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Using SOR framework to explore the driving factors of older adults smartphone use behavior

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At a time when the population is aging and the digital divide among older adults is becoming increasingly prominent, the research on the smartphone use behavior of the older adult in China is slightly insufficient. Therefore, this study aims to develop a smartphone acceptance model for older adults in China to predict the factors of their behavioral intention to use smartphones. Using Stimulus-organism-response (SOR) theory as the framework, planned behavior theory, self-efficacy theory and technology acceptance model as the theoretical basis, and employed a mixed quantitative and qualitative research approach to analyze the data from 244 older adults using structural equation modeling. The results show that technology anxiety, subjective norms, self-efficacy, perceived usefulness, facilitating conditions, and perceived ease of use had significant effects on the behavioral intention smartphones among older adults. In addition, perceived usefulness was directly influenced by subjective norms and perceived ease of use, facilitating conditions significantly influenced perceived ease of use and self-efficacy, and subjective norms and self-efficacy significantly affect technology anxiety. This study expanded the applicability of SOR framework, further expanded the technology acceptance model, and enriched the theory of smart phone use behavior of older adults users. The results of this study provide a valuable theoretical framework for the study on older adults users' behaviors and have implications for the design and marketing of smartphones with high acceptancy from older adults.

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Introduction

Currently, many countries and regions around the world are already in the stage of population aging, such as Japan and China. In order to improve the quality of life, the use of smart technologies by older adults is gradually increasing (Ha and Park, 2020). The rapid development of information and communication technologies has contributed to the intelligence and mobile convenience of devices (Choudrie et al. 2020), and smartphones are one of the representatives. Smartphones are intelligent devices that incorporate smart technologies such as operating systems on the basis of cell phones (Mehra et al. 2022). According to the report released by the China Internet Network Information Center (2023), in 2022, the overall shipment of mobile phones in China's domestic market was 272 million, and as of December 2022, the scale of mobile Internet users in China was 1.065 billion, 36.36 million new mobile Internet users compared with December 2021, and the proportion of Internet users using mobile phones was 99.8%. However, not everyone is using smartphones, and older people who are less familiar with technology do not use smartphones as expected (Omotayo, 2018). As the report (China Internet Network Information Center, 2023) shows that the number of non-netizens in China is 344 million, among which the proportion of non-netizens aged 60 and above in the total number of non-netizens is 37.4%. Overall, despite the increasing use of smartphones and the Internet by older adults, previous studies have indicated that Internet use among older adults remains lower than among younger adults (Magsamen-Conrad et al. 2015). Therefore, it is necessary to pay attention to the older adult's use of mobile phones.

The convenience brought to users by using smart phones is countless. Smartphones have functions such as making phone calls, taking photos, and helping with office work (Xue et al. 2012). It also provides geospatial global positioning system data (Hswen et al. 2022). In the case of older adults only, previous studies have shown that smartphones can facilitate disease control (Bonoto et al. 2017), improve their sense of happiness (Khosravi et al. 2016), increase their social participation (Hardill and Olphert., 2012), and enhance their well-being and quality of life (Jun et al. 2021). However, although smartphones have many benefits, these benefits need to be maximized by making smartphones widely available to users at all levels. Currently, there are some barriers to the use of new technologies among older adults (Friemel, 2016), such as the lack of knowledge, fear of technology, low self-confidence, and lack of assistance (Guner and Acarturk, 2020). To this end, what factors drive smartphone use among older adults needs to be explored.

In recent years, much attention has been paid to the study of smartphone acceptance (Julsrud and Krogstad, 2020). For example, Fernández-Ardèvol and Prieto (2012) revealed that the educational level of older adults has an impact on their intention to use cell phones. Omotayo (2018) conducted a study on smartphone adoption among older Nigerians and found that most older Nigerians are not yet accustomed to using smartphones. Dobre et al. (2023) conducted a study on the continuous use of mobile branded apps by fashion retail users, and the results show the effects of cognitive value and application incentives on users' usage intention. Hsu et al. (2022) conducted a study on the intention of older adults to use their cell phones for application registration, and Rahardja et al. (2023) explored the ripple effect of Indonesian users' sentiment towards Go-Pay, a popular mobile payment application in Indonesia, and their intention to continue using it from the perspective of user experience, while the study by Morris and Venkatesh (2000) emphasized the age difference in technology adoption in their study. In addition, in previous studies, countries such as the United Kingdom, Australia or North American countries were mostly selected as representatives of

Western countries (Ashraf et al. 2021). In summary, most of the current studies emphasize demographic characteristics (such as education level, age), however, users' technology use behaviors are influenced by various factors, including the impacts of environments (Hoque and Sorwar, 2017). At present, there are fewer studies have systematically considered product, environmental, and user-level factors. In addition, much of the current research focuses on Western countries, and there is still insufficient attention to older adults users in China, the world's second largest economy, given its large older adults population and smartphone market. Therefore, there is a need for a more systematic study of smartphone use among older adults in China.

Stimulus-organism-response (SOR) theory (Mehrabian and Russell, 1974; Jacoby, 2002) provides a theoretical framework for the study of user behavior, which considers three important elements: stimulus, organism and response. The theory points out that the external environment incentive can stimulate the inner or perceptual state of the individual user, and then drive the individual behavior response. SOR serves as a research framework for exploring the underlying mechanisms of conceptual connections between studied constructs (Raj et al. 2023). It provides a scientifically sound sequencing mechanism for understanding the complexity of human behavior (Perez-Vega et al. 2021). SOR is one of the key theories to explain consumer behavior, and it has been widely used in the field of user behavior research (Song et al. 2022). Talwar et al. (2022) pointed out that this theoretical model is flexible and extensible, and can better reflect the broader research background of SOR framework, and SOR framework is applicable in capturing complex psychological processes of users (Talwar et al. 2022). Therefore, this study takes SOR theory as the research framework. In addition, The technology acceptance model (Davis, 1989) is a common theoretical model to predict the acceptance of new technologies among older adults (Guner and Acarturk, 2020; Dogruel et al. 2015). The technology acceptance model can be used as a basis to effectively explore the technology adoption behavior of older adults (Steele et al. 2009). However, Venkatesh and Davis (2000) point out that TAM is oversimplified and variables should be added depending on the study context. TAM needs to be extended to predict technology acceptance by users in depth (Martinez-Torres et al. 2015). As Yang et al. (2022a) points out, TAM is primarily used to test technology systems in workplace and organizational Settings, and may need to be adjusted when it is used to test technology usage intentions of older users. Therefore, the above theories need to be further clarified and validated in the research regarding the technology use behaviors of older adults users with smartphones as a technology object and an aging population.

To sum up, in the face of China's huge older adults population and smart phone market, it is urgent to build a smart phone acceptance model suitable for Chinese older adults on the basis of rich theories, so as to explore the factors affecting the intention of Chinese older adults to use smart phones. Therefore, this study uses SOR theory as the research framework, integrates technology acceptance model, planned behavior theory and self-efficacy theory, and construct a smartphone acceptance model for the older adults to predict the acceptance of smartphones among older adults. Using a mixed method of structural equation modeling and qualitative interviews, this study investigated the effects of perceived usefulness, perceived ease of use, technology anxiety, self-efficacy, subjective norms, and facilitating conditions on older adults' intentions to use smartphones from the dimensions of stimulus, organism and response. The model proposed in this study transforms the important variables in the technology acceptance model, planned behavior theory and self-efficacy theory into the relevant stimuli and organic states of the older

adult's smartphone use, and ultimately drives the response of the older adult's smartphone use intention. This study expands the applicability of SOR framework, and the empirical model is a further expansion of the technology acceptance model, providing a theoretical framework for older adults users' smartphone use behavior. The findings of this study can enrich the research on smartphone user behaviors among older adults and provide a reference for the sustainable development of smartphones.

Theory and hypothesis

Stimulus-organism-response (SOR) theory. Stimulus-organism-response (SOR) theory (Mehrabian and Russell, 1974; Jacoby, 2002) provides a theoretical framework for interpreting user behavior. The theory is that external stimuli drive the state of the internal organism, which in turn triggers a behavioral response from the user. That is, SOR's mechanism comes into play when an external stimulus induces an organism's internal psychology, which in turn triggers a behavioral response (Mehrabian and Russell, 1974). Sampat and Raj (2022) argue that SOR theory helps to evaluate the progressive thought processes of individual users when anticipating, internalizing, and acting on stimuli from the external world and internal cognition. The framework has been applied to e-commerce (Lin et al. 2021), instant messaging social software (Li et al. 2023), online shopping (Gong et al. 2022), and user adoption studies of mobile apps (Ashraf et al. 2021; Wu et al. 2021; Lee and Chen, 2022) and other areas. For example, Liu et al. (2023) used SOR theory to explore the impact of a series of external stimuli on consumer sentiment in mobile social commerce and their relationship with consumer behavior. This study believes that the older adult's smartphone use behavior is also influenced by external factors and corresponding emotional responses. Therefore, this theoretical framework provides a suitable basic framework for this study, which can provide insights into older adults users' smartphone use decision-making behavior.

This study uses SOR framework mainly for the following four reasons. First, SOR theory is widely used in user adoption studies of mobile apps (Ashraf et al. 2021; Wu et al. 2021; Lee and Chen, 2022). It is used in many fields such as retail, consumer behavior, online shopping, etc. (Huang, 2017). In other words, the applicability of SOR theory to people's understanding of the complexity of human behavior has been verified in many studies, so it is appropriate to study the smartphone use behavior of older adults. Second, the theory uses external environmental stimuli to influence internal individual psychological or cognitive states, shaping externally driven behaviors that are reflected in the individual's final choices and behaviors (Kumar et al. 2021). That is, the model provides a well-structured architectural perspective for understanding the effects of smartphone-related antecedents on the mental and cognitive states of the older adult, and subsequently on smartphone usage intentions. This is important for this study because it applies to the decision-making process of current smartphone technology products for older people. Third, considering that the mental process of the user is complex, the use of the smartphone is always subject to the user's emotions (Mehra et al. 2022), and the emotional or psychological factors of the internal state of the organism are supported by SOR theory (Jabeen et al. 2022). The applicability of the SOR framework in capturing the complexity of these mental processes (Talwar et al. 2021) makes it suitable for capturing the emotional or mental states of the older adult. Fourth, the SOR theory is flexible and extensible, and can better reflect the broader research context of the SOR framework (Talwar et al. 2021). It describes one-way causality between its components (Kumar et al. 2021), thus making it suitable for explaining users' positive or negative tendencies towards smartphone products.

Stimuli (S). A stimulus (S) is an external or environmental factor that affects a user's individual psychological or perceptual state (Fu et al. 2021). It is a ubiquitous indicator marker in the physical environment (Talwar et al. 2021). In SOR, stimuli (S) such as the external environment are the premise of a series of individual perceptions or psychological and behavioral production, and these stimuli can trigger the cognitive and emotional organism (O) within the user, and then trigger the behavioral response (R) of the user (Mehrabian and Russell, 1974). The theory of planned behavior in social psychology (Fishbein and Ajzen, 1975) is a theory that explores the relationship between behavior and psychology in order to clarify the key factors that affect behavior. The theory suggests that users' behavioral intentions are influenced by social factors such as subjective norms, and that older people's technology use may also be influenced by subjective norms. Thus, the expectations or behaviors of others can serve as motivators for individual behavior of users (Kim, 2021). In addition, in China, limited by education and social services system, some older adults lack the ability to use technology products or services (Ma et al. 2016). However, facilitating conditions such as technical resource support will limit and influence users' willingness to use technology (Cimperman et al. 2016). At the same time, there are inconsistencies in the conclusions about the influence of externally-induced variable facilitating conditions on users' behavioral intentions (Gopinath et al. 2022). Therefore, subjective norms and facilitating conditions are taken into account as stimuli in this study.

Subjective norms. The theory of planned behavior (Fishbein and Ajzen, 1975) in social psychology is an important theory that explores the relationship between behavior and psychology in order to clarify the key factors that influence behavior. It is widely used in the field of social behavior research, and subjective norms are an important variable in the theory of planned behavior, which is interpreted as the extent to which users are pressured by others or groups to adopt a behavior (Fishbein and Ajzen, 1975). This means that users will use a technology or product when they think it is useful, or when they do not like the technology or product, but important people around them think it is useful and should be adopted. Similarly, when others have strong expectations and beliefs about a user's behavior, the user will behave in a certain way according to the expectations and beliefs of others (Wang et al. 2016). Latimer and Martin Ginis (2005) pointed out that the predictive effect of subjective norms is particularly evident among users who show a higher fear of social disapproval. In Kim's (2021) psychological research on users' use of bitcoin, it is found that subjective norms have a significant positive impact on anxiety. In Rong's (2018) study on smartphone usage behaviors of migrant workers, the authors replaced "subjective norms" with "acquaintance influence", which is easily understood by the migrant workers' population. Through the valid data from 407 migrant workers, the study of Rong (2018) empirically demonstrated the effect of acquaintance influence on perceived usefulness. At the same time, Srinivasan (2015) found that subjective norms positively affect consumers' perception of the usefulness of online clothing shopping. In Liu et al. (2021) 's study on older adults's acceptance of mobile services, subjective norms have been confirmed to have a direct positive effect on behavioral intention of mobile services. The research of San-Martin et al. (2013) reveals the positive influence of subjective norms on the mobile shopping intention of potential mobile shoppers. Theodorou et al. (2023) pointed out that subjective norms have a significant direct impact on consumers' online shopping intentions during the epidemic period. In addition, Xue et al. (2012) showed that subjective norms had a direct positive effect on perceived usefulness and intention to use in an exploratory study of older

women's access to health information via cell phones. However, the effect of subjective norms on perceived usefulness and intention to use has not been significant in previous studies (Liebana-Cabanillas et al. 2014). Based on the inconsistent results of previous studies, and considering that current Chinese older adults were not born in the information age, it is suspected that they may have different perceptions about the perceived usefulness and use of new technologies such as smartphones. Furthermore, their perceived usefulness and adoption behaviors may be partially influenced by the opinions of important people in their lives, such as the influence of the views of family members or relatives and friends. Therefore, we defined subjective norms as the extent to which significant others believe that older adults should use smartphones (Fishbein and Ajzen, 1975). At the same time, it is believed that the views of important people such as family, relatives or friends around the older adult may affect the use of smart phones by the older adult. Therefore, it is assumed as follows:

H1: Subjective norms positively influence technology anxiety.

H2: Subjective norms positively influence older adults' perceived usefulness of smartphones.

H3: Subjective norms have a significant positive effect on older adults' intention to use smartphones.

Facilitating conditions. Facilitating conditions refer to the extent to which the resources users perceive that they own (e.g., at their disposal or provided by the organization) to support their use of the technology. Previous research (Ma et al. 2016) showed that facilitating conditions significantly influence perceived ease of use, and this variable is also positively correlated with users' intentions to use technology (Chen and Chan, 2014b). Li et al. (2019) study on the acceptance of smart wearable devices among older adults consumers found that facilitating conditions has a positive effect on perceived ease of use. Man et al. (2022) showed in the study on older adults's acceptance of Online mapping technology that facilitating conditions have a positive impact on perceived ease of use. Chaveesuk and Chaiyasoonthorn (2022) show that facilitating conditions directly affects students' perception of the ease-of-use of virtual learning systems. Similarly, Rokhim et al. (2022) revealed that facilitating conditions has a positive impact on perceived ease of use in the context of learning management systems as systems that support employee learning and development. Meanwhile, Hsu et al. (2022) showed that facilitating conditions were a significant predictor of behavioral intention in a study on the intention of older adults to use cell phone registration applications in Taiwan. A study by Sun et al. (2013) also showed a direct positive effect of the variable of facilitating conditions on the intention to use health services. In addition, previous studies on mobile commerce adoption in China (Chong, 2013) and social commerce in Malaysia (Momani et al. 2018) have both confirmed the important determining role of facilitating conditions in behavioral Intention. However, Yang et al. (2022a, 2022b) using meta-analysis showed that facilitating conditions had no effect on the intention to use smartphones. There is inconsistency in the findings of the effect of the exogenous variable of facilitating conditions on the endogenous variable of user behavioral intention (Gopinath et al. 2022), which needs to be further clarified. In addition, for self-efficacy, facilitating conditions also has a certain promoting effect. In the empirical study of iPad adoption, Kumi et al. (2012) found that facilitating conditions had a significant positive impact on consumers' computer self-efficacy. Dahri et al. (2023) 's research on mobile learning technology revealed the significant influence of facilitating conditions on mobile Self-efficacy. Wang and Chu (2023) confirmed the positive effect of facilitating conditions on self-efficacy. Similarly, Cardullo et al. (2021) studied the self-

efficacy of teachers in distance learning during the pandemic, and the results showed that facilitating conditions significantly affected self-efficacy. This study defines facilitating conditions as older adults having many personal or external resources to support their smartphone use. Therefore, in order to clarify the relationship between facilitating conditions and behavioral intention in the context of the use of smartphones by older adults, this study suggested that older adults users may perceive smartphones as easy to use when they have more resources to support their smartphone use, and they may also have the intention to use it. Therefore, the hypotheses were proposed below:

H4: Facilitating conditions positively affect the perceived ease of use of smartphones by older adults.

H5: Facilitating conditions positively affect the intention of older adults to use smartphones.

H6: Facilitating Conditions positively affect self-efficacy in older adults.

Organism (O). The organism is the perception or feeling of the individual user (Tandon et al. 2021) and the cognitive, psychological, and emotional state of the individual (Duong, 2023). It includes a wide range of contents, such as attitudes, beliefs, motives, cognitions, etc. (Jacoby, 2002). Individual users analyze the preceding environmental stimuli and use their cognition and emotion to consider the relevant information before responding to the stimuli externally (Sun et al. 2021). Previous research (Sun et al. 2021; Chou et al. 2022) pointed out that organism presents an individual's emotional, cognitive and psychological states. The user's mental state or needs are the result of external stimuli (Illeris, 2003). This study believes that some external factors will stimulate the older adult's perception and psychological feeling of smart phones. The organisms studied in this study include technology anxiety, self-efficacy, perceived ease of use, and perceived usefulness.

Self-efficacy. In the self-efficacy theory (Bandura, 1977), self-efficacy refers to the degree to which an individual estimates their ability to perform a given task. In other words, self-efficacy can be used to assess how easy it is for a user to perform a task using technology (Purnomo and Lee, 2013). It is one of the important predictors of users' behavioral activities (Bandura, 2006) and needs to be considered in the study of older users. In a smart environment, self-efficacy is important because it links older users' efforts with external help to make better use of technology.

The role of self-efficacy has been confirmed in previous studies. Users with low self-efficacy feel anxious because they think they are incompetent (Awofala et al. 2019). Hong et al. (2015) pointed out that user self-efficacy has a significant negative correlation with Competitive anxiety. Liu et al. (2022) found a negative correlation between users' self-efficacy and anxiety in the study of obstacles to face recognition technology. Bandura (1988) pointed out that enhancing self-efficacy can reduce users' anxiety. Chen et al. (2018) pointed out that the older adult in Taiwan generally have a high sense of self-efficacy, for which they have a high liking for mobile phone technology and a relatively low sense of anxiety. Similarly, studies have shown that older users who have high self-efficacy are more likely to perceive the ease of use and usefulness of smartphones (Scott and Walczak, 2009). The direct positive effect of self-efficacy on users' perceived usefulness and perceived ease of use was confirmed in the studies by Abdullah et al. (2016) and Zheng et al. (2020). Zhu et al. (2022) investigated the perception and use of smartphones among older adults in China and found that self-efficacy had a direct and significant positive effect on perceived usefulness and perceived ease of use. In a review of 107 articles, Abdullah and Ward (2016) pointed out

that self-efficacy has a strong influence on perceived usefulness, and self-efficacy is the best predictor of perceived ease of use. The TAM model expanded by Zheng and Li (2020) confirms the positive impact of self-efficacy on perceived usefulness and perceived ease of use. In addition, Rokhim et al. (2022) 's study on employees' acceptance of learning management system confirmed that employees' self-efficacy has a significant positive effect on perceived usefulness and perceived ease of use. Chaveesuk and Chaiyasoonthorn (2022) explored the use of virtual learning system cloud classroom by Thai students, and the results showed that students' computer self-efficacy had a significant impact on perceived usefulness and perceived ease of use. Doan's (2021) study confirmed that users' self-efficacy has a direct and significant impact on perceived usefulness and perceived ease of use.

High self-efficacy will bring some confidence and satisfaction to technology users and improve users' usage intentions (Rahmi et al. 2021).The significant effect of perceived self-efficacy on technology adoption has been confirmed in previous studies (Beh et al. 2021; Kim and Ho, 2021). Gopinath et al. (2022) showed a positive correlation between self-efficacy and users' behavioral intention to use in a study on the application of meta-analysis to the factors of wearable devices for health promotion. Dash et al. (2022) conducted a multi-group analysis in a transnational context, and the results showed that self-efficacy enhanced the e-learning intention of teacher-student users. In addition, Doan (2021) studied and confirmed the direct impact of self-efficacy on behavioral intention. In this study, self-efficacy was defined as the degree to which older adults believe they have confidence in the use of smartphones, and it is believed that when the older adult users have high confidence, their intention to use smart phones will increase. Therefore, the following hypotheses were proposed:

H7: The high self-efficacy of the older adult has a direct and significant impact on technical anxiety.

H8: Self-efficacy of older adults has a direct positive effect on their perceived usefulness of smartphones.

H9: Self-efficacy of older adults has a direct positive effect on their intention to use smartphones.

H10: Self-efficacy of older adults has a direct positive effect on their perceived ease of use of smartphones.

Technology anxiety. Anxiety is defined as a state of mind in which users worry about future difficulties or threats (Freeman and Leaf, 1989). Technology anxiety is an emotion in which users feel fearful and have negative attitudes towards a technology or product when using it (Hasan and Ahmed, 2010). It is also known as technophobia (Gilbert et al. 2003). Users' fear of technology may limit their acceptance of new technologies (Zheng and Li, 2020). Parasuraman (2000) noted that while there are users who are enthusiastic about technology, there are also those who are fearful and resistant toward technology. Technology anxiety is used to explore the psychological state of users' abilities and intentions to use technology (Meuter et al. 2003). It is often considered as an antecedent of technology acceptance models (Abdullah and Ward, 2016) and can be used to study the acceptance of smartphones among older adults (Zhu and Cheng, 2022). Older adults have less confidence in the use of technological products due to age and cognitive deterioration (Deng et al. 2014), and they have less ability to use technology than younger adults (Czaja et al. 2006). Therefore, technology anxiety is considered as one of the barriers to technology adoption among older adults (Moehr et al. 2006). It is an aging factor associated with behavioral intention (Xue et al. 2012).

In a study by Hoque et al. (2017) on older adults' intention to use mobile health services, technology anxiety, as the most important variable, had a significant negative effect on their

behavioral intention to adopt healthcare in Bangladesh. Hsu and Peng (2022) conducted a study on the intention of the older adult to use mobile phones to register applications, and the results showed that the technical anxiety of the older adult would have a significant negative impact on their intention to use mobile phones to register applications. The research of Hoque and Sorwar (2017) shows that technology anxiety, as an important factor, has a significant negative impact on the behavioral intention of older adults users in mobile medical service. At the same time, Lim et al. (2011), in a study on women's acceptance of using mobile phones to seek health information, showed the significant impact of technology anxiety on their behavioral intentions. In addition, technology anxiety was proved to have a significant impact on the perception of technology usefulness and ease of use in both Jun et al. (2021) and Zhu and Cheng (2022). In Guo et al. (2013) 's study on mobile health service adoption among older adults users, technology anxiety has been confirmed to have a negative effect on perceived ease of use. In the wearable cardiac warming system behavior study conducted by Tsai et al. (2020), it is pointed out that technology anxiety has a significant negative impact on the perceived ease of use of older adults in general. Heerink et al. (2010) showed a negative correlation between anxiety and perceived ease of use among older adults users. Therefore, in this study, technology anxiety is interpreted as the emotional attitude of older people who are afraid of smartphones when using them, and this study suggested that when older adults hold negative anxiety about smartphones, it may negatively affect their perception and adoption of smartphones. Therefore, the following hypotheses were proposed:

H11: Technology anxiety has a negative significant effect on the usefulness of smartphones.

H12: Technology anxiety has a negative significant effect on the intention to use smartphones among older adults.

H13: Technology anxiety has a negative significant effect on the perceived ease of use of smartphones.

Perceived ease of use. Perceived ease of use refers to the degree to which a particular technology is effortless or easy for consumers to use (Davis, 1989). In the proposed technology acceptance model (Davis, 1989), perceived ease of use is an important perceived factor that has a direct impact on the user's perception of the usefulness of the technology. In a study by Lee (2019) on the intention to use mobile devices among older adults in Korea, the use intention behavior was indicated to be directly determined by perceived ease of use, with perceived ease of use positively influencing perceived usefulness. The positive relationship between ease of use and use intention has also been verified in a previous study (Talukder et al. 2019). In addition, Sajid et al. (2022) investigated the influencing factors of consumers' online purchase behavior during the COVID-19 epidemic, and the results showed that perceived ease of use had a significant positive impact on consumers' online purchase intention. Chan et al. (2022) confirmed that perceived ease of use has a direct and significant impact on Malaysian consumers' mobile shopping intentions. However, the relationship between perceived ease of use and perceived usefulness has been found to be different in different studies. Liu et al. (2021) confirmed that older adults's perception of ease of use of mobile services has a significant impact on perceived usefulness. The study of Gopinath et al. (2022) showed that perceived ease of use was a valid predictor of perceived usefulness. In contrast, the study of Vongurai (2020) showed no direct effect between them. Therefore, it is necessary to clarify the relationship between the three dimensions of perceived ease of use, perceived usefulness, and behavioral intention in the context of smartphone use among older adults. This study interprets perceived ease of use as older people believing that

using a smartphone is effortless. Therefore, this study believes that in the face of the technology product of smart phones, when the older adult perceive the ease of use of mobile phones, their perception of the usefulness of smart phones and their intention to use them may increase. It is therefore proposed that:

H14: Perceived ease of use has a significant positive effect on the perceived usefulness of smartphones.

H15: Perceived ease of use has a significant positive effect on older adults' intention to use smartphones.

Perceived usefulness. The development of information technology has, to some extent, given rise to the development of user technology acceptance theories such as the technology acceptance model (Davis, 1989). The technology acceptance model proposed by Davis (1989) specifies the predictive utility of perceived usefulness and perceived ease of use for user technology acceptance. This model has been widely used in the fields of websites (Smith, 2008) and applications (Cho, 2016), and is a common theoretical model for predicting the acceptance of new technology use by older adults (Guner and Acarturk, 2020). Many previous studies (Lee, 2019; Gopinath et al. 2022; Cho, 2016) have shown a significant positive effect of perceived usefulness on users' technology use intention. At the same time, Liu et al. (2021) pointed out that perceived usefulness has a positive impact on the behavioral intention of the older adult in mobile service behavior. Chan et al. (2022) showed that Malaysian consumers' mobile shopping intention is directly affected by perceived usefulness. Mehra et al. (2022) confirmed that consumers' usage intention of the latest version of android smartphone will be positively affected by the perceived usefulness. In addition, Lee's (2019) study on the intention of the older adult to use mobile devices in South Korea also shows that the behavioral intention of the older adult to use mobile devices is positively influenced by perceived usefulness. Maduku and Thusi (2023) confirmed the positive effect of perceived usefulness on mobile shopping continuance intention through 437 South African consumers. Wang et al. (2021) revealed the positive impact of perceived usefulness on behavioral intention in Social Commerce. This study interprets perceived usefulness as older people believing that the use of smartphones is

helpful for their life and work. Therefore, this study believes that in the face of the technology product of smart phones, when the older adult perceive the usefulness of mobile phones, their use intention may increase. It is therefore proposed that:

H16: Perceived usefulness positively influences older adults' intention to use smartphones.

Response (R). Floh and Madlberger (2013) and Sultan et al. (2021) define "response" as the behavioral intention presented by an individual user based on cognitive and emotional responses. It is the result that individual users get from the organism (Perez-Vega et al. 2021). It includes the behavioral intention to approach or avoid. Actions or intentions, whether approaching or avoiding, can be considered reactive content (Sherman et al. 1997). Jacoby (2002) pointed out that when the user has a perceptual response under the influence of the external environment, the user will have a positive or negative behavior. In the current era of digital intelligence, the use of smartphones is particularly important for individual users to carry out daily life activities and participate in society (Pan and Jordan-Marsh, 2010), while non-use of smartphones may lead to situations such as digital exclusion (Zhu and Cheng, 2022). Therefore, in this study, intention refers to the willingness of older people to use smartphones. The research regards the user's smartphone usage intention as a response, which is the result of the emotion and cognition of the older adult. In other words, this study examined the smartphone usage intentions of the older adult.

In summary, this study proposed a conceptual model as shown in Fig. 1, which has 7 variables and 16 research hypotheses. The model proposed in this study transforms the important variables in the technology acceptance model, planned behavior theory and self-efficacy theory into the relevant stimuli and organic states of the older adult's smartphone use, and ultimately drives the response of the older adult's smartphone use intention.

Methods
Respondents. The interviewees for this study were older adults aged 60 years old or older who were able to travel independently.
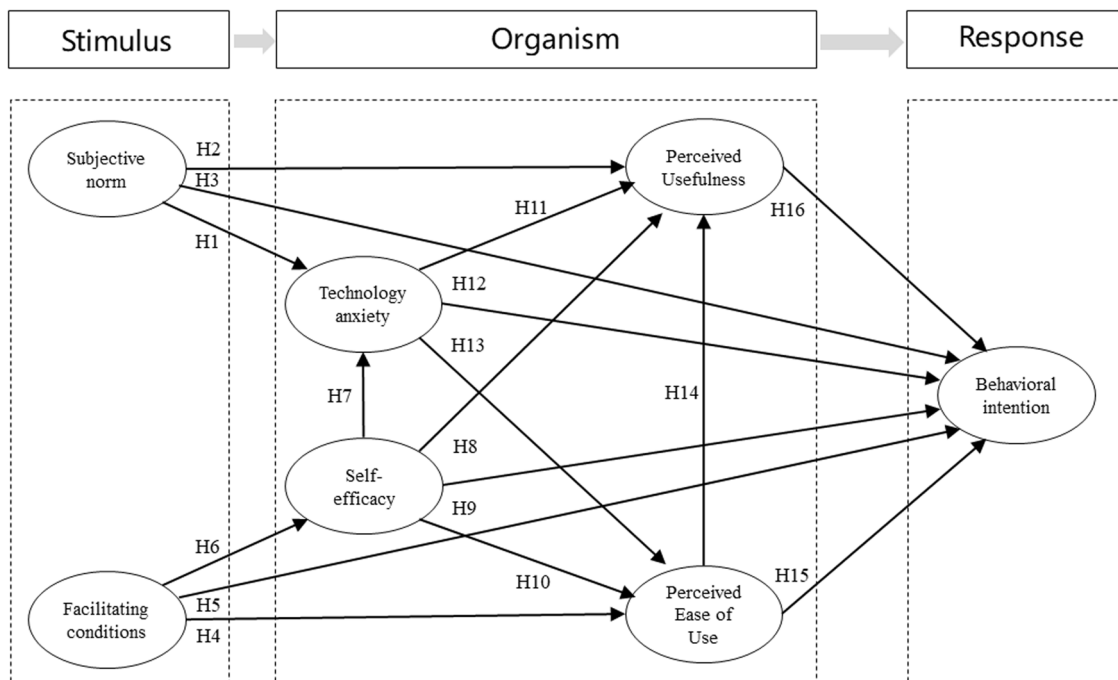

Fig. 1 The proposed conceptual model. This model providing a theoretical framework for older adults users' smartphone use behavior.

Table 1 Basic information of interviewee ($N = 244$).

Profile	Items	Number	Percentage(%)
Gender	Male	131	53.7
	Female	113	46.3
Age	60~64	55	22.5
	65~69	80	32.8
	70~74	56	23.0
	75~79	35	14.3
	≥80	18	7.4
Education	Elementary school or lower	81	33.2
	Junior high school	86	35.2
	High school	61	25.0
	Graduate and above	16	6.6
Smart phone usage experience	No experience at all	37	15.2
	0~1	84	34.4
	1~2	71	29.1
	2~3	35	14.3
	≥3	17	7.0

The interviewees were all from China. The researchers used purposive sampling method to recruit respondents. The interviewees were informed of the purpose of this study and introduced to smartphones after being selected by the researchers. Afterwards, the interviewees' verbal consent was obtained before their filling out of the paper questionnaires. For the interviewees with low vision and low literacy, the researchers read the questionnaire questions aloud to them and checked the answers for them according to their responses. After the respondents completed the questionnaire, the researchers conducted the recruitment of semi-structured interview respondents, taking into account the principle of voluntalization and respecting the personal time and energy of the respondents.

A total of 266 questionnaires were collected from the interviewees in this study. After the invalid questionnaires were removed, 244 valid questionnaires remained, with a validity rate of 92.075%. The information on the interviewees is shown in Table 1. As see, there were more males (131) than females (113). More than 30% of the interviewees were 65–69 years old and most of them were 60–69 years old. Among all interviewees, 86 interviewees received a junior high school education, 81 interviewees had an elementary school education or lower, and 25% had a high school education. In addition, in terms of smartphone usage experience, the majority of older adults had 0-1 years of experience, with 34.4%; 71 had 1-2 years of experience; 17 had more than 3 years of experience; meanwhile, 37 interviewees said they had no experience with smartphones. Moreover, after completing the questionnaire, 11 interviewees were interviewed semi-structurally, 5 of them were males and 6 of them were females, and all of them indicated that they had experience in using smartphones.

Measurements Scales. In order to obtain a more comprehensive verification of the drivers of older adults's smartphone use proposed in this study, the mixed method of questionnaire survey and semi-structured interview was adopted for data collection. The questionnaires were adapted from previous studies with the themes of this study, as shown in Table 2. The part of subjective norms was adapted from Fishbein et al. (1975); technology anxiety from Hsu et al. (2022); perceived usefulness and perceived ease of use from Davis (1989) and Venkatesh et al. (2003); facilitating conditions and behavioral intention from Venkatesh et al. (2012); self-efficacy from Compeau et al. (1995). The questions for all variables were measured with a 7-point Likert scale, scale from 1 (totally disagree) to 7 (totally agree). Of course,

we also collected personal information about the older adult, namely gender, age range, educational level, and experience with smartphones. In order to make the questionnaire understandable to the interviewees, the researchers administered a pre-test to three interviewees prior to the formal questionnaire, and refined and replaced a few words in the questions based on their comments. In addition, in order to further understand the real thoughts of the interviewees and verify whether the driving factors proposed before are reasonable, this study also conducted semi-structured interviews after the interviewees filled in the questionnaire. In addition to taking into full account the actual situation of the older adult interviewees' time and energy, the interview was conducted in full compliance with the principle of voluntary and initiative of the older adult interviewees. Semi-structured interviews were conducted to understand the users' real thoughts on smartphones, and their responses were recorded by the researchers for three main questions, which were specifically: (1) What problems do you encounter in using smartphones or smart devices? (2) What kind of smartphones do you like? (3) What was the reason that motivated you to use your smartphone last time?

Data Analysis. In this study, SPSS Statistics 25.0 was used to analyze the data for missing values, descriptive statistics, and internal consistency reliability. In addition, considering that partial least squares structural equation modeling can analyze models dealing with complexity (Hair et al. 2012), which is suitable for theoretical test analysis (Hair, 2009). At the same time, it does not have strict requirements on the distribution of the study data (Hair et al. 2021). Therefore, this study applied the partial least squares structural equation modeling for model evaluation and validation of research hypotheses.

Common Method Bias. Common method bias is a problem to be considered in this study. Therefore, the common method deviation problem is controlled and detected in this study. First, use concise language to describe the questions, and anonymously ask respondents to fill out the questionnaire to reduce common methodology bias. At the same time, we conducted a Harman single factor analysis (Podsakoff et al. 2003) based on the suggestion of Podsakoff et al. (2003), and the results show that the single factor interpretation rate was 42.876%, which is less than the criterion of 50% (Podsakoff et al. 2003), indicating that there was no common method bias in this study (Lavuri et al. 2022).

Results
Questionnaire results
Measurement model. Table 2 shows the loading values of the measurement indicators, which ranged from 0.791–0.908, higher than the threshold of 0.7 suggested by Fornell and Larcker (1981a), indicating that the measurement questions had good reliability. As shown in Table 3, the minimum value of Cronbach's alpha of all variables was 0.752, which also met the criterion of greater than 0.7 (Anderson and Gerbing, 1988). The composite reliability was 0.858–0.922, which met the criterion of higher than 0.7 (Nunnally, 1994). The average variance extracted (AVE) of the variables ranged from 0.668–0.796, which exceeded the recommended value of 0.5 (Nunnally, 1994), indicating the convergent validity of the current study. Following the suggestion of Fornell and Larcker (1981b), we assessed the discriminant validity of this study. The results of Table 3 show that the square root of AVE for all variables was greater than the correlation coefficient among variables, which indicates that the variables of the model had good discriminant validity. In addition, according to Table 4, the HTMT values of all the constructs were less than

Table 2 Question and loading.

Construct (Sources)	Question	Loading
Perceived usefulness (Davis 1989; Venkatesh et al. 2003)	1. Using a smartphone makes my life more convenient.	0.861
	2. Using a smartphone allows me to get some useful information.	0.860
	3. Using a smartphone enriches my life.	0.851
Subjective norm (Fishbein and Ajzen 1975)	1. My family thinks I should use a smartphone.	0.881
	2. My friends think I should use a smartphone.	0.867
	3. My neighbors think I should use a smartphone.	0.883
Technology anxiety (Hsu and Peng 2022)	1. Using a smartphone makes me nervous.	0.881
	2. Using a smartphone makes me worry.	0.824
	3. Using a smartphone bothers me.	0.900
Perceived ease of use (Davis 1989; Venkatesh et al. 2003)	1. I think the operation of the smartphone is simple.	0.880
	2. I think learning to use a smartphone is easy.	0.855
	3. I find it easy to use a smartphone.	0.838
Facilitating conditions (Venkatesh et al. 2012)	1. I have the necessary resources to use my smartphone.	0.791
	2. When I have trouble using my smartphone, I can get help from others.	0.792
	3. I can get technical support using my smartphone.	0.867
Behavioral intention (Venkatesh et al. 2012)	1. I will try to use a smartphone.	0.907
	2. I plan to use a smartphone.	0.875
	3. I will recommend others to use the smartphone.	0.895
Self-efficacy (Compeau and Higgins 1995)	1. Although I have never used a smart phone before, I think I will use it.	0.869
	2. I think I can use a smartphone without any help.	0.792
	3. If there is a manual, I will use a smartphone.	0.884
	4. If I had someone to guide me, I would use a smartphone.	0.908

Table 3 Construct reliability and validity.

Variables	α	CR	AVE	BI	FC	PEOU	PU	SE	SN	TA
BI	0.872	0.921	0.796	**0.892**						
FC	0.752	0.858	0.668	0.552	**0.817**					
PEOU	0.820	0.893	0.736	0.647	0.498	**0.858**				
PU	0.820	0.893	0.735	0.621	0.425	0.552	**0.857**			
SE	0.887	0.922	0.748	0.599	0.535	0.508	0.654	**0.865**		
SN	0.850	0.909	0.769	0.581	0.485	0.575	0.533	0.601	**0.877**	
TA	0.843	0.905	0.760	0.202	0.229	0.232	0.224	0.527	0.381	**0.872**

Note. The value in bold is the square root of the average variance extracted for all variables.

Table 4 Heterotrait monotrait ratio.

Variables	BI	FC	PEOU	PU	SE	SN	TA
BI							
FC	0.675						
PEOU	0.765	0.625					
PU	0.733	0.528	0.673				
SE	0.674	0.643	0.586	0.764			
SN	0.675	0.605	0.690	0.638	0.683		
TA	0.228	0.284	0.267	0.264	0.607	0.442	

0.9 (Teo et al. 2008), which also confirmed the discriminant validity of the variables. In conclusion, this study confirmed the good reliability of the measurement model through confirmatory factor analysis.

Structural model. Chin (1998) stated that the predictive power of the model can be assessed by the cross-validated redundancy index (Q^2) of endogenous variables, and a Q^2 value greater than 0 indicates the predictive relevance of the structural model for endogenous variables. In this study, the Q^2 value for behavioral intention was 0.456, for perceived ease of use was 0.235, and for perceived usefulness was 0.374, the Q^2 value of self-efficacy was 0.208, the Q^2 value of technical anxiety was 0.206, which indicate that the predictive power of the model was good. The explanatory power of the model can be assessed by the coefficient of

determination R^2 (Keil et al. 2000), which represents the amount of variance explained by exogenous variables (Kline, 2015). As shown in Fig. 2, the R^2 of the variable of behavioral intention in this study was 0.589, the R^2 for perceived ease of use was 0.520, the R^2 for perceived ease of use was 0.330, the R^2 of technical anxiety was 0.284, and the R^2 for self-efficacy was 0.286. which indicated that the model has better explanatory power. Goodness of Fit is used as an indicator to evaluate the fit of the model. When the GOF exceeds 0.36, the model has a high fit (Tenenhaus et al. 2005). The calculated Goodness of Fit in this study is 0.547, which has reached the standard of high compatibility. In addition, Tenenhaus et al. (2005) pointed out that when the Standardized Root Mean Square Residual (SRMR) was lower than 0.080, it also indicated that the model had good compatibility. The SRMR value of the model in this study is 0.060, which meets the standard. In summary, the model in this study has a high fit.

In this study, the significance of the path coefficients was checked by applying the bootstrapping method, and the results are shown in Table 5. The results show that out of the 16 research hypotheses proposed in this study, 14 research hypotheses were validated and two research hypothesis was not supported. Among them, Subjective norms positively influenced older adults' perceived usefulness ($\beta = 0.134$, t = 2.172, $p < 0.05$) and use intention ($\beta = 0.145$, t = 2.744, $p < 0.01$) of smartphones, so H2 and H3 were valid. However, the influence of subjective norms on technical anxiety was not significant ($\beta = 0.101$, t = 1.403, $p = 0.161$), so H1 was not established. Facilitating conditions
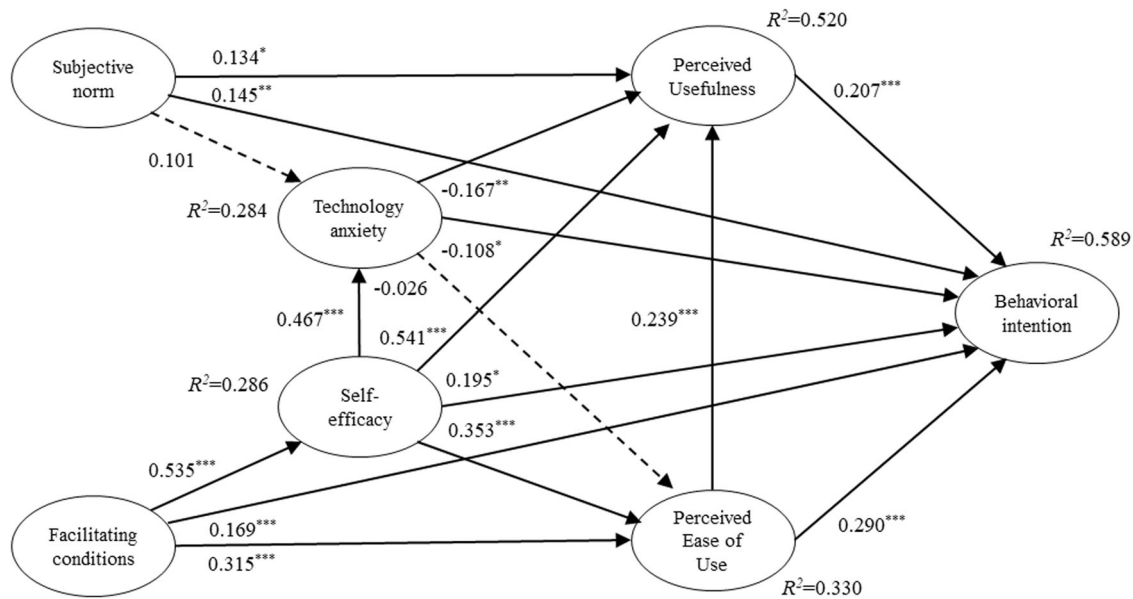
Fig. 2 Results of model analysis. It explored the effects of technology anxiety, subjective norms, perceived usefulness, facilitating conditions, perceived ease of use, and self-efficacy on older adults' intention to use smartphones.

Table 5 Hypothesis validation results.

Code	Path	β	t -Value	p -Value	Outcome
H1	SN - > TA	0.101	1.403	0.161	Unsupported
H2	SN - > PU	0.134	2.172	0.030	Supported
H3	SN - > BI	0.145	2.744	0.006	Supported
H4	FC - > PEOU	0.315	4.142	0.000	Supported
H5	FC - > BI	0.169	3.857	0.000	Supported
H6	FC - > SE	0.535	9.997	0.000	Supported
H7	SE - > TA	0.467	6.178	0.000	Supported
H8	SE - > PU	0.541	8.128	0.000	Supported
H9	SE - > BI	0.195	2.452	0.014	Supported
H10	SE - > PEOU	0.353	4.038	0.000	Supported
H11	TA - > PU	−0.167	3.009	0.003	Supported
H12	TA - > BI	−0.108	2.352	0.019	Supported
H13	TA - > PEOU	−0.026	0.379	0.705	Unsupported
H14	PEOU - > PU	0.239	4.185	0.000	Supported
H15	PEOU - > BI	0.290	4.874	0.000	Supported
H16	PU - > BI	0.207	3.321	0.001	Supported

positively influenced older adults' perceived ease of use ($\beta = 0.315$, $t = 4.142$, $p < 0.001$), self-efficacy ($\beta = 0.535$, $t = 9.997$, $p < 0.001$), and use intention ($\beta = 0.169$, $t = 3.857$, $p < 0.001$) of smartphones, so H4, H5 and H6 were found to be valid. Self-efficacy had a direct positive effect on older adults' perceived usefulness ($\beta = 0.541$, $t = 8.128$, $p < 0.001$) and ease of use ($\beta = 0.353$, $t = 4.038$, $p < 0.001$), as well as use intention ($\beta = 0.195$, $t = 2.452$, $p < 0.05$) of smartphones. Therefore, H8, H9, and H10 were all established. Similarly, the effect of self-efficacy on technical anxiety was also significant ($\beta = 0.467$, $t = 6.178$, $p < 0.001$), so H7 was supported. The negative effect of older adults' technology anxiety affected their perceived usefulness ($\beta = -0.167$, $t = 3.009$, $p < 0.01$) and use intention ($\beta = -0.108$, $t = 2.352$, $p < 0.05$) of smartphones, so H11 and H12 were established. However, older adults' technology anxiety did not significantly affect perceived ease of use ($\beta = -0.026$, $t = 0.379$), and H13 was not supported. Perceived ease of use was shown to have a direct positive effect on perceived usefulness ($\beta = 0.239$, $t = 4.185$, $p < 0.001$) and use intention of smartphones among older adults ($\beta = 0.290$, $t = 4.874$, $p < 0.001$), so H14 and

H15 were supported. Furthermore, the results also show that perceived usefulness had a direct positive effect on the intention to use smartphones among the older adult ($\beta = 0.207$, $t = 3.321$, $p < 0.001$), so H16 was supported.

Interview results. This study attempted to understand what older adults think about smartphones through three questions (Table 6). In response to the question "What problems have you encountered in using smartphones or smart devices?", older adults mostly expressed problems with smartphone operation, their own abilities and experience, and the confusion of having no one to guide or help them. For example, Interviewee 2 (male) said, "Because of my lack of experience, I often make mistakes, such as confusing the volume buttons with the on/off button". Interviewee 6 (female) said: "I can't read. If my daughter could spend more time teaching me, then I would be able to use the phone faster than now. But she is too busy and now I rarely use the phone". In response to the question of "What kind of smartphone do you like?", interviewees were mostly concerned with the operation of the phone itself, its features, and guidelines. For example, one interviewee said, "The operation of cell phones is still a bit complicated nowadays. I prefer simple operation" (Interviewee 4, female); another interviewee said, "I would like to have a phone that is not too complicated and takes into account the situation of the older adult" (Interviewee 5, male). In response to the question "What was the reason that motivated you to use your smartphone last time?", the interviewees expressed that they missed their family and friends, and they were influenced by their family. For example, Interviewee 6 (female) stated that the reason for using a smartphone was to look at her daughter's photos; Interviewee 10 (male) stated: "I want to try using my cell phone when I see all the older adult in my neighborhood watching videos and listening to operas on their phones".

Discussion
This study constructed a smartphone acceptance model for older adults based on the theories, such as the theory of planned behavior, self-efficacy theory, and technology acceptance model, and applied structural equation modeling to empirically validate the theoretical framework. This study showed that technology

anxiety, perceived ease of use, facilitating conditions, subjective norms, perceived usefulness, and self-efficacy were effective predictors of older adults' intention to use smartphones. The explanatory power of the model reached 58.9% and the model fit was good. This study further extended the technology acceptance model and enriched the acceptance theory of older adults users, and the results can be used as a reference for academic research and the practice of smartphones.

This study showed that technology anxiety had a negative significant effect on perceived usefulness, a finding that has been confirmed in previous studies(Zhu and Cheng, 2022). This study did not find a negative significant effect of technology anxiety on perceived ease of use, a finding that was also confirmed in the study of Xue et al. (2012). However, this finding differs from that of Zhu et al. (2022), possibly because more than half of the interviewees in that study were 50–59 years old, whereas all of our interviewees were over 60 years old, and older adults may have difficulty perceiving the usefulness of smartphones. After all, older adults have a more severe loss of sensory and motor systems, and they experience more confusion when using new technologies (Phang et al. 2006). As our interviewee stated: ""I'm over 70 years old, my eyes are dizzy, I'm at home and in the neighborhood almost every day, so I don't think the phone is useful for me" (Interviewee 7, male)". Furthermore, our findings showed that technology anxiety had a negative significant effect on the intention to use smartphones among older adults, which is consistent with the findings of (Hoque and Sorwar, 2017). This suggested that the interviewees in this study had anxiety about using smartphones and they may possess lower skills in smartphone use. After all, technology anxiety arises as a result of the user's lack of experience with effective control of technology (Oyedele and Simpson, 2007). The interviewees stated, "I only started to learn how to use my smartphone three months ago, so I am not familiar with many operations and I am always afraid of pressing the wrong button (Interviewee 3, female)" and "Because of my lack of experience, I often make mistakes, such as confusing the volume buttons with the on/off button (Interviewee 2, male) ". Technology anxiety as a negative feeling and response of the user is related to the fear or anxiety they feel when using technology (Hoque and Sorwar, 2017). Therefore, reducing the discomfort of older adults users using smartphones is something to be urgently considered. For example, in terms of smart phone design functions, you can set up voice functions and other human-computer interaction methods, give the older adult instructions on mobile phone use, add user guidance videos in smart phones, carry out large key design and large size display design, set one-button operation in smart phones or simplify the operation steps, so as to reduce the anxiety of the older adult on the use of mobile phones and increase their perception of the usefulness and use intention of smartphones.

Subjective norms in the theory of planned behavior are an important variable that influences user technology adoption. The results of our questionnaire indicate that the variable of subjective norms had an impact on older adults' perceived usefulness and use intention of smartphones. Also, our interviewee noted: "I saw that my friend was using her smartphone very conveniently, so I went home and used my son's phone to experiment with it. Then, I could immediately see my grandson who was away at school through WeChat. This was amazing (Interviewee 9, female)". This indicated that our older adults interviewees' smartphone usage behavior was influenced by personal or group perceptions such as friends and family members. The direct effect of subjective norms on perceived usefulness and behavioral intention has also been confirmed in previous studies (Xue et al. 2012; Zhang et al. 2019). Hsiao's (2015) study also indicated that subjective norms influenced older users' smartphone use behaviors. As our interviewee stated: When I see old people in my neighborhood watching videos and listening to operas on their smartphones, I would like

to try using the cell phone, too (Interviewee 10, male). Previous research (Blok et al. 2020) has also shown that older people may not be able or need to use technology such as mobile phones, but the people around them can influence their intention to use mobile phones. So to speak, the utility of the social influence of subjective norms highlights the collectivistic nature of Eastern cultures (Zhao et al. 2021). Therefore, based on the effectiveness of subjective norms, in the promotion of smart phones, the user group should not only focus on the older adult themselves, but also the family members, friends and other groups of the older adult, through the publicity of people around the older adult, so as to further influence the behavior of the older adult. In addition, due to the influence of subjective norms, in the design of smart phones, industrial designers should adhere to the user-centered idea, take universal design as the design concept, and fully consider the needs of the older adult and other groups in the functional design, operating procedures, interaction methods, and color design of mobile phones. Let non-older adults users feel the usefulness and other performance characteristics of smart phones, and then cause non-older adults users to consciously and actively influence the older adult around them, and convey the positive evaluation of smart phones to older adults users, and promote the older adult's perception of the usefulness of smart phones and the improvement of their use intention. After all, in the current China where collectivism is prevalent, the influence of family members and friends cannot be ignored. In addition, in the Chinese culture of filial piety, many children also buy smartphones as gifts for older adults to express their filial piety and love. In conclusion, smartphone marketers can hold various promotional activities to attract people from the periphery of older adults. In addition, our study shows that subjective norms have no significant impact on technology anxiety in the older adult, which is consistent with the findings of Chen et al. (2022). This hypothesis may not have gained support because subjective norms, as one of the expectations of others, may have increased the stress and anxiety of older users.

The results of this study show that facilitating conditions positively influenced perceived ease of use, a finding validated by the study of Ma et al. (2016). At the same time, our study also verified that the exogenous variable of facilitating conditions positively influenced the intention of older adults to use smartphones, which was also confirmed in a study by Hsu et al. (2022) on the use of smartphones for the registration of applications by older adults. This suggests that the knowledge reserve of their own or the help received is important for the acceptance of smartphones among older adults. Therefore, based on the positive utility of the variable of facilitating conditions, it is necessary to increase the number of support services and related knowledge about smartphone use among older adults, such as the training courses on the introduction and use of smartphones offered in neighborhoods, senior colleges, and parks. Also, as Tamilmani et al. (2021) pointed out, the facilitating conditions of enhancing the support services and knowledge have a positive effect on users' technology use. In addition, in order for older adults to use technology systems, family members and technology practitioners should provide them with appropriate instructional support resources which are highly meaningful to older adults (Li et al. 2019). After all, when users are supported in their technology use resources, their intention to use technology increases as well (Cimperman et al. 2016). As the interviewee in our study stated: "I can't read. If my daughter could spend more time teaching me, then I would be able to use the phone faster than now. But she is too busy and now I rarely use the phone (Interviewee 6, female) ". Similarly, this study found that facilitating conditions has a significant positive impact on the self-efficacy of the older adult, which is similar to previous studies (Kumi et al. 2012; Dahri et al.

2023). Therefore, whether as a family member or as a business organization, it is necessary to provide auxiliary support for the use of smart phones by the older adult. At the same time, the government, as a policy maker, should play the role of policy guidance, through the formulation of relevant policies and encouragement measures, the organization of communities, industry associations, etc., through the concerted efforts of the government, society, and enterprises, to provide support and facilitating conditions for the use of smart phones by the older adult in an all-round way, help the use of smart phones by the older adult and improve the quality of life.

Our findings showed that self-efficacy had a positive significant effect on perceived usefulness and perceived ease of use. This result is consistent with the results of previous studies on technology use (Chen and Chan, 2014a) and with the results of the study on smartphone acceptance (Zhu and Cheng, 2022). In the interviews, our older adults interviewees stated: "My smartphone is too advanced. I can't operate it (Interviewee 4, female)"; "A smartphone with tutorials such as voice or video would be good, as it should be easy to use (Interviewee 2, male)". User self-efficacy is a key factor influencing user technology adoption (Macdonald et al. 2019). And older people have lower self-efficacy for technology than younger people (Czaja et al. 2006). Therefore, in addition to setting up paper-based user guides in large font sizes, smartphone developers should also simultaneously develop audio and video versions of the tutorials and focus on improving the confidence of older adults in using the technology. At the same time, by adding real-time feedback and instant encouragement functions and prompts in smart phones, the confidence and patience of the older adult to use mobile phones can be increased. In addition, the children should provide more guidance and assistance to older adults to increase their confidence and enthusiasm for using smartphones. Our study also found that self-efficacy has a significant impact on technology anxiety, which is consistent with the research results of Chen et al. (2018). This suggests that when older people have a higher sense of self-efficacy, they have a higher degree of love for smartphones and a relatively lower sense of anxiety. In other words, by increasing the self-efficacy of older people, anxiety in old age can be reduced. Therefore, the older adult can improve their own smart phone use ability. Of course, the government can also formulate some policies and standards for the use of smart phones by smart phone-related enterprises and institutions, so as to enhance the self-efficacy of the older adult and reduce their technological anxiety.

This study revealed the positive effect of perceived ease of use on perceived usefulness, which is similar to the results of a study in an Eastern cultural context (Talukder et al. 2019). As our interviewee stated: "Smartphones are too complicated to use. They are for young people, not for us old people (Interviewee 7, male)". In addition, our study also showed that the intention of older adults to use smartphones was directly influenced by perceived usefulness and perceived ease of use, which is consistent with the findings of Lee (2019), as with the responses of our interviewees. For example, Interviewee 8 (female) stated: "To have a companion function. It would be nice if the smartphone could bring me child-like companionship" ; Interviewee 5 (male) said: "I would like to have a phone that is not too complicated and takes into account the situation of the older adult". Therefore, it can be concluded that both perceived ease of use and perceived usefulness are very important influencing factors. Based on the above findings, smartphone designers can improve the ease of use by simplifying the operation and adding tutorial videos and user manuals (Lunney et al. 2016). Considering that problems such as vision loss with age are challenges that older people need to overcome when consulting mobile phone screens and using

keyboards (Zhu and Cheng, 2022), this is a prominent age difference between younger and older users (Fang et al. 2019). For this, they need optimize the visual and dimensional planning of the smartphone interface to meet the needs for companionship and entertainment by taking into account the possible vision loss and companionship and entertainment needs of older adults. For example, through continuous innovation, one-touch intelligent remote video and one-touch intelligent opera opening functions may be set up to enhance older adults' perceived usefulness of smartphones. In addition, industrial designers should also take full account of the daily life service needs of the older adult, add supporting functional modules such as living fees, emergency calls, telemedicine, and health care in the supporting functions of the mobile phone, and open the corresponding functions in a simplified way, so that older adults users can fully perceive the beneficial effect of smart phones on their daily lives, and finally realize the diversity of smart phone use (Griffioen et al. 2021).

Conclusions and future directions

Conclusions. This study takes SOR theory as the research framework, integrated the theory of planned behavior, self-efficacy theory, and technology acceptance model to construct a model of smartphone acceptance among older adults. It also explored the effects of technology anxiety, subjective norms, perceived usefulness, facilitating conditions, perceived ease of use, and self-efficacy on older adults' intention to use smartphones. As found from the results, perceived usefulness was directly influenced by technology anxiety, subjective norms, self-efficacy, and perceived ease of use, perceived ease of use was significantly influenced by facilitating conditions and self-efficacy, and technology anxiety, subjective norms, perceived usefulness, self-efficacy, facilitating conditions and perceived ease of use were direct predictors of older adults' intention to use smartphones. Facilitating conditions had a direct impact on self-efficacy, while subjective norms had a positive impact on technical anxiety, and self-efficacy had a significant impact on technical anxiety. This study expands the applicability of SOR framework, further expands the technology acceptance model, and provides a theoretical framework for older adults users' smartphone use behavior. The results of this study may help to improve the study of technology use among Chinese older adults, enrich the theory of technology acceptance among older adults, and provide a reference for subsequent design and marketing of smartphones of high acceptance.

Implications. This study has some theoretical implications. First, this study takes SOR theory as the research framework, integrates technology acceptance model, planned behavior theory and self-efficacy theory, and analyzes the influencing factors of older adults's mobile phone use behavior from three aspects of SOR theory. The empirical theoretical model of the research conforms to SOR framework and expands the application of SOR theory in the field of user technical behavior (Pandita et al. 2021; Zhang et al. 2021). Second, this study provided a framework for smartphone acceptance and a theoretical framework for the smart phone use behavior of older adults users, which can be used to predict the smartphone usage behaviors of older adults users and enrich the theory of smart technology behavior of older adults users. Third, In addition to the stimulus, organic and reactive dimensions of SOR theory, this study also considered multiple variables comprehensively, including the dimensions of product (usefulness and ease of use), user (self-efficacy and technology anxiety), and environment (subjective norms and facilitating conditions), to confirm the influence of perceived usefulness and perceived ease of use with other factors. It is a further extension of the technology acceptance model (Davis, 1989) with fewer

Table 6 Main Responses of Semi-structured Interviews.

Questions and answers

Q1: What problems have you encountered in using smartphones or smart devices?
"I often don't know where to start when I turn on the phone" (Interviewee 1, male);
"Because of my lack of experience, I often make mistakes, such as confusing the volume buttons with the on/off button" (Interviewee 2, male.)
"I only started to learn how to use my smartphone three months ago, so I am not familiar with many operations and I am always afraid of pressing the wrong button" (Interviewee 3, female);
"My smartphone is too advanced. I can't operate it" (Interviewee 4, female);
"I can't read. If my daughter could spend more time teaching me, then I would be able to use the phone faster than now. But she is too busy and now I rarely use the phone" (Interviewee 6, female);
"Smartphones are too complicated to use. They are for young people, not for us old people" (Interviewee 7, male);
"Whenever I want to call my friends, I can't find my address book" (Interviewee 8, female);
"I can't download apps on my phone, so I have to ask my grandson to do it for me" (Interviewee 9, female);
"I can't store phone numbers because I'm not educated, so it's a lot of trouble and takes a long time for searching every time I call" (Interviewee 11, female).

Q2: What kind of smartphone do you like?
"The kind of phone that I can operate just by talking" (Interviewee 1, male);
"A smartphone with tutorials such as voice or video would be good, as it should be easy to use" (Interviewee 2, male);
"Not too complicated, just with simple functions for making phone calls, or watching TikTok" (Interviewee 3, female);
"The operation of cell phones is still a bit complicated. I like to use something simple" (Interviewee 4, female);
"I would like to have a phone that is not too complicated and takes into account the situation of the elderly" (Interviewee 5, male);
"I'm over 70 years old, my eyes are dizzy, I'm at home and in the neighborhood almost every day, so I don't think the phone is useful for me" (Interviewee 7, male);
"To have a companion function. It would be nice if the smartphone could bring me child-like companionship" (Interviewee 8, female);
"I like a cheap one that works well" (Interviewee 9, female);
"Because I like to watch videos and listen to operas lately, my phone will run out of battery after a while. It would be good if it doesn't consume battery so fast" (Interviewee 10, male);
"I don't need a smartphone. It would be good if I can make a phone call." (Interviewee 11, female).

Q3: What was the reason that motivated you to use your smartphone last time?
"I wanted to see my grandchildren." (Interviewee 2, male);
"I called my friend and asked to go for a walk." (Interviewee 3, female);
"I want to play with my phone for a while because I'm bored, but I don't know how to do it every time." (Interviewee 4, female));
"To contact my wife" (Interviewee 5, male);
"To look through my daughter's photos" (Interviewee 6, female);
"My former colleague often shares pictures of his travels, and I wanted to see where he had recently been." (Interviewee 7, male);
"My friend called me and said she sent out red packets in a WeChat group and asked me to grab them." (Interviewee 8, female);
"I saw that my friend was using her smartphone very conveniently, so I went home and used my son's phone to experiment with it. Then, I could immediately see my grandson who was away at school through WeChat. This was amazing." (Interviewee 9, female);
"When I see old people in my neighborhood watching videos and listening to operas on their smartphones, I would like to try using the cell phone, too." (Interviewee 10, male);
"My son taught me how to use the WeChat video function." (Interviewee 11, female).

dimensional variables and enriches relevant research theories and literature of smart phones, especially in the user object and technical object of the technology acceptance model. Four, this study confirmed the important role of technology anxiety in the research model. The significant relationship between technology anxiety, an extrinsic factor, and intrinsic factors such as perceived usefulness, as well as between technology anxiety and use intention was elucidated to advance the development of knowledge. These findings are of great value for both academic research and practice.

In addition, this study has some practical implications. First, technology anxiety had a significant effect on perceived usefulness and use intention. This finding provides inspirations to both smartphone providers and policy makers. Therefore, it is particularly important to help older adults eliminate technology use anxiety through various measures, For example, in terms of the design functions of smart phones, it is possible to set up human-computer interaction methods such as voice functions, add user guidance videos in smart phones, set one-click operations in smart phones or simplify operation steps, so as to reduce the anxiety of the older adult on the use of mobile phones, and thus improve the perception and use of the usefulness of smart phones for the older adult. Second, considering that usefulness and ease of use affect the use of smartphones by older adults, smartphone designers should return to the important role of the product in user behavior. Therefore, designers should fully explore the usage requirements of smartphones by older adults and develop user-centered product features that are suitable for the use and operation of older adults to enhance product usefulness and ease of use. For example, smart phone industrial designers fully consider the daily life service needs of the older adult, add supporting functional modules such as living payment, telemedicine, and health care in the supporting functions of the mobile phone, and open the corresponding functions in a simplified way to improve the older adult's perception of the utility and ease of use of smart phones. Finally, the results of this study can provide inspiration for smartphone marketers and senior policy makers. For example, the positive effects of self-efficacy, subjective norms and facilitating conditions on the ease of use, usefulness, and use intention of smartphones in this study all suggested that these people can promote and advertise smartphones to the relatives and friends around older adults to enrich their recognition of smartphones and influence their perceptions of smartphones. At the same time, through the policy of encouraging the use of smart technology among older adults, a mutual help atmosphere can be created and the help of non-older adults groups to the older adult is enhanced. In addition, increasing the confidence and patience of the older adult in using

mobile phones by adding real-time feedback and instant encouragement functions and prompts in smart phones, so as to increase the intention of older adults to use smartphones.

Limitations and future directions. Despite the contributions of this study, there are some limitations. First, the interviewees in this study were all from China, and the limited sample size could not represent all Chinese older adults from multiple cultures, thus limiting the generalizability of the research findings to other regions and countries. In follow-up studies, large samples of older adults from different regions and countries with different cultural backgrounds should be collected for analysis to obtain interesting findings. Secondly, this study was conducted during the COVID-19 pandemic, when smartphones were commonly used to register for nucleic acid tests in various regions of China, including the city of Zhanjiang, and this contributed to the use and understanding of smartphones among older adults. In the post-COVID-19 era, the frequency and experience of smartphone use among older adults are unknown. Therefore, longitudinal studies in the future are a way to avoid the limitations of this cross-sectional study. Finally, this study only explored from the perspective of older adults, yet there may be different findings if the focus is on the groups closely related to older adults, who are also more familiar with older adults and may have a better understanding of their lives, habits, and thoughts. Therefore, future studies are suggested to explore and compare the groups around older adults, such as their family members, which may be useful for the study of this topic.

Data availability

All data generated or analyzed in the course of this study are included in this published article and its supplementary file.

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Competing interests

The author declare no competing interests.

Ethical approval

The ethical application for this research was approved by the Academic Committee of Guangdong Ocean University. All research was performed in accordance with relevant guidelines and regulations.

Informed consent

After understanding the content and purpose of the study, all subjects agreed verbally and voluntarily participated in the study. This study did not collect any identification, sensitive and private information during the investigation.

Additional information

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