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RESEARCH

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Evaluation of 3D apparel design spatial visualization training for cognitive function of older adults: cross-cultural comparisons

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Abstract

This study examined how older adults of four different ethnic groups evaluate the spatial visualization training using 3D apparel design software. The model tested was derived from the Technology Acceptance Model (TAM) and a Unified Theory of Acceptance and Use of Technology (UTAUT). A quantitative research design with an online questionnaire using the purposive quota sampling was used. Structure equation modeling and ANOVAs were performed to test the hypotheses with 600 completed data. The result shows significant ethnic differences of the perceptions, attitude, and behavioral intention for our spatial visualization training. Especially, Asian Americans found the training easy to be involved with and were more likely to use it, whereas Caucasian Americans felt the training to be most difficult and were less likely to use it, compared to other ethnic groups. Also, perceived ease of use and the performance expectancy are cardinal in increasing the positive attitude toward the training. This study discovered the significant factors influencing the intention to use the apparel design virtual technology to improve cognitive functioning. The ethical differences found on the latent variables among four ethnic groups indicate the need of more thoughtful training development by considering the different cultural requirements and challenges.

Keywords: Spatial visualization, Cognitive functioning, Older adults, Cross-cultural study, Technology acceptance model, Unified theory of acceptance, Use of technology, Quantitative study

Introduction

One of the major challenges of aging is the decline of cognitive functioning and memory. Past research found that most older adults experience varying degrees of cognitive decline (Downer et al., 2017; Mejia-Arango & Gutierrez, 2011; Zlatar et al., 2018). This cognitive decline can cause difficulty in the daily activities of older adults (Wolinsky et al., 2006). As an individual's cognitive function is closely related to health and quality of life, it is important to find a way to prevent cognitive decline and memory loss through effective training and programs. Especially, visual-spatial skills are closely related to cognitive development, including memory improvement, problem solving, and decision-making (Charcharos et al., 2016). However, currently available visual-spatial activities are mainly designed for children and teens, and there are limited resources for older adults (Salkind, 1976). Though some resources are available for older adults, these activities are tiresome and difficult to complete (Chandler & Sweller, 1991). Especially, virtual tasks of spatial visualization are less familiar for older adults than younger adults (Ariel & Moffat, 2018). Also, the level of cognitive functioning differs according to the ethnic group due to their diverse cultural characteristics and educational opportunities. For example, minority ethnic older people get relatively less cognitive tasks in education and they perceive that the cognitive training is more difficult (Bohnstedt et al., 1994). It is hence crucial to understand how and why it is different, when developing an effective cognitive health training for each ethnic group.

McGee (1979) reviewed the literature regarding spatial ability and asserted that two spatial factors, visualization, and orientation, demonstrate the concept of spatial ability. According to McGee (1979), spatial ability is often related to the individual's visualization ability, mathematical ability, and orientation ability. Patternmakers utilize manipulative, analytic, and visualization skills to understand how the two-dimensional pattern pieces will connect to create the 3D shape of the finished garment and how adjustments, such as dart position or manipulation, will impact the resulting silhouette (Workman & Zhang, 1999). Therefore, 3D patternmaking activities could positively affect an individuals' spatial visualization skills.

Especially, 3D patternmaking activities will be beneficial for female older adults, as women underperform in spatial skills than men and as their cognitive functions tend to get weaker than their male counterparts when they are aging (Hyde, 2016; Yeh & Liu, 2003). In addition, for the reason that the level of cognitive functioning varies depending on the ethnicity due to their diverse cultural characteristics and educational opportunities aforementioned, it is important to understand how female older adults perceive the cognitive training based on the ethnicity. However, no prior study has utilized the patternmaking concepts as a method to train female older adults' spatial visualization skills and evaluate their experience with the concept. Therefore, the purpose of this study is (1) to examine how older adults evaluate the spatial visualization training using 3D apparel design by applying the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) and (2) to compare the level of each construct (i.e., self-efficacy, perceived ease of use, performance expectancy, effort expectancy, attitudes, and behavioral intention) for four ethnic groups (i.e., Caucasian American, Hispanic/Latino American, African American, and Asian American are chosen for this study as they are four largest ethnic groups in the US) (US Census, 2022).

TAM and UTAUT

Research in technology adoption has revealed various cardinal factors influencing usage intention and actual usage of certain technologies (Al-Saedi et al., 2020). First, the Technology Acceptance Model (TAM) is widely used to understand the acceptance of computer or technological advancement in diverse environments and explain key factors influencing users' technology adoption intention (Davis, 1989; Hur et al., 2017). TAM is considered an extended version of the Theory of Reasoned Action (TRA). According to TRA, a person's decision usually influences their intended action (Hur et al., 2017;

Rauschnabel et al., 2016). On the other hand, according to TAM, attitudes and subjective norms determine the individual's action (Shin & Kim, 2008).

TAM has been used to understand a wide variety of technological adoption in different arenas, including using a website, and attitude toward online shopping and virtual fitting rooms (Heijden, 2003; Kim, 2012; Li, 2019). Two key factors influencing the user perception in TAM include the perceived ease of use and perceived usefulness, which can describe how the technology is adopted and accepted by the users (Rauschnabel et al., 2016). Perceived ease of use has a significant influence on consumer attitude towards adopting new technology. According to Davis (1985), perceived usefulness implies that a person would adopt and use technology if that person finds it helpful to perform the jobs in a better way. For example, consumers perceived virtual fitting room experience such as trying on experience as a useful tool and influence to use such technology while shopping (Li, 2019). Perceived usefulness can provide a reliable prediction about the usage of technology. For example, past research revealed a relationship between the easy use of web interface and conducting a business (Pavlou, 2003). Besides, Chuttur (2009) showed that usage and perceived usefulness are mutually correlated. Moreover, perceived usefulness is considered the most influential factor that determines the willingness to adopt technology.

Along with the attitude, perceived ease of use, usefulness, and enjoyment can also affect an individual's decision to adopt a technology. For example, Alalwan et al. (2018) found that the individual's perceived enjoyment plays an important role in using mobile internet in Saudi Arabia. Davis et al. (1992) showed that an individual perceived that using a computer in the workplace can improve performance as well as productivity in different professional programs like MBA. Davis (1985) also refers that an individual's intention to use any technology is directly influenced by the affording required to use that technology. Lastly, there are some other external factors such as design and implementation process that may also affect the belief of an individual about technology (Li, 2019; Venkatesh & Davis, 1996).

A Unified Theory of Acceptance and Use of Technology (UTAUT) is another important theory to explain the antecedents of technology adoption intention (Al-Gahtani et al., 2007). To predict the user's willingness to accept and use technology, researchers have combined some of the concurrent models such as TAM and proposed a Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). According to UTAUT, there are four key factors (i.e., social influence, expectation of performance, expectation of effort, and conditions to facilitate) and four key moderators (i.e., voluntary tendency, gender, age, and experience) associated with predicting the intension to use technology and empirical use of technology in an organization (Venkatesh et al., 2016). Nowadays, with the emergence of new technology, the application of UTAUT in different areas of research has increased, including consumers' mobile internet use (Venkatesh et al., 2012) and enterprise systems (Sykes et al., 2014). However, researchers identified that cultural difference may influence the outcome of using UTAUT (Al-Gahtani et al., 2007). Therefore, cultural difference should be considered while designing any experiments to understand the tendency to adopt technology in organizational and non-organizational settings (Venkatesh & Zhang, 2010).

Literature review

Cognitive functioning and memory issues of older adults

Cognition is related to an individual's brain action that functions and understands external stimuli when necessary (Hirschfeld & Gelman, 1994). It is required for a better decision-making process in every domain of older adults' life. Generally, the memory skills of older people are not as good as those of younger people. The increasing rate of growth of the older population necessitates more resources for them (Vincent & Velkoff, 2010). The percentage of older adults, aged over 65, is continuously increasing and the health of this population becomes more important than ever before (Semega et al., 2019). Besides, research demonstrates that the older population has lower cognitive functioning than the younger population (Hartman et al., 2007; Lindeboom & Weinstein, 2004), evident from the T observed performance of different cognitive domains such as premorbid intelligence, attention, processing speed, motor skills, and global cognitive functioning.

Research also shows that the older population possesses cognitive deficits and comorbidities, thus making the treatment of older adults more complex and challenging (Schuitevoerder et al., 2013). Several reasons have been identified for the irregular cognitive function of older adults, such as depression, Alzheimer's, side effects of various medications, lack of nutrients, hormonal imbalance, and metabolic issues. Further, older adults tend not to prefer to take medication for their cognitive functioning. It is hence difficult to know the number of people suffering from irregular cognitive functioning in old age. Research indicates that nearly 40% of the older adults suffer from a lack of cognitive functioning (Kernisan, 2018; National Institue on Aging, 2020). All the cognition-related problems of older adults are called cognitive impairments. Cognitive impairments include memory-related issues, concentration, thinking, and some other brain-related issues that affect the activities of older adults (Kernisan, 2018). In addition, cognitive impairments are related to other sensory impairments, including vision and hearing, of older adults (Davidson & Guthrie, 2019). Irregular cognitive function of older adults may set in slowly with the aging process or it can occur suddenly (Kernisan, 2018). In most cases, functioning of cognition in older adults deteriorates over time (National Institue on Aging, 2020). Besides, older adults are unaware or reluctant to talk about their cognitive decline to others (Kernisan, 2018). Researchers have studied strategies to improve age-related memory declination (Kernisan, 2018; Reese et al., 1999). For example, Reese et al. (1999) examined the memory self-efficacy, management, and remediation of older adults, and found the importance of everyday memory performance and clinical memory management.

Spatial visualization activities for cognitive training

Past research has used several interventions to improve the cognitive function of older adults (Jobe et al., 2001; Thiamwong, 2021; Troyer, 2001; Quinn, 2018). Jobe et al. (2001) examined the effects of three distinct cognitive interventions, memory training, reasoning training, and speed of processing training, on measuring older adults' performance on cognitively demanding daily activities related to living independently, such as food preparation, driving, medication use and financial management. As one of the essential aspects of cognitive functioning, memory improvement was also examined by the different intervention programs (Troyer, 2001). Troyer (2001) used the memory and aging intervention program to improve the cognitive tasks of older adults, including self-report assessments. Another interesting intervention used by Quinn (2018) was the social media training for older adults. The research team hosted social media training workshops for the older adults aged over 65 living in their neighboring communities. The participants learned how to set up and use social media, and they were encouraged to use social media outside of the workshops. As a result, positive cognitive effects of engagement with social media technologies were found in older adults, with significant improvement in cognitive functioning (Quinn, 2018).

Spatial mental rotation activity provides a skill to manipulate the information about a 2D or 3D object rotating in an imaginative space (Lin & Chen, 2016; Lee et al., 2016). The aging process affects the spatial cognition of an adult, which is also related to the ability of mental rotation (De Beni et al., 2006). Thus, the regular spatial mental rotation training, converting 2D to 3D or 3D to 2D in the imaginative space, can help maintain and improve cognitive functioning. As the activities of mental rotation can improve cognitive functioning, the proper maintenance and manipulation of visual stimuli will improve mental rotation as well as cognitive functioning (Pazzaglia and Moè, 2013; Hoe et al., 2019).

Self-efficacy related to technology usage

An individual's belief in his/her ability to accomplish a given task or behavior is called self-efficacy (Bandura, 1986; Holden & Rada, 2011). Self-efficacy is a skill that a person possesses, with which that person can learn a new behavior or operation. Self-efficacy makes a person confident, which comes from their personal belief (Kulviwat et al., 2014). A person's self-motivation can be influenced by self-efficacy; thus, it helps in determining the time and effort required to learn a new behavior or technology (Barling & Beattie, 1983; Kulviwat et al., 2014). Technology-based self-efficacy is the behavioral intention to learn and become proficient in a newly learned technology (Holden & Rada, 2011). Researchers evaluated self-efficacy regarding e-learning and internet and found that technology acceptance has an indirect effect on the learner's intention and perceived ease of use (Grandon et al., 2005; Ma & Liu, 2003). According to the Technology Acceptance Model (TAM), an individual's attitude about the usefulness of learning a new technology determines and influences that person's behavioral intention about adopting that technology (Davis et al., 1989). In terms of technology adoption, persons with a high level of self-efficacy are more likely to develop a positive attitude about adopting it (Venkatesh, 2000).

Unlike youth, older adults generally do not show enthusiasm and a positive attitude towards adopting a new technology (Kuo et al., 2012). Research shows that in home-based service, customer care, healthcare and shopping activities, the older adults prefer to stay with old fashion ways which are not connected to the smart and advanced technology (e.g., shopping in the brick-and-mortar stores instead of using the online shopping platforms). Therefore, it is important to understand the factors that influence an older adult's attitude towards accepting and adopting new technology (Chen & Chan, 2014). According to Kulviwat et al. (2014), Perceived ease of use, perceived usefulness, and brand romance have a positive relationship with self-efficacy. Research indicates that in the case of a technological product, if a consumer feels confident and comfortable, they find it useful, enjoyable, and know how to control it. Self-efficacy has a strong relationship with perceived ease of use, usefulness, and pleasure. Therefore, having self-efficacy shapes and determines an individual's perceived ability to quickly learn and use that technology or operation (Kulviwat et al., 2014).

Perceived ease of use, performance expectancy, and effort expectancy

Perceived ease of use is defined as the user's perception about whether the particular technology or internet function is intuitive and easy to operate (Davis, 1989). This is closely related to the openness to using a certain technology (Moslehpour et al., 2018). This construct has been examined in various technology-related topics, including e-commerce and internet applications (King & He, 2006). Based on the Technology Acceptance Model (TAM), perceived ease of use influences the attitude toward using the technology. For example, Rahmi et al. (2018) found that the perceived ease of use is an important antecedent of the attitude toward e-learning systems.

In addition, performance expectancy and effort expectancy play important roles in predicting the intension to use technology and empirical use of technology in an organization, based on the Unified Theory of Acceptance and Use of Technology (UTAUT). Performance expectancy is defined as the belief of an individual regarding how well the technology and/or a system will operate to achieve his or her goal (Ghalandari, 2012). Effort expectancy refers to the perception regarding the effectiveness of using the technology and/or a system based on the effort he/she put in on learning it (Venkatesh et al., 2003). When individuals have high performance and effort expectancy, they will have a positive attitude toward the technology/system and will be more likely to use it (Dwivedi et al., 2019).

Technology usage intention

The rapid technological advancement makes our life more convenient in general; however, it also poses the question of how this can be applied and adopted by the ageing population, as they often found some of the technology challenging to use (Macedo, 2017). Thus, it is important not only to provide universal access to these technologies for all generations, but also provide customized education and the right method for each generation. According to Macedo (2017), the UTAUT can be applied also to understand technology-related behavior of older adults; her research findings revealed that hedonic motivation and habit are important antecedents of behavioral intention of information and communication technology in older adults. Further, self-efficacy, one's belief about one's abilities to accomplish the given task, was also found to be an important indicator to understand computer usage (Igbaria & Ilvari, 1995). Further, the attitude toward the technology is expected to have a positive effect on behavioral intention and actual behavior of individuals (Bhattacherjee & Premkumar, 2004).

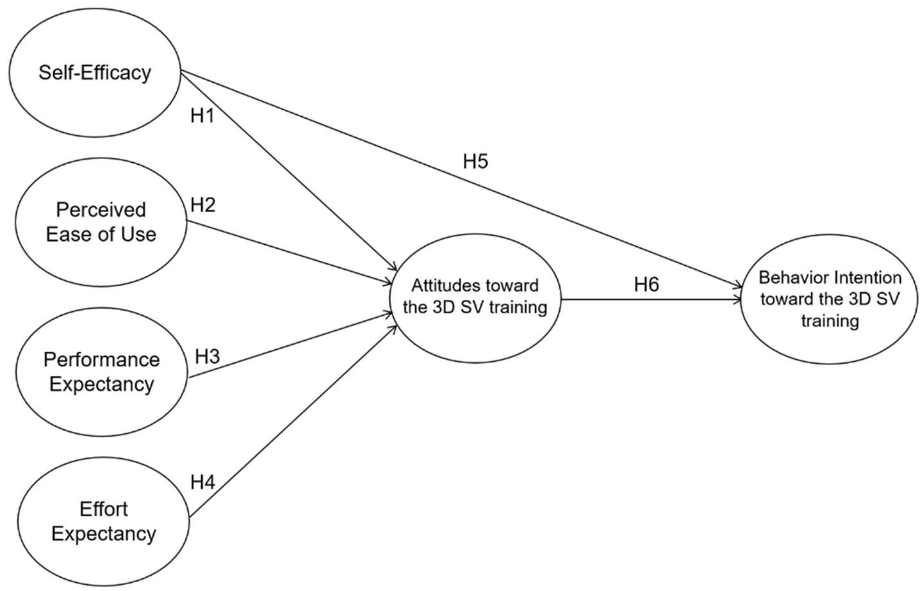

Fig. 1 Theoretical framework of this study. *SV* spatial visualization

Ethnic differences in cognitive functioning and technology learning

The findings of past research indicated that cognitive health is differs according to the ethnic group (Díaz-Venegas et al., 2016). Due to the different cultural and educational backgrounds of people, the level of cognitive functioning is found to be different, and education plays an important role in improving the cognitive health of each ethnic group. Bohnstedt et al. (1994) mentioned that minority ethnic older people, especially in the developing countries, are getting relatively short and less cognitive tasks in education, and this affects their cognitive development and skills. According to Díaz-Venegas et al. (2016), Hispanic Americans have a lower level of cognitive functioning than White Americans and African Americans. There are various types of cognitive screening tests for different ethnic groups, including memory, language, and visuo-spatial tests (Anthony et al., 1982; Lindesay et al., 1997).

Further, past research found differences in terms of computer usage among ethnic groups (Kamalu, 2012), with the minorities in the United States, including African Americans and Hispanic Americans tending to have less access to the internet and computers. The reasons are often related to the differences in income, access, and educational opportunities (Valdez et al., 2012). These can be further linked to the cognitive health-related opportunities for different ethnic groups (Díaz-Venegas et al., 2016). However, the current cognitive training programs have educational and cultural challenges, such as the problem in setting the level of difficulty based on the needs of diverse ethnic groups.

Figure 1 shows the theoretical framework with the hypothesized paths of this study. Especially, our framework is built upon TAM with most of the variables from the model (i.e., perceived ease of use, attitudes toward the training, behavioral intention toward the training) and we adopted additional variables from UTAUT (i.e., performance expectancy and effort expectancy) to evaluate the training more in-depth and removed the construct with the overlapping concept between TAM and UTAUT, along with adding the self-efficacy variable. To summarize, it was hypothesized that self-efficacy, perceived ease of use, performance expectancy, and effort expectancy will positively affect the attitude toward the spatial visualization training using the 3D apparel design program, and in turn, self-efficacy and attitude will affect the intention to use this training. In addition to the paths proposed in Fig. 1, the significant mean differences of all variables were expected for the four ethnic groups. Seven hypotheses tested in this study are listed below.

H1. Self-efficacy will positively affect the attitudes toward using the 3D spatial visualization training.

H2. Perceived ease of use will positively affect the attitudes toward using the 3D spatial visualization training.

H3. Performance expectancy will positively affect the attitudes toward using the 3D spatial visualization training.

H4. Effort expectancy will positively affect the attitudes toward using the 3D spatial visualization training.

H5. The behavioral intention toward using the 3D spatial visualization training will be positively and directly influenced by self-efficacy.

H6. The behavioral intention toward using the 3D spatial visualization training will be positively and directly influenced by attitudes.

H7. There will be significant differences in self-efficacy, perceived ease of use, performance expectancy, effort expectancy, attitude, and behavioral intention to use the 3D spatial visualization training among the four ethnic groups.

Methods

This study used a quantitative research design with an online survey and questionnaires. To achieve the research purpose, the researchers purposively focused on female participants who are 65 and older. Gender differences in cognitive activities have been extensively studied and found (Laws et al., 2016). For example, significant gender differences have been found in cognitive functioning, including verbal and non-verbal reasoning (Weiss et al., 2003). Even though women excel in verbal reasoning, they underperform in math and spatial skills (Hyde, 2016). Furthermore, female older adults tend to have weaker cognitive functions than male older adults (Yeh & Liu, 2003). In particular, regarding cognitive impairment, female older adults show greater deterioration than male older adults (Laws et al., 2016). Moreover, when given visual-spatial tasks, men outperform women, which shows the need for spatial ability training for women (Weiss et al., 2003). Therefore, this study specifically focused on female older adults.

Also, four largest ethnic groups in the US are Caucasian American, Hispanic/Latino American, African American, and Asian American and Pacific Islanders (US Census, 2022). Especially, previous studies investigated the cognitive functions among Caucasian American, Hispanic/Latino American, and African American (Díaz-Venegas et al., 2016; Lindesay et al., 1997). The findings of these studies show the needs of understanding cognitive functioning based on ethnic groups as there were cognitive differences. Thus, the female older adults belonging in one of these four ethnicities were recruited.

Four screening questions were asked for the purposive sampling. After the initial screening questions, participants watched the virtual technology training video that applies the concept of spatial visualization to apparel design. After the training, the participants were asked to answer questions to evaluate the training. A quota sampling method with the Qualtrics' panel was used to recruit participants from the aforesaid four ethnic groups in the US. A total of 600 usable data were used for data analyses (n = 150 for each ethnic group). Structure equation modeling (SEM) was conducted, followed by a confirmatory factor analysis (CFA) using LISREL for this study (Brown & Moore, 2012). Further, Analyses of Variance (ANOVAs) were conducted to ascertain whether there were significant mean differences of the latent variables among the four ethnic groups (see Fig. 2).

Respondent profile and smart device usage

Table 1 outlines the demographic profile of participants including education, household income, and marital status. As regards the education, most of the Caucasian American, Hispanic/Latino American, and African American participants finished high school or completed college. For Asian American and Pacific Islanders, most of them either completed college (51.3%) or graduate school (31.3%). Respondents' household income varies, however, Asian American and Pacific Islanders had higher income of $100,000 or above (38.7%) compared to other ethnic groups. The marital status of participants was mainly married or widowed. We also asked what type and brand of the smart device they used to participate in this study (i.e., What smart device are you using to participate in this study? Which brand's device is it?). The most often used smart device was laptop (27.5%), followed by desktop (24.3%). Regarding the brand, they use not only Apple (21.7%), Samsung (18.2%), and Microsoft (12.5%), but also various other brands (47.7%) including Acer, Amazon Fire, Asus, Chrome, HP, Lenovo, and LG (see Table 2).

Measurements

All the six key constructs were measured with multiple items, drawn from past literature and modified to suit this study. The five-point Likert scale was used to measure all variables (1 = strongly disagree; 5 = strongly agree), except the attitude variable, for which the five-point Semantic Differential scale was used. The self-efficacy scale was adopted from Bandura et al. (1996), the perceived ease of use scale from Davis (1989), and the items to measure performance and effort expectancy from Onaolapo and Oyewole, (2018) and Venkatesh et al. (2016). The items to measure attitude toward the spatial visualization

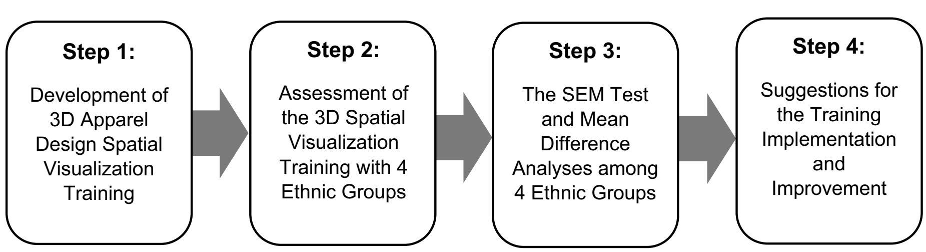

Fig. 2 Research process of this study. *SEM* structure equation modeling

Table 1 Demographic information

Characteristics	Ethnic groups (Frequency/percentage)			
	Caucasian American (n = 150)	**Hispanic American (n = 150)**	**African American (n = 150)**	**Asian American (n = 150)**
Education	n (%)			
Finished high school	43 (28.7)	43 (28.7)	40 (26.7)	12 (8.0)
Completed technical college	12 (8.0)	80 (5.3)	16 (10.7)	20 (1.3)
Completed community college	28 (18.7)	27 (18.0)	28 (18.7)	10 (6.7)
Completed college	34 (22.7)	37 (24.7)	37 (24.7)	77 (51.3)
Completed graduate school	23 (15.3)	26 (17.3)	25 (16.7)	47 (31.3)
Other	10 (6.7)	90 (6.0)	40 (2.7)	20 (1.3)
Household income				
$19,999 or less	21 (14.0)	28 (18.7)	20 (13.3)	80(5.3)
$20,000–34,999	42 (28.0)	32 (21.3)	43 (28.7)	10 (6.7)
$35,000–49,999	25 (16.7)	32 (21.3)	25 (16.7)	17 (11.3)
$50,000–64,999	22 (14.7)	28 (18.7)	16 (10.7)	26 (17.3)
$65,000–79,999	15 (10.0)	60 (4.0)	20 (13.3)	14 (9.3)
$80,000–99,999	50 (3.3)	90 (6.0)	10 (6.7)	17 (11.3)
$100,000 or above	20 (13.3)	11 (7.3)	13 (8.7)	58 (38.7)
Other	0 (0.0)	40 (2.7)	30 (2.0)	0 (0.0)
Marital status				
Single, never married	90(6.0)	13 0(8.7)	24 (16.0)	15 (10.2)
Married	67 (44.7)	60 (40.0)	52 (34.7)	90 (44.8)
Widowed	39 (26.0)	38 (25.3)	35 (23.3)	24 (22.7)
Divorced	33 (22.0)	36 (24.0)	38 (25.3)	21 (21.3)
Other	20 (1.3)	30 (2.0)	10 (0.7)	0 (0.0)

Table 2 Smart device usage of the participants

Type	Frequency	Percentage	Brand	Frequency	Percentage
Smartphone	144	24.0	Apple	130	21.7
Tablet	80	13.3	Samsung	109	18.2
Laptop	225	37.5	Microsoft	75	12.5
Desktop	145	24.3	Other	286	47.7
Other	5	00.8			

training developed for this study were adopted from Wang and Sun (2016) and modified, while the behavioral intention scale was adopted and revised from Shahid et al. (2018). The specific items used in this study are presented in Table 3.

Results

Exploratory Factor Analysis (EFA) and reliability tests were conducted using SPSS 27 to determine the model constructs. Then, Confirmatory Factor Analysis (CFA) was carried out to investigate the reliability and validity of the study measurement items using LISREL 9.1. The measurement model analysis was based on six latent variables: self-efficacy,

Table 3 The results of factor loading, reliability, and validity

Constructs and items	α	FL	CR	AVE
Self-efficacy	0.950		0.972	0.815
I will be able to achieve most of the goals that I set for myself		0.793		
When facing difficult tasks, I am certain that I will accomplish them		0.860		
In general, I think that I can obtain outcomes that are important to me		0.865		
I believe I can succeed at most any endeavor to which I set my mind		0.879		
I will be able to successfully overcome many challenges		0.885		
I am confident that I can perform many different tasks effectively		0.884		
Compared to other people, I can do most tasks very well		0.836		
Even when things are tough, I can perform quite well		0.891		
Perceived ease of use	0.952		0.974	0.862
Learning virtual garment design would be easy for me		0.874		
I would find it easy to get virtual garment design to do what I want it to do		0.919		
My interaction with virtual garment design would be clear and understandable		0.904		
I would find virtual garment design to be flexible to interact with		0.849		
It would be easy for me to become skillful at using virtual garment design program		0.919		
I would find the virtual garment design program easy to use		0.925		
Performance expectancy	0.941		0.967	0.832
The virtual garment design enables me to access information relevant to my spatial visualization skills		0.705		
I can learn more efficiently with the use of virtual garment design		0.801		
Implementation of spatial visualization and information retrieval are easy with the use of virtual garment design		0.713		
The information resources that can be accessed motivate me to use virtual garment design		0.821		
I am convinced that the use of virtual garment design will add value to my learning activities		0.801		
Using virtual garment design for spatial visualization learning enables me to follow the trend in learning globally		0.795		
Effort expectancy	0.854		0.909	0.670
The use of virtual garment design for mobile learning is not characterized by stress		0.721		
I do not require much technical expertise to effectively use virtual garment design for spatial visualization learning		0.783		
I can access information resources anywhere and anytime through my virtual garment design use		0.826		
The use of virtual garment design for spatial visualization learning reduces the cost, time, and effort associated with the conventional learning system		0.832		
The use of virtual garment design for spatial visualization learning is not frustrating		0.811		
Attitude All things considered, my attitude towards the virtual garment design training is that it is a _____ idea	0.892		0.933	0.823
Bad–Good		0.926		
Foolish–Wise		0.913		
Harmful–Beneficial		0.885		
Usage intention	0.798		0.878	0.714
The probability that I will use the virtual garment design knowledge from the video again is high		0.895		
The likelihood that I would recommend this virtual garment design activity to a friend is high		0.893		
If I had to do the virtual garment design over again, I would make the same choice		0.734		

α Cronbach's Alpha, *FL* factor loadings, *CR* composite reliability, *AVE* average variance extracted, $p < 0.05$

Table 4 The correlation between variables

	Composite reliability	1	2	3	4	5	6
1. Self-efficacy	0.972	**0.90**					
2. Perceived ease of use	0.974	0.26	**0.93**				
3. Performance expectancy	0.967	0.23	0.76	**0.91**			
4. Effort expectancy	0.909	0.20	0.71	0.79	**0.82**		
5. Attitude	0.933	0.16	0.58	0.64	0.58	**0.91**	
6. Usage intention	0.878	0.20	0.67	0.82	0.70	0.55	**0.84**

Square root of AVEs reported along diagonal in bold

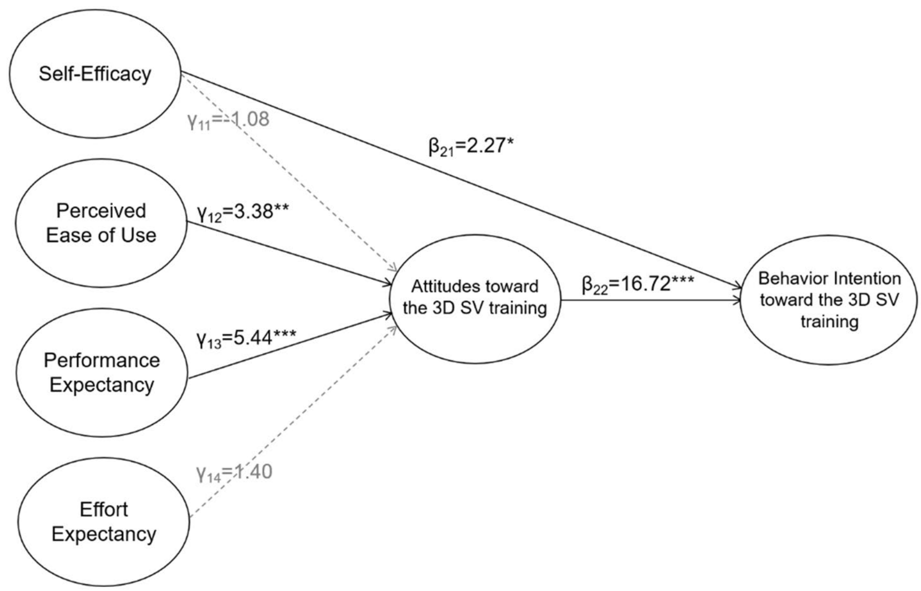

Fig. 3 Structural equation model for the main effects. *z-value (two-tailed) = 1.96 ($p \leq 0.05$), **z-value = 2.58 ($p \leq 0.01$), ***z-value = 3.45 ($p \leq 0.001$)

perceived ease of use, performance expectancy, effort expectancy, attitude, and behavior intention. As the AVE values of all the constructs are beyond 0.5, it indicates the strong validity of each measurement of this study. Further, the square roots of the AVE values are all greater than the correlation estimates (Table 4).

The result of the CFA model shows a good model-data fit: (RMSEA = 0.062, NFI = 0.98, CFI = 0.98, and TLI = 0.98). The SEM result using the maximum-likelihood estimation procedure also shows a good model-data fit (RMSEA = 0.074, NFI = 0.97, CFI = 0.98, and TLI = 0.97) with significant relationships among most of the latent variables. Perceived ease of use and performance expectancy affected the attitude toward the training significantly ($\gamma_{12} = 3.38^{**}$; $\gamma_{13} = 5.44^{***}$). However, self-efficacy and effort expectancy did not affect the attitude. Self-efficacy and the positive attitude toward the spatial visualization training positively affected the training usage intention ($\gamma_{21} = 2.27^{*}$; $\beta_{31} = 16.72^{***}$) (see Fig. 3).

The results of ANOVAs show significant mean differences of all the latent variables among the ethnic groups, except self-efficacy ($F = 2.243$, $p = 0.082$). Asian

Americans had the significantly highest means, followed by Hispanic Americans and African Americans and Caucasian Americans for five factors, including perceived ease of use ($F=20.292$, $p<0.001$***), performance expectancy ($F=26.372$, $p<0.001$***), effort expectancy ($F=18.392$, $p<0.001$***), attitude ($F=11.914$, $p<0.001$***), and usage intention ($F=26.339$, $p<0.001$***). Interestingly, Hispanic American and African American groups did not have significant mean differences for all variables (see Tables 5 and 6).

Discussion

This paper aimed to expand the understanding of how older adults of four different ethnic groups evaluate the innovative spatial visualization training using 3D apparel design. The results and discussion of this study are twofold: (1) the discovery of the significant factors influencing the intention to use the apparel design virtual technology to improve the cognitive functioning, and (2) the finding of the cultural differences on the latent variables among four ethnic groups. First, we revealed the importance of perceived ease of use and performance expectancy in increasing the positive attitude toward the training for older adults, i.e., if they felt the training platform easy to use and if they were convinced that the training provided value to their learning, they had a positive attitude toward the training. Therefore, it is crucial to provide them clear guidelines and support to start the training conveniently. This shows that the TAM and UTAUT can be applied to the technology usage context for the older adults as well (Davis et al., 1992; Venkatesh et al., 2003). In addition, our finding showed the positive responses of the technology-based training we provided, which contradicts the finding of Kuo et al. (2012) that older adults do not show enthusiasm and a positive attitude towards adopting new technology, though our training using the virtual design technology might be a little difficult for some of our older adult participants. To the open-ended question "Share your thoughts about this training," participants responded that though the training itself was fun, the spatial visualization questions were a little hard. This shows the need for review and modification

Table 5 Latent variable means for four ethnic groups

	White American	Hispanic American	African American	Asian American
Self-Efficacy	4.01 (0.72)	4.15 (0.86)	4.15 (0.81)	4.24 (0.68)
Perceived Ease of Use	2.79 (0.77)	3.32 (1.07)	3.23 (1.02)	3.73 (0.99)
Performance Expectancy	2.91 (1.02)	3.40 (1.02)	3.32 (1.02)	3.91 (0.87)
Effort Expectancy	2.95 (0.90)	3.24 (0.87)	3.22 (0.84)	3.70 (0.90)
Attitude	3.65 (1.10)	3.96 (1.06)	3.98 (1.05)	4.34 (0.81)
Behavioral Intention	2.66 (0.99)	3.10 (1.09)	3.00 (1.07)	3.70 (0.98)

The five-point Likert scale was used to measure all variables (1 = strongly disagree; 5 = strongly agree) except the attitude variable using the five-point Semantic Differential scale

Mean (SD)

Table 6 The results of construct mean comparison among ethnic groups

Variable	Comparison a	Comparison b	Mean difference (a−b)	SE	Sig
SE	White American	Hispanic American	− 0.137	0.893	0.420
		African American	− 0.141	0.893	0.393
		Asian American	− 0.229	0.893	0.051
	Hispanic American	African American	− 0.004	0.893	1.000
		Asian American	− 0.093	0.893	0.729
	African American	Asian American	− 0.088	0.893	0.756
PEU	White American	Hispanic American	− 0.522	0.120	0.000***
		African American	− 0.436	0.120	0.002**
		Asian American	− 0.932	0.120	0.000***
	Hispanic American	African American	0.087	0.120	0.888
		Asian American	− 0.410	0.120	0.004**
	African American	Asian American	− 0.500	0.120	0.000***
PE	White American	Hispanic American	− 0.497	0.113	0.000***
		African American	− 0.413	0.113	0.002**
		Asian American	− 1.002	0.113	0.000***
	Hispanic American	African American	0.083	0.113	0.883
		Asian American	− 0.506	0.113	0.000***
	African American	Asian American	− 0.589	0.113	0.000***
EE	White American	Hispanic American	− 0.291	0.102	0.023*
		African American	− 0.271	0.102	0.040*
		Asian American	− 0.744	0.102	0.000***
	Hispanic American	African American	− 0.020	0.102	0.997
		Asian American	− 0.453	0.102	0.000***
	African American	Asian American	− 0.473	0.102	0.000***
ATT	White American	Hispanic American	− 0.311	0.117	0.039*
		African American	− 0.338	0.117	0.020*
		Asian American	− 0.696	0.117	0.000***
	Hispanic American	African American	− 0.027	0.117	0.996
		Asian American	− 0.384	0.117	0.006**
	African American	Asian American	− 0.358	0.117	0.012*
BI	White American	Hispanic American	− 0.438	0.120	0.002**
		African American	− 0.338	0.120	0.025*
		Asian American	− 1.040	0.120	0.000***
	Hispanic American	African American	− 0.100	0.120	0.837
		Asian American	− 0.602	0.120	0.000***
	African American	Asian American	− 0.702	0.120	0.000***

The five-point Likert scale was used to measure all variables (1 = strongly disagree; 5 = strongly agree) except the attitude variable using the five-point Semantic Differential scale; *SE* self-efficacy, *PEU* perceived ease of use, *PE* performance expectancy, *EE* effort expectancy, *ATT* attitude, *BI* behavioral intention; $*p < 0.05$, $**p < 0.01$, $***p < 0.001$

of the spatial visualization questions before and after the training. This finding about the challenges of adopting new technology by older adults is in line with that of Kuo et al. (2012). Therefore, it is cardinal to measure the difficulty perception of the training by different ethnic groups and implement culture-specific programs.

Interestingly, self-efficacy did not directly affect the attitude toward the training but directly influenced the usage intention of the spatial visualization training. This shows that when participants feel confident about their abilities in general, they are more likely to try the new training to improve their cognitive functioning. As performance expectancy has a strong influence on the positive attitude toward the garment design spatial visualization training, the expected outcomes of the training should be clearly stated to the older adults, so that they understand the performance benefits of using the training. On the other hand, effort expectancy was not found to be an important factor affecting the attitude, which contradicts the hypothesis of the original UTAUT model (Venkatesh et al., 2003). Therefore, performance expectancy might be a more important factor for technology usage than effort expectancy for older adults. Interestingly, the participants found the training to be a little difficult, but at the same time, fun and interesting. Thus, more ease-to-use training should be provided for them to engage in the training more effectively.

Regarding the cross-cultural comparisons, there are significant mean differences in all variables except self-efficacy, among the four ethnic groups. Asian Americans and Pacific Islanders had the significantly highest means, followed by Hispanic/Latino Americans, African Americans, and Caucasian Americans, for perceived ease of use, performance expectancy, effort expectancy, attitude, and usage intention, which is different from the finding of past studies (Díaz-Venegas et al., 2016). This result might be related to the demographic characteristics of each ethnic group in our study, which can be different from demographic dynamics of the previous studies (e.g., Caucasian American participants of our study have relatively lower education levels and household incomes, whereas Asian American participants have relatively higher education levels and household incomes compared to the other ethnic groups). However, Hispanic Americans and African Americans did not have significant mean differences for all variables. This indicates that Asian Americans and Pacific Islanders found the training easy to be involved with and were more likely to use it, whereas Caucasian participants felt the training to be most difficult and were less likely to use it, compared to other ethnic groups. As hypothesized, there are significant differences in the perceptions regarding the training. However, this finding is contrary to our assumption that the minorities in the US (e.g., African Americans and Hispanic/Latino Americans) will find the training more difficult due to technology accessibility and cultural characteristics. This shows that the training design needs to consider the different needs of each ethnic group.

Implications and future research

There are practical and academic implications of the unique findings of our study. First, this study found the theoretical support of the TAM and UTAUT to examine the new technology training, utilizing the concept of apparel design. Hence, other technology trainings in the apparel field can adopt and broaden the use of this framework for further research. In addition, as the perceptions about the spatial visualization training and cognitive functions vary over time based on the ethnic groups, researchers should consider the interaction effects of the ethnic groups and training perceptions as well as cognitive functions to provide effective interventions for these ethnic groups. Further, the finding of this study has practical implications concerning the design of the training based on the needs of different ethnic groups. Companies developing cognitive programs for older adults should implement a culture-specific and/or personalized system, which can be useful and efficient for their users.

One of the limitations of this study is that we focused on the evaluation of the training, rather than on cognitive ability improvement. Therefore, the actual cognitive ability test of different ethnic groups before and after the training will deepen the understanding of the topic. It would also be beneficial to develop following training program that could positively affect older adults' 3D spatial visualization. Future research should consider different age and gender groups and explore how these factors affect their evaluation of the apparel design-based spatial visualization training. For example, our target population was female older adults, as our developed training is focused on women's apparel items (i.e., skirts). Thus, future research can be carried out with male populations with our training with different apparel items. Age is another factor which needs to be further examined related to other factors. We recruited participants aged over 65 based on our research purpose, but did not ask their specific age. Thus, our result could not capture the differences in each construct among four ethnic groups based on the different age distribution. Thus, the future research needs to investigate the relationship among age, ethnic groups, and other variables. In addition, qualitative research regarding the motivations and challenges in the of use certain technologies will provide in-depth understanding about older adults and their needs. Last but not least, paths of the framework need to be tested for each ethnic group and differences in paths should be compared for the future research to provide more valuable insights.

Authors' contributions

HC and SM originated the research idea and designed the research. HC and SM conducted the research and collected data. HC analyzed the data and drafted the manuscript. HC and SM drafted literature review. HC and SM revised and improved the manuscript. HC and SM contributed on the improvement of the manuscript. Both authors read and approved the final manuscript.

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Availability of data and materials

The data presented in this study are available on request from the corresponding author on reasonable request. The data are not publicly available due to security issues.

Declarations

Ethical approval and consent to participate

This research was conducted under the approval and supervision of Texas Tech University Institutional Review Board (IRB Approval No: IRB2020-191) regarding ethical issues including consent to participate.

Competing interests

The authors declare that they have no competing interests.

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