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A Systematic Review on user Experience in Mobile Application Design Among Senior Citizens

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***Abstract*—This paper presents a review of user experience (UX) in mobile application design among senior citizens. Mobile applications are not always adapted to the special needs of senior citizens. Studies have also found that a good UX design can better promote the physical and mental health of senior citizens, however, more research needs to be conducted about what senior citizens need and expect from the UX elements in mobile application design. The results of the study show, there are many types of mobile applications designed for enhancing senior citizens' well-being, and the most commonly used application among seniors is "Health". It also identified "Usability" as the most frequently used UX element based on the findings in the SLR analysis, and the commonly used tool for testing mobile applications is "SUS".**

Keywords—User experience, Mobile application design, Senior citizens

I. INTRODUCTION

Technology interventions designed for senior citizens have been proven to be available in improving loneliness, life content, social support, quality of life, and other emotional responses [10]. Especially some applications that facilitate communication with family and friends have been designed [45].

Mobile applications can be used as an effective instrument in different user groups [54]. It also has some key benefits for senior citizens such as providing safety and security, healthcare, socializing, and entertainment; improvement of the quality of life of elderly people [22]. However, research also indicated that limited attention has been given by the designer to develop mobile applications for seniors, and the specific needs of senior citizens with mobile applications are not satisfied [27].

ISO9241-210 make a definition with User Experience (UX) as "a person's perceptions and responses which originated from user's use or anticipated use with a product, system or service" in the international standard on ergonomics of human-system interaction. Nielsen Norman Group [39] proposed that UX includes all the aspects of the interaction between the end-user with the company, its services, and its products. He also indicated that there are four simple levels in UX as Utility; Usability; Desirability and Brand Experience.

This paper aims to identify and review what type of UX elements have been used most frequently among senior citizens in mobile applications, as well as the commonly used tool for testing mobile applications. It will first describe the review method performed in this study, including the research questions that will present the findings from the review. Finally, the paper will conclude with a closing remark and propose future work.

II. METHODS

A. Research Questions

This paper is based on considerations of which the following research questions that are related to UX in application design among senior citizens:

[Q1] What type of UX elements has been studied most frequently among senior citizens in mobile application design?

[Q2] What are the research instruments often used to examine mobile application design among senior citizens?

B. Data Collection

The keywords of the SLR paper were derived from the research objective, the research questions, and through an initial scoping of the literature [28]. Three main groups of keywords were established to construct the search strings, "User Experience" or "Utility" or "Usability" or "Desirability" or "Brand Experience" and "Mobile Application" or "Application Design" and "Seniors" or "Elderly" were used. These keywords constitute the set of search strings with different wordings in this study (Table 1).

Table 1. Search strings

Keyword theme	**Search strings**
User experience	user experience OR utility OR usability OR desirability OR brand experience
Mobile application design	mobile application OR application design
Senior citizens	seniors OR elderly

A systematic search was performed in Scopus databases which have been recognized as one of the largest databases of peer-reviewed literature representing high-quality journals and providing advanced search methods [9, 17].

Derived from the research objective and the research questions, articles were screened from exclusion and inclusion criteria [12, 28] (Table 2). First, exclusion criteria regarding the publication timeline, article type, and language from 143 to 87 articles. Then a total of 11 duplicates were removed leading to 66 articles. Further, articles which not focus on "User Experience" were excluded. 23 articles were evaluated as false positives as they were not within the scope

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of this study [28]. This process led to the final sample of 43 articles included in this study (Fig1).

Table 2. Inclusion and exclusion criteria

Criterion	Exclusion	Inclusion
Publication timeline	2015 and before	2016-2022
Article type	Chapters in book, book series, books etc	Article (research journal, conference paper, proceeding)
Language	Non-English	English
Focus	Not focus on user experience	Focus on user experience

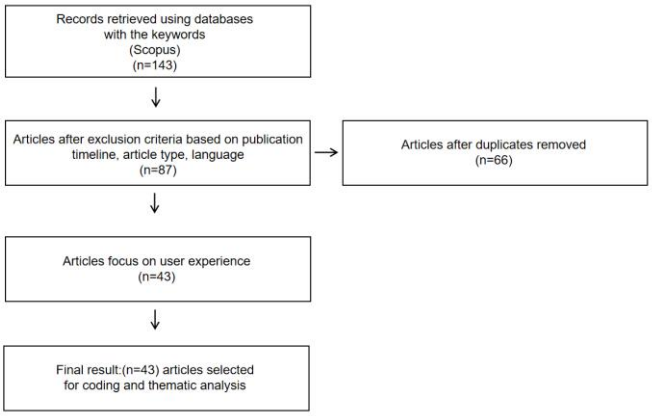

Fig.1. Results of the systematic literature review

C. *Inclusion Criteria*

According to the selection criteria, the data extraction should be relevant to the user experience field. As a guideline to gather papers that are related to the research, qualitative analysis questions were developed to extract potential articles from the Scopus databases. All collected articles were screened and selected based on the Q1, Q2, Q3, and Q4 analysis questions (Table 3).

Table 3. Qualitative Analysis Questions

Questions	Answers
Q1:Was the article about mobile application design among senior citizens?	Yes/No/Partially
Q2:Were user experience elements mentioned in the article?	Yes/No/Partially
Q3:Did the article proposes an application design for senior citizens?	Yes/No/Partially
Q4:Did the article mention about mobile application design enhance seniors' user experience?	Yes/No/Partially

III. FINDINGS

Table 4 shows the results of articles found by using the systematic search which was described in Methods. Articles that did not meet the criteria under the qualitative analysis question were eliminated. Finally, according to the qualitative analysis questions in Table 4, a total of 43 articles were selected and analyzed.

Table 4. List of Selected Reviewed Articles

Paper ID	Author	Year	Title	Type	Q1	Q2	Q3	Q4	Theme
P1	Kangeswaran, Varniah. et al.	2021	A Bilingual Audio Based Online Shopping Mobile Application for Visually Impaired and the Elderly People	Journal	Y	Y	Y	Y	Online shopping
P2	Ismail, N. A. et al.	2021	A Comparative Study of Unimodal and Multimodal Interactions for Digital TV Remote Control Mobile Application among Elderly	Journal	Y	Y	Y	Y	Application function
P3	Lunardini, F. et al.	2021	A mobile app to transparently distinguish single- from dual-task walking for the ecological monitoring of age-related changes in daily-life gait	Journal	Y	N	Y	N	Health
P4	Kokubo, N. et al.	2018	A new device-aided cognitive function test, User eXperience-Trail Making Test (UX-TMT), sensitively detects neuropsychological performance in patients with dementia and Parkinson's disease	Journal	P	N	P	N	Health
P5	Klimova, B., & Sanda, L.	2021	A Novel Educational Smartphone Application for Cognitively Healthy Seniors: A Pilot Study	Journal	Y	Y	Y	Y	Learning
P6	Kő, A., Molnár,	2018	A User-centred	Conference	Y	Y	Y	Y	Social

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	T., & Mátyus, B		Design Approach for MobileGovernment Systems for the Elderly						
P7	Goodridge, D. et al.	2021	An App-Based Mindfulness-Based Self-compassion Program to Support Caregivers of People With Dementia: Participatory Feasibility Study	Journal	Y	Y	Y	Y	Health
P8	Li, X., et al.	2020	An Investigation of Assistive Products for the Elderly	Conference	N	Y	N	Y	Health
P9	Bergquist, R., et al.	2020	App-based Self-administrable Clinical Tests of Physical Function: Development and Usability Study	Journal	Y	Y	Y	Y	Health
P10	Rodríguez, I., et al.	2017	Are notifications a challenge for older people?: a study comparing two types of notifications	Journal	Y	Y	Y	Y	Application function
P11	Broekhuis, M., et al.	2019	Assessing usability of eHealth technology: A comparison of usability benchmarking instruments	Journal	P	Y	N	Y	Usability Evaluation
P12	Valtolina, S., & Hu, L.	2021	Charlie: A chatbot to improve the elderly quality of life and to make them more active to fight their sense of loneliness	Conference	P	Y	P	Y	Application function
P13	Fang, Y. M., & Huang,	2021	Comparison of Digital Applications and	Journal	P	Y	N	N	Entertainment

	S. Y.		Conventional Equipment in Group and Individual Recreational Activities: Social Psychology, Social Interactions, Emotional Reaction, and Perceived Usability in Middle-Aged and Senior Citizens						
P14	Raghunath, N., et al.	2019	Creating a digital memory notebook application for individuals with mild cognitive impairment to support everyday functioning	Journal	Y	Y	Y	Y	Health
P15	Rot, A., et al.	2017	Design and Assessment of User Interface Optimized for Elderly People. A Case Study of Actgo-Gate Platform	Conference	Y	Y	Y	Y	Design guidelines
P16	Macis, S., et al.	2019	Design and Usability Assessment of a Multi-Device SOA-Based Telecare Framework for the Elderly	Journal	Y	Y	Y	Y	Health
P17	Liu, Y. C., et al.	2020	Design and Usability Evaluation of Mobile Voice-Added Food Reporting for Elderly People: Randomized Controlled Trial	Journal	Y	Y	Y	Y	Health
P18	Xiong, W., et al.	2019	Design of Online Learning Mobile APP for the	Journal	Y	Y	Y	Y	Learning

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			Elderly Based on Attention, Relevance, Confidence, and Satisfaction (ARCS) Motivation Model						
P19	Silva, T., et al.	2019	Development and UI/UX Testing of an iTV Companion Application for Seniors	Conference	Y	Y	Y	Y	Entertainment
P20	Castilla, D., et al.	2016	Effect of Web navigation style in elderly users	Journal	N	Y	N	Y	Application function
P21	Martínez-Alcalá, C. I., et al.	2020	Effectiveness of Using Web Applications to Preserve Cognitive Functionality in Older Adults: Mobile First Experience	Journal	Y	Y	Y	Y	Health
P22	Mehra, S., et al.	2020	Evaluation of a Blended Physical Activity Intervention for Older Adults: Mixed Methods Study	Journal	Y	Y	Y	Y	Exercise
P23	Martinez-Millana, A., et al.	2019	Evaluation of an App Based Questionnaire for the Nutritional Assessment in Elderly Housing	Journal	Y	Y	Y	Y	Health
P24	Cao, Y., et al.	2020	Examining the Effect of Overload on the MHealth Application Resistance Behavior of Elderly Users: An SOR Perspective	Journal	Y	Y	N	Y	Health
P25	Rodríguez, I., et al.	2017	Helping Elderly Users Report Pain Levels: A Study of User Experience with Mobile and Wearable Interfaces	Journal	P	Y	Y	N	Health
P26	Kalimullah, K., & Sushmitha, D.	2017	Influence of Design Elements in Mobile Applications on User Experience of Elderly People	Journal	Y	Y	Y	Y	Health
P27	Dantas, T., et al.	2016	Mobile Applications in the Management of Headache	Journal	Y	Y	Y	Y	Health
P28	Wildenbos, G. A., et al.	2019	Mobile health for older adult patients: Using an aging barriers framework to classify usability problems	Journal	Y	Y	Y	N	Health
P29	Ureña, R., et al.	2020	m-SFT: A Novel Mobile Health System to Assess the Elderly Physical Condition	Journal	Y	Y	Y	Y	Health
P30	Stutzel, M. C., et al.	2019	Multi-part quality evaluation of a customized mobile application for monitoring elderly patients with functional loss and helping caregivers	Journal	Y	Y	Y	Y	Health
P31	Reading Turchioe, M., et al.	2020	Older Adults Can Successfully Monitor Symptoms Using an Inclusively Designed Mobile Application	Journal	Y	Y	Y	Y	Health
P32	Zenun Franco, R., et al.	2018	Online dietary intake assessment using a graphical food	Journal	Y	Y	Y	Y	Health

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			frequency app (eNutri): Usability metrics from the EatWellUK study						
P33	Bhayana, R., et al.	2020	Sahayak: An Application for Social and Physical Well-Being for the Elderly	Conference	N	Y	Y	N	Health
P34	Fenu, C., & Pittarello, F.	2018	Svevo Tour: The Design and the Experimentation of an Augmented Reality Application for Engaging Visitors of a Literary Museum	Journal	P	Y	Y	Y	Museum
P35	Vitiello, G., & Sebillo, M.	2018	The Importance of Empowerment Goals in Elderly-Centered Interaction Design	Conference	P	Y	Y	P	Social
P36	Lindberg, R. S., & De Troyer, O.	2021	Towards an Up to Date list of Design Guidelines for Elderly Users	Journal	P	Y	N	P	Design Guidelines
P37	Salman, H. M., et al.	2018	Usability Evaluation of the Smartphone User Interface in Supporting Elderly Users from Experts' Perspective	Journal	Y	Y	N	Y	Usability Evaluation
P38	Balsa, J., et al.	2020	Usability of an Intelligent Virtual Assistant for Promoting Behavior Change and Self-Care in Older People with Type 2 Diabetes	Journal	Y	Y	Y	Y	Health
P39	Ubam, E., et al.	2021	User Interface/User Experience (UI/UX) Analysis & Design of Mobile Banking App for Senior Citizens: A Case Study in Sarawak, Malaysia	Conference	Y	Y	Y	Y	Finance
P40	Kim, H., et al.	2020	User-Dependent Usability and Feasibility of a Swallowing Training mHealth App for Older Adults: Mixed Methods Pilot Study	Journal	Y	Y	Y	Y	Health
P41	Kuo, M. H., et al.	2016	Using information and mobile technology improved elderly home care services	Journal	Y	Y	Y	Y	Health
P42	de Garibay, V. G., et al.	2016	Utility of a mHealth App for Self-Management and Education of Cardiac Diseases in Spanish Urban and Rural Areas	Journal	Y	Y	Y	Y	Health
P43	Aranyanak, I., & Charoenporn, P.	2020	UX-Based Design of A Mobile Application for Thai Seniors	Conference	Y	Y	Y	Y	Social

Fig 2 shows the number of publications from the year 2016 to 2021. The year 2020, shows the highest number of publications with 14 articles, the lowest number of publications was in 2016 and 2017 with 4 articles in each year, and 5 articles from 2018. 7 articles were found in the year 2019, and 9 articles in 2021. The studies of user experience in mobile applications among senior citizens are becoming popular research. This might be due to senior citizens' increased need for mobile applications. In addition, the study of UX in mobile application design among senior citizens will improve senior citizens' UX when using the mobile app and help them overcome the barriers with technology tools.

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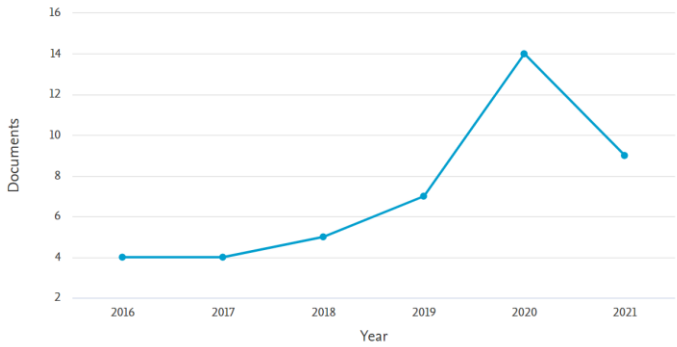

Fig.2. Numbers of publications vs years

IV. DISCUSSION

Nowadays, Mobile applications have some key benefits for senior citizens such as providing safety and security, healthcare, socializing, and entertainment which can improve the quality of life among seniors [22]. According to the findings in Table 4 above, UX has been used in various fields of mobile application design with elderly people, such as health, learning, entertainment, social, and so on. According to the data in Table 4, there are 24 articles about the theme of seniors' health, 4 articles talk about mobile application function, 3 articles are related to seniors' social activity, and in the area of learning, usability evaluation, entertainment, and design guidelines, each field has 2 articles, only 1 article in the theme of online shopping, exercise, museum, and finance area. Fig 3 shows that Health-themed apps appear the most frequently which reveals that health apps are the seniors care most about. There are 6 documents related to this research in Italy which country has the most numbers, the second is Spain, and then China, as shown in Fig 4. These countries all have serious aging problems such as baby boomers growing old, an increase in longevity, and a low birth rate [36].

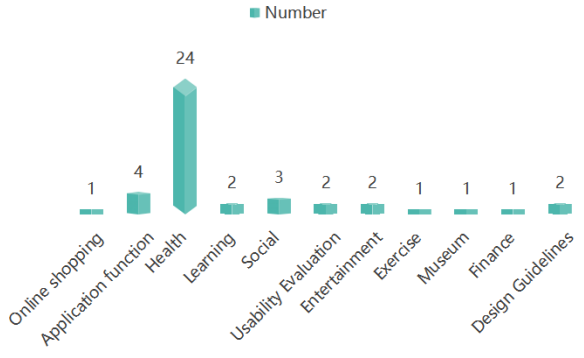

Fig.3. Numbers of theme in mobile application among senior citizens

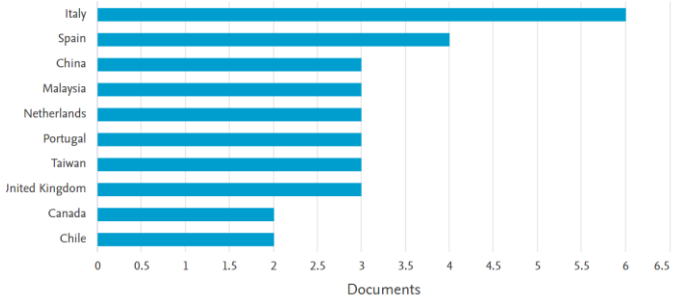

Fig.4. Numbers of documents by country

This section will also discuss the research questions put forward in section 2.1 earlier. Table 5 shows a list of Q1 and Q2 from the selected articles.

Table 5. List of Q1 and Q2 from the selected article

Paper ID	Theme	UX elements	Test approach
P1	Online shopping	Speech recognition technology	Not mention
P2	Application function	Unimodal interaction design	SUS
P3	Health	Gait monitoring, Phone registry monitoring	5-point Likert scale
P4	Health	Not mention	Not mention
P5	Learning	Instructional manual, Visual interface, Easy navigation	Not mention
P6	Social	Usability, User-friendliness	Not mention
P7	Health	Feasibility (Acceptability, Practicality, Implementation, Efficacy)	Not mention
P8	Health	Internal factors（Easy to learn and use, Quality, Function, Safety, Storage, Maintenance, Price); External factors (Color, Product experience, Product appearance, Friend recommendation)	Not mention
P9	Health	Ease of use	SUS, UEQ, Thematic analysis
P10	Application function	Multimodal form of notification (Visual, Vibration, Sound)	DIGCOMP, IMI, SUS
P11	Usability Evaluation	Not mention	SUS
P12	Application function	Gamification, Active notifications, Self-compassion	Structured interview
P13	Entertainment	Virtual community interaction	SAM, SUS, QUIS
P14	Health	Utility(Specific types of text, various icons to helpusers more easily keep track of their daily activities, Clarify instructions)	QUIS, PSSUQ
P15	Design guidelines	Visualization, Navigation, Communication, Support, Safety sense, Socialization of the system, Personalization of the system	Not mention
P16	Health	The ease of use, Usefulness, Acceptance, Quality	SUS, PSSUQ, UEQ
P17	Health	Voice reporting	SUS
P18	Learning	Initiative, Efficiency	Not mention
P19	Entertainment	Notification, Voice command	Cognitive walkthrough, SAM, Focus group
P20	Application function	Linear navigation	Eye tracker, Self-report questionnaires
P21	Health	Effectiveness	TAD
P22	Exercise	Usefulness, Satisfaction, Ease of use	A mixed-methods
P23	Health	Ease of use, Useful, Cost saving	SUS

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P24	Health	Simple, Easy to understand, Intergenerational support	Not mention
P25	Health	Not mention	DIGCOMP, SUS, Usability questionnaires
P26	Health	Convenience	SUS, AttrakDiff tool, W3C-WAI guidelines related to mobile, QUIS
P27	Health	Usability	ICF-US
P28	Health	Not mention	MOLD-US framework
P29	Health	Usability, Reliable, Ease to use, Useful	SUS
P30	Health	Useful, Ease to use	SUS
P31	Health	Feasibility	PROMIS
P32	Health	Usability	FFQ, SUS
P33	Health	Visuals, Language, Emergency services	Interview
P34	Museum	AR, Storytelling, Feasibility	Survey, a 5-point Likert scale
P35	Social	Decision-making, Self-management, Communication, Engagement	Capacity indicators
P36	Design Guidelines	Usability	Likert scale
P37	Usability Evaluation	Usability (appearance, language, dialogue, information)	SMASH, Nielsen scale
P38	Health	Intelligent virtual assistants	SUS
P39	Finance	Fast loading time, Security, Friendly UI elements	Closed-ended questions
P40	Health	Usability, Feasibility	SUS, mCSES, Semi-structured interviews
P41	Health	Feasibility, Efficiency	Interview
P42	Health	Utility	ANOVA
P43	Social	Usability(Effectiveness, Efficiency, Satisfaction)	MAZE, SUS

[Q1] What type of UX elements has been used most frequently among senior citizens in mobile application design?

There are approximately 8 articles from 43 selected articles showing "Usability" as the key words of UX elements in mobile application design among seniors which is P6, P27, P29, P32, P36, P37, P40, P43. P6 presents that the key aspects for seniors' high acceptance are usability and user-friendliness. P27 is about searching for mobile applications related to headaches, especially in content and usability, the result is in Portuguese that 3 mobile applications related to headaches are usability for seniors. P29 states that mobile application design should perform the analysis of the elderly physical condition as well as in an easy-to-use manner. P32 concludes that online apps have great potential for epidemiological challenges. P36 suggests that a more user-friendly AR such as smart glass might be needed for the new design guidelines among seniors. In P37 the results show that usability problems were grouped into four categories: appearance, language, dialogue, and information, it also indicates that improvements in the design of "elderly-friendly" interfaces would help seniors to reduce their reluctance of using smartphones. P40 is the first research about a swallowing training app to improve seniors' swallowing function, despite there being some early difficulties when seniors are using the app, later they expressed comfort with app usage, which highlights the potential of mHealth apps for seniors. Results in P43 present that the main usability metrics in this study are effectiveness, efficiency, and satisfaction. It also shows that it is better not to design too many functions in one app and most needed functions should be displayed on the first screen as well as avoid using a hamburger icon. The application for seniors should focus on their particular needs.

P7, P31, P34, P40, P41 mention about feasibility in mobile application design among seniors. P7 concludes that the app design with feasibility such as acceptability, practicality, implementation, and efficacy can provide a much-needed resource for better support caregivers of persons with dementia. P31 demonstrates feasibility of an inclusively designed mobile application for monitoring and management of seniors in clinical practice. P34 explores the relationship between AR technology and storytelling especially the feasibility of using AR in literary museums with adult and senior people. P40 is the first usability and feasibility study of a swallowing training app for seniors. P41 demonstrates that mobile communication technology is a feasibility and efficiency tool for improving seniors' home care services.

P14 and P42 point out the importance of utility in mobile application design. P14 makes some suggestions from both participants and examiners to add features to improve the utility of the DMN application to guide participants. New features for example, specific types of text, and various icons such as alarms and notifications help users more easily keep track of their daily activities, and clarify instructions to improve their understanding. P42 indicates that the evaluation of factors such as usage, utility, and effectiveness is vital to improve the mobile health apps for seniors.

[Q2] How to test the mobile application design among seniors?

Nielsen and Shneiderman [38] indicated that usability is part of "usefulness" and comprises the elements such as learnability, efficiency, memorability, error, and satisfaction. The approach to measuring usability includes the System Usability Scale (SUS) and the Questionnaire for User Interaction Satisfaction (QUIS) etc. There are 15 papers including P2, P9, P11, P13, P16, P17, P23, P25, P26, P29, P30, P32, P38, P40, P43 using the System Usability Survey (SUS) questionnaire for interaction design test. The QUIS is conducted using a seven-point Likert scale from "very dissatisfied" to "very satisfied". P13, P14, and P26 used this way to measure screen visibility, system information, learning factors, and system capabilities. The UEQ comprises 26 pairs of antithetic adjectives as a part of the question, which focuses on six aspects: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. For each aspect, the scale ranges from "most negative answer" to "most positive answer". The UEQ comprises a complete data analysis tool including a benchmark data set (www.ueqonline.org), which allows for a

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more sensible judgment about the product. P9 and P16 also use the User Experience Questionnaire (UEQ) for the usability test as well as perceive seniors' ease of using apps. Besides these Questionnaire approaches, P12, P33, P40, and P41 also use the interview to analyze the usability of the product.

V. CONCLUSION

Enhancing senior citizens' user experience when they are using the mobile application will surely improve their loneliness, life content, social support, quality of life, and other emotional responses. But most of the mobile application designs are not friendly to seniors. And have not fully considered senior citizens' mental health, psychological needs, and cognitive behavior changes [57]. This paper aims to review the user experience (UX) in mobile application design among senior citizens. There is clear evidence that good mobile application design can enhance seniors' user experience and well-being. The most commonly used application among seniors is the theme of "Health" compared to social, learning, entertainment, online shopping, exercise, museum, and finance areas. And it also identified "Usability"as the most frequently used UX element, especially user-friendliness. In addition, we should pay attention to the following frequent elements such as feasibility with acceptability, practicality, implementation, and efficacy, as well as utility to improve seniors' UX when they are using mobile apps. It is worth noting that AR technology has been suggested for mobile application design among seniors. To test the mobile application design among seniors, quantitative analysis is used more than qualitative analysis. Moreover among the quantitative method of SUS, QUIS, and UEQ, the commonly used research instrument to test mobile applications is "SUS". Hopefully, this paper can be a guide for research in the field to develop a better application for enhancing seniors' user experience when they are using the mobile application.

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