one's cognitive appraisal of his or her overall satisfaction with life (Huebner et al., 2004). The research in this area puts a significant emphasize on life conditions of individuals. Steele et al (Steele et al., 2009) suggest that monitoring health conditions of elderly people using wireless sensors improves their health condition and as such seniors feel better about their lives. Perceived usefulness refers to a cognition that an elderly believes that using a given technology will be useful to support or empower her/his functional abilities. For instance, tele-monitoring technology has been found useful by seniors to support them for their health conditions (Huang, 2011). The shooter game has been found useful by seniors to empower their visual abilities that help them to be able to live independently longer (McKay and Maki, 2010). Older people are traditionally resistant to change but may adopt new technological products (Pan et al., 2015), if they think they are easy enough to use, which refers to perceived ease to use. For example, McKay and Maki (McKay and Maki, 2010) found if seniors at the very early stage of adoption think that shooter game is easy to play, this significantly motivates them to adopt the technology even on when they realize some difficulties in playing the game. McKay and Maki (McKay and Maki, 2010) has related this to the primary motivator that can attract seniors to the technology. In contrast with the perception perspective of ease of use, Renaud and Biljon (Renaud and van Biljon, 2008) are proposing STAM as a measure of the impact of the actual ease of use on the adoption of technologies among seniors. However, STAM has been negated in several other studies e.g. (Huang, 2011). Perceived risk occurs when seniors feel in danger while they are using a technology. Laver et al (Laver et al., 2011) have deployed Wii fit as a rehabilitation therapy and found seniors believe that there are potential risks associated with the use of Wii fit and they are very concerned about these risks. Zaad and Allouch (Zaad and Allouch, 2008) suggest that if older people perceive a risk in using a technology sooner or later they might feel reluctant and decide to stop using it eventually. Perceived enjoyment refers to the perception of the elderly about the entertainment aspect of a given technology. McKay and Maki (McKay and Maki, 2010) asked seniors to play the shooter game to empower their visual abilities. They found that the elderly who, prior to play, believed that the game was going to be entertaining showed more willingness to play the game. Perceived sociability refers to the perception of the elderly to the technology enabling them to perform sociable behaviors. Heerink et al (Heerink et al., 2010) ran an experiment and asked elderly to interact with iCat robot (“Communist Robot - iCat Robot Information,” n.d.). It was found that the socially expressiveness of the robot made the seniors believe the robot had some social abilities and this accordingly improved their adoption. For instance, if the robot uses the participant’s name in its communication, keeps eye-contact or apologizes for its mistakes; older
people consider the robot social expressiveness of the robot and would adopt it easier. *Perceived value* explains the utility derived from the technology due to the reduction of its perceived short term and longer term costs. It was found that elderly are concerned about the value return of the money when they spent on buying smartphones to access to mobile healthcare information services (Boontarig et al., 2012). This was identified as a significant factor on their intention to use these services. *Perceived need* defines the seniors’ belief that they would require the assistance of a technological intervention now or in the future. Through multiple case studies in aged care settings in Ireland, it was found that elderly who believe that they need ICT services for better care, they are willing to adopt these services (Walsh and Callan, 2011). *Perceived learning benefits* refers to the perception of seniors on the benefits that they receive by the effort that have to make to learn a new technology. In a survey conducted in (Kiel, 2005), it was found that if seniors think that the effort of learning email is worthy enough to stay connect with family and friends, they would be happy to put this effort and learn how to use emails. *Perceived trustworthiness* explains the elderly’s belief that a technology performs as it is supposed to perform. Zaad and Allouch (Zaad and Allouch, 2008) deployed an intelligent monitoring system consisting motion sensors at the seniors’ home, which learns their life style. Any changes in the life style might indicate that the person’s abilities have started to degrade or that there has been a problem (Chaurasia et al., 2016). As such a report should be sent to the care giver. They studied the fully automated version of the system that directly sends the report and a semi-automated system that verifies the report with the elderly before sending the report. It was found that seniors believed that the semi-automated version is more trustworthy and they adopted it more easily. *Self-efficacy* defines the elderly’s self-perceived capability on certain technology-specific tasks. For example, if seniors do not think that they are able to enter URLs, or create bookmarks and folders they would not to use computers to surf the Internet (Lam and Lee, 2006).

4.3.1. Theoretical Support: Empowering vs. Supportive

Many of the factors in this category can be explained with the theory of attributes such as perceived risk, trustworthiness, and enjoyment. However, we believe in many cases, it is important to clarify the details of those factors in the adoption of technology among seniors. To this end, we consider it important to define the specific features of the context. For example, although perceived independency plays a significant role in defining the context of adoption among seniors, this influencing factor has been remained unexplained by adoption theories. It was also found that perceived quality of life needs further attention from a theoretical perspective. The definition given in (Huebner et al., 2004) and applied in (Steele et al., 2009) relies on an overall satisfaction with life. The definition commits the application of the construct to the ambiguity of the definition of satisfaction with life, which will may vary from one person to another. The Seniors’ Technology Acceptance Model differentiates between perceived and confirmed usefulness and states that confirmed usefulness is achieved with an early exploration of the elderly with respect to the technology. Although STAM fails to explain what happens in the exploration stage that converts perceived usefulness to confirmed usefulness. This theory presents the impact on the successful exploration, but does not justify how this confirmation of belief can be achieved or, in other words, what experience elderly should have to convert the initial beliefs to confirmed usefulness. This exploration stage should be different in supportive technologies in comparison with empowering technologies because it would be a different experience when seniors use technology to support or empower. Although STAM attempts to utilize the actual ease of use as an antecedent on the exploration stage, other literature such as (Huang, 2011) and (McKay and Maki, 2010) found actual ease of use does not contribute much to adoption as long as seniors in the early stage believe that the technology should be easy to use. This conflict also requires further study. Although there is a conceptual relationship among perceived usefulness, need, learning benefits and value; this relationship has not been theorized from a seniors’ perspective. The differentiation of support and empowerment between two different
types of assistive technologies should clarify different cognitive process for the supportive and empowering technology in order to relate perceived usefulness, need, learning benefits and value constructs. It is also interesting to observe that not all the perception factors can be explained by the theory of attributes of technology, but also some are related to the perception of the elderly about themselves such as self-efficacy or about their conditions such as perceived need.

4.4. Technology Factors

The characteristics of technologies impact on successful adoption among seniors. This suggests that in development or selection of existing technologies, there are factors related to the feature of technology that can influence adoption. These factors refer to actual features of technologies as opposed to perception of seniors in the previous group.

Complexity is the degree to which a technology is perceived as being difficult to understand. It was found that when seniors are asked to use a technology at their home and use it personally, not surprisingly, less complex technologies have higher chance of adoption (Ahn et al., 2008). Reliability of a technology refers to providing required functionalities for desired period without failure. It was found that seniors were concerned that what would happen when the battery of the monitoring system runs out (Steele et al., 2009) and this has led to resistance by some seniors after using the system for a while. Interface design can influence the adoption of technologies among seniors particularly. It was found that in adoption of mobile phones the design of the touchscreen and keyboard should fit to the elderly’s requirement e.g. the display layout is easy to understand, the characters are legible (Umemuro, 2004). Compatibility refers to fit of the product into the daily lives of seniors. Peeters et al (Peeters et al., 2012) believe that adoption of home-based telecare is heavily depends on whether the facilities, procedures and conditions of the technology fit to the everyday life of seniors or not. Functionalities are abilities of a technology that help older people satisfy their needs. Features are appropriate/ inappropriate features of devices. For example, when seniors asked to play the shooter game to improve their visual abilities, they said playing this game needs rapid reaction that they are not able to cope with (McKay and Maki, 2010). Aesthetics refer the appearance of technology or how the individual would look like by having the technology attached to her/himself. For an instance, seniors are concerned of appearance by wearing supportive technologies such as vision aids, hearing aids, mobility aids (McCREADIE and Tinker, 2005). It was also suggested that higher cost can lead to a delay of obtaining technologies or even giving up (Cameron et al., 2001). This is very much related to perceived value introduced in the previous section.

4.4.1. Theoretical Support: Empowering vs. Supportive

Although the factors of this group are well described by theories identified in this review, some of the technology factors such as functionalities and features can be related to nature of the assistive technology being supportive or empowering. For instance, relating functionalities and features to the perceived usefulness, the definition of usefulness would be different in supportive in comparison with empowering technologies. Supportive technologies should provide functionalities and features that assist elderly in some of the functional abilities required for everyday activities. However, empowering technologies require functionalities and features that provide training in which the elderly can keep his/her functional abilities longer. Therefore, having two different objectives differentiates the conversion process of functionalities and features to perceived usefulness in supportive and empowering technologies. This has not been looked at or explained by existing theories.
4.5. Environmental Factor

Environmental factors refer to the social context for adoption of technologies among seniors. A significant impediment to adoption is the negative social influence of seniors being discouraged in the use of technology by friends and family. However, if friends and families positively enforce the effectiveness of a particular technology, seniors would be more likely to adopt that technology. For example, the adoption of self-reporting devices for monitoring health conditions such as blood pressure has been failed in Australia among those elderly whose friends and neighbors had not been using it and believed that they do not work accurately (Smith et al., 2002). Another barrier in the adoption of some of the technologies is the image that the use of the technology can create in the social context around the elderly; called social implications. This can refer to the appearance; for instance seniors don’t want to wear neck or wrist pendant because they may feel ashamed about wearing a medical device (Steele et al., 2009). It can also refer to the perception that the use of a particular technology can create an image about the person within their network of friends and family or even within society as a whole. If in a society or a culture, playing video game is perceived as something only for kids, seniors may think they are too old to play and would develop a negative attitude toward playing games for improving their functional skills (Bronikowska et al., 2011). Technology has come to characterize the today’s world. The society has been changed and attitudes have improved with respect to using new technological innovations. Czaja et al (Czaja et al., 2008) think a reason why older people adopt technologies is because they are in a technology-oriented society, so they are more open towards using technological products. However, this is not specific to seniors but can be generically said for technology adoption in today’s societies. Group participation refers to the degree in which seniors value an environment where they have other older adults who are involved in the same program with them. Laver et al (Laver et al., 2011) found although some older people suffer from mobility issues, they still prefer joining others in fitness programs conducted in clinics as compared to using a Wii Fit game in their own home.

4.5.1. Theoretical Support: Empowering vs. Supportive

While social influence and their implications have been extensively addressed by different adoption theories, group participation is a topic of the learning theory where adoption is attached to an individual’s social context. At the same time, the growth in the population of older people and the increasing expenses of aged care and clinic facilities pushes us towards technological innovations to keep seniors in their home as long as possible. However, as it is shown in (Laver et al., 2011), this should not stop or limit the social context of an elderly’s daily activities. Despite that, the empirical evidence supports the positive contribution of group participation in adoption of technology among seniors.

4.6. Support and Training Factors

Training, quality of training and tech support are integral parts that impact on technology adoption among seniors. It was found that training can significantly improve the adoption of mobile phones among seniors (Wilkowska and Ziefle, 2009). Furthermore, the quality of the training, available materials, manuals, tutorials that can make learning easier have been shown positive impacts on perceived usefulness and accordingly adoption of touch screen tablets by seniors(Barnard et al., 2013). Similarly, it was found (Marzano and Lubkina, 2017) that ongoing tech support and facilitation by service provider of the program that encourages seniors to use a technological intervention improves the seniors’ intention to use of mobile phones (Biljon and Renaud, 2008).
4.6.1. Theoretical Support: Empowering vs. Supportive

There has been a lot of emphasis on the significant role of the training and ongoing support of technology for better adoption among seniors in most of adoption theories and empirical evidence. However, Mort et al (Mort et al., 2013) believe that the most successful adoption among seniors occurs when they use the technology, but they may engage with it in a creative way that is not necessarily the purpose of the intervention. However, they believe that in most of technologies designed for elderly, this element has been largely ignored. Although this should be taken into account in providing training and support for supportive technologies, the theoretical process should also be defined for empowering technologies where the elderly can realize and practice the empowering benefits of the technologies in an intuitive way.

5. Summary, Discussion and Outlook

The presented systematic literature study looked at adoption research in the context of assistive technologies for seniors, which requires attention in three main perspectives; (1) What are the empirically significant antecedents for the elderly’s adoption of assistive technologies, (2) What theoretical perspectives have been utilized to explain the empirical evidence and (3) What are the differences in terms of theoretical supports for supportive and empowering technologies. These were our research questions that will be discussed below.

5.1. Practical Contributions: Antecedents for Elderly’s Adoption of Assistive Technologies

In response to the first question, the review has extracted the antecedents of adoption that have shown a significant influence in adoption of technologies from the elderly’s perspective. The factors, with consultation from five experts from Europe, USA, Australia, Asia and Middle East, were analyzed and categorized in 6 groups; namely individual factors, psychological factors, either attitudinal or perception, technology factors, intervention factors, environmental factors, supporting and training factors; See Figure 5.

The findings of this paper informs nursing professionals and aged carers to consider the differentiation of supportive and empowering technologies in factors influencing the elderly’s adoption. This would result in efficiencies in the aged care sector and providing more targeted interventions for independent living of the elderly. From a technology developers’ perspective, the findings of this research can make an awareness of the right mapping of adoption factors to the technology introduced to the elderly possible. Our findings also demonstrate that empowering technologies, because of their indirect effect create a different context to adoption than supportive technologies. In many cases, empowering technologies involve the nature of training that requires further investigation with respect to the influencing factors.

Table 2 highlighting this difference, proposes future research in comparison of these two types of assistive technologies in terms of their antecedents of adoption.

<table>
<thead>
<tr>
<th>Proposition 1: Individual, psychological (either attitudinal or perception) technology, intervention, environmental, supporting and training factors influence on the adoption of assistive technologies among seniors.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposition 2: Empowering and supportive technologies create different context for adoption among seniors.</td>
</tr>
<tr>
<td>Claim: Considering the type of assistive technologies, being empowering or supportive, is essential for successful adoption among seniors.</td>
</tr>
<tr>
<td>Suggested Question for Future Research: How are empowering and supportive technologies compared in terms of their antecedents of adoption?</td>
</tr>
</tbody>
</table>
5.2. Theoretical Supports for Elderly’s Adoption of Assistive Technologies: Empowering vs. Supportive

In answer to the second question, the systematic review has found that most of the papers did not use any theory in their work, or if they used any, they could not adequately justify their empirical findings. Not surprisingly, the review found that among 42.8% of the relevant papers using a theoretical foundation, there exists a limitation of focus on the major adoption theories such as TAM, DoI and UTAUT. However, in most of these cases, the papers could not sufficiently justify the empirical evidence supporting the role of some antecedents. Like many other fields, researchers have modified TAM to different versions such as Parsimonious TAM, Ubiquitous computing acceptance model and most interestingly Seniors’ TAM. However, none of these could widely be utilized and explain the adoption of assistive technologies among seniors.

We found that the theoretical aspects of adoption of assistive technologies lack a more specific approach to seniors’ conditions and particularly in adopting empowering technologies. For example, the factors mentioned in this paper have been revealed by studies as being influential while in some cases theories are unable to describe how they can be systematically applied. The literature review found many studies did not use any theory to explain their results and in several cases if they used the theory they could not justify the empirical findings. This needs further attention by the research community.

The analysis of different antecedents of adoption and their suitability to the theories has led us to the fact that in many occasions the theories should provide a process in which the elderly’s living situation such as their age-related conditions can be converted from perceived to actual usefulness. This should improve the adoption of technologies by seniors. The usefulness here is judged in many cases and of course not all in terms of facilitating independent living for the elderly. However, theorizing this process is very much related to whether the technology is being adopted is supportive or empowering. Supportive technologies help seniors in their functional difficulties and empowering technologies help seniors to maintain their functional difficulties.

For instance, the adoption of supportive technologies requires actual usefulness of technology for elderly to be able to live independently. This has been theorized in Seniors’ Technology Acceptance Model. STAM introduces the exploratory stage of adoption where perceived usefulness can be converted to actual usefulness by trying the technology. This, in many cases is applicable to supportive technologies in that usefulness can be demonstrated by literally managing the elderly’s functional difficulties and conditions. Therefore, this would help seniors to live independently or as independently as possible.

For the empowering technologies, the process of seniors’ conditions and lifestyle converting perceived to actual usefulness is more difficult. The empowering technologies provide training to maintain the functional abilities of seniors. This would allow them to live independently longer. However, the effectiveness expected from these technologies occurs over the time and cannot be easily demonstrated like supportive technologies. This involves a mental state or opinion of seniors about the empowerment caused by the use of technology. This cannot be seen directly.

The definition of empowering technologies, cited in Introduction of this paper, refer to such a process in which an empowering technology has a positive impact on functional abilities of elderly that themselves have a synchronous impact on an elderly’s capability that is required for her/his independent living. This is called the Transfer Effect (Woo et al., 2011). Although the conversion of perceived to actual usefulness cannot be seen directly in empowering technologies, the perception of seniors about the transfer effect of empowering technologies can lead to adoption. However, this requires further studies supported by empirical data; See Table 3.
Table 3 Proposing Future Research in antecedent of adoption for assistive technologies

<table>
<thead>
<tr>
<th>Proposition 1:</th>
<th>For supportive technologies conversion of perceived usefulness to actual usefulness impacting the adoption among seniors can be demonstrated directly by the success of the technology in literally managing the elderly’s functional difficulties and conditions. This has been theorized by STAM.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposition 2:</td>
<td>The effectiveness expected from empowering technologies occurs over the time and therefore the conversion of perceived usefulness to actual usefulness cannot be easily demonstrated like supportive technologies.</td>
</tr>
<tr>
<td>Claim:</td>
<td>The adoption of empowering technologies occurs not by converting the perceived to actual usefulness, but by only the elderly’s perception about a process in which effect of a technology on their functional ability can be transferred to a capability that they need in their everyday lives i.e. perceived transfer effect. This is a mental process that does not need actual usefulness and seniors adopt empowering technology only if they believe to such a process.</td>
</tr>
<tr>
<td>Suggested Questions for Future Research:</td>
<td>1. How seniors’ perceived transfer effect to an empowering technology help them adopt the technology? 2. What are the theories that can support a perceived transfer effect in adoption of empowering technologies?</td>
</tr>
</tbody>
</table>

5.3. Limitations

This review, like any other literature review, is highly dependent on the keywords that have been chosen and the databases that have been selected for the search. However, in this study, we have conducted a background and exploratory search that selected keywords and databases according to an experimental method proposed by (Dieste et al., 2009).

Because our reviews embraced complexity and sought to map out the operation of multiple theories in multiple contexts, they grew quite large. Therefore, we could only cover a limited number of papers. For instance, the resources that have been selected in this review were only papers published since 2000. Although this decision was made in order to focus the study on recent developments in the field, it is still arguable that authors may have missed valuable adoption approaches that are applicable to today’s aged care settings.

In order to ensure the reliability of the results and avoid bias, we have deployed the proportional reduction in loss (PRL) method. We asked five experts from North America, Australia, Europe, Asia and Middle East to review our results; see Section 2.5. However, it is still arguable that the results might have been impacted by subjectivity of the authors as well as the judges.

The theoretical views suggested here are not supported by empirical evidence and authors encourage researchers in this area to collect empirical data.

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