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Use of 3D Printing Technology to Create Personal Fashion: UTAUT and Need for Uniqueness

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3D printing, fashion, UTAUT, need for uniqueness

Abstract

This study investigated the perceptions, attitudes, and behaviors of potential consumers toward using 3D printers to create their personal clothes. An online survey and a series of Welch's t-tests and ANOVA were conducted to investigate the differences in demographic characteristics, prior experiences in 3D printing, and levels of need for uniqueness among the sub-groups. A multiple linear regression analysis was performed to test the relationships among variables of the modified Unified Theory of Acceptance and Use of Technology (UTAUT). There were significant differences in gender and prior experiences regarding the UTAUT of personal 3D printing. The need for uniqueness has a positive effect on consumers' intention to use 3D printing technology for designing personal clothes and perception of the price of the 3D printer used to create individual clothes is important. Positive relationships were found between UTAUT variables as well as the use and purchase intentions. This study analyzed the potential for popularization of 3D printing technology to create fashion items and explore consumer willingness to embrace and use personal fashion designs. The results of this study are expected to assist consumers, designers, retailers and marketers, and experts in 3D printing technology by providing insight into consumer awareness and acceptance of personalized 3D-printed fashion and products.

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This research is part of a master's thesis.

I. Introduction

The popularity of 3D printing has rapidly increased in the 2010s since 1980s when it was developed. This 3D printing technology is now used in many areas, such as the medical, automotive, aerospace, architecture, and fashion industries ("25+ interesting," 2019; Kim & Kim, 2018). According to "3D printing market" (2019), the global 3D printing market will grow to $32.78 billion by 2023, with an average annual growth rate of 25.76%. The average global spending on 3D printing in 2019 is set to reach $26.7 billion ("25+ interesting," 2019). Global companies such as Stratasys, 3D Systems in the United States, and Electro Optical Systems in Germany are developing not just various types of 3D printers and materials but also user-friendly software. 3D printing is expected to continue to develop with its many advantages, such as its ability to reduce time and labor costs, its all-in-one process, freedom of design, and customization ("10 advantages," n.d.).

The 3D printing technology has the potential to change the structure of the future fashion industry (Choi, 2017; Han & Kim, 2018; Petrick & Simpson, 2013). This technology could adapt to the variety of design preferences and body sizes and types of consumers (Clark, Çallı, & Çallı, 2014). Thus, consumers can create their own clothes from scratch or download designs and 3D print at home (Bley, 2018; Yap & Yeong, 2014). 3D-printed fashion items could implement unique designs and textures by satisfying consumers' need for uniqueness (NU) (Yap & Yeong, 2014).

However, several 3D printing technology problems, such as the limited size of printable products and limited types of printable, flexible material choices, continue to persist and need to be overcome to make these end products possible. Flexible materials, such as thermoplastic polyurethane (TPU), have been developed but are still not as flexible as fiber fabrics and thus are difficult to wear in real life ("Making clothes," 2013). There is little research on consumers' perceptions, attitudes, and intentions of using this technology in fashion. To encourage consumers to use 3D printing technology to create their own clothing, it is important to understand their perceptions, attitudes, and intentions toward 3D printing technology. Most extant research has focused on 3D printing technology for professional designers, not for consumers, and there is a lack of awareness on consumers' use intention (UI) and purchase intention (PI) of 3D-printed fashion products.

Thus, this study aimed to investigate potential consumers' perceptions, attitudes, and behaviors toward creating and wearing personalized 3D-printed clothing. The results of this study are expected to help consumers, designers, retailers and marketers, and experts in 3D printing technology by providing insight on current consumers' awareness and acceptance of personalized 3D-printed fashion and products.

II. Literature Review

1. Personalized 3D-Printed Fashion Items

3D printing at home has become popular in the fashion industry recently. Globalization of 3D printing opens the possibility to directly manufacture clothing using 3D printing equipment that consumers have in their homes (Wohlers & Caffrey, 2013). However, students and designers are currently the main users, but given the potential of the 3D printing industry, the personal 3D printer's popularity will be a major driver of the industry's growth and is expected the compound annual growth rate to be 29.48% from 2020 to 2025 ("3D printing," n.d.).

While 3D printing is yet to be generalized in the home, the following examples show that home 3D printing is already being used in real life, which shows the potential for its popularization. 3D printing is offering the opportunity to print a wide range of products. The ease of access to a variety of designs and 3D printing's short manufacturing time, it is possible to 3D print items even if the user is not familiar with CAD or other design programs. For example, there is a variety of online platforms, such as cults.com or thinkiverse.com, for 3D printed designs that can be used to create office

supplies, kitchenware, and household items (Kang & Kim, 2019; "Paper clip," 2018).

Jewelry and accessories are most common among 3D-printed items because they are easy to create and customize ("Cat ring," 2013; "Demi-sphere flowerpot," 2013), different with clothing or unlike clothing, which is difficult to create with 3D printing due to the low flexibility of 3D printing filaments. Many DIY pioneers employ 3D printing to create full garments such as dresses. For example, one of the designs that can be found on thingiverse.com is a chainmail dress that was designed in OpenSCAD and entirely 3D printed on an old Makerbot Replicator. It is modular and extensible, so it can fit any body size ("Chainmail dress," 2018).

Another example showing the possibility of combining traditional clothes-making with 3D printing technology is the Antolini dress, also found on thingiverse.com ("Antolini dress," 2014). Specifically, the top part of the dress is 3D printed, sewed onto a tulle yoke, and then attached to the skirt ("Antolini dress," 2014). In addition to 3D printing a whole garment, there are some other interesting ways of using 3D printing in DIY clothing, such as printing decorative pieces on garments. These can be created by directly printing the design on the existing shirt ("Westworld t-shirt," 2018).

Personal 3D printers are expected to play a leading role in the upcoming fourth industrial revolution. The advantages of these personal 3D printers can be broadly divided into seven categories. First, personal 3D printers have high accessibility. This means that not only experts and designers but also the general public will be able to use 3D printers to print products at home at their convenience (Perry, 2017). Second, they cost relatively little. As 3D printing technology becomes more common, free software for creating 3D models such as Google Sketchup or Meshlab have been released, making 3D printing more affordable. The third advantage is easy customizability. The 3D printer allows users to create products they want with little restriction (Perry, 2017), and easier and faster printing methods are continuously being researched and developed (Kang & Kim, 2019). Fourth, personal 3D printers are a new tool for realizing one's creativity. People can watch the production process at home and make clothing from their imagination. Fifth, there is no need for delivery. The global prevalence of 3D printers has also made it possible for existing orders to be printed directly at home (Perry, 2017). The sixth advantage is improved accuracy and quality. Advancements in 3D printing technology have improved the accuracy and quality of 3D printing, which has previously been pointed out as a problem. These advancements now allow households to design and construct products of the same quality at home as factories without requiring specialized production facilities ("8 benefits," 2016). Finally, a new business model can be built. The spread of personal 3D printers enables consumers to act as producers who make and sell goods themselves. This means that the boundaries between traditional producers and consumers will be broken ("8 benefits," 2016).

2. Unified Theory of Acceptance and Use of Technology

Despite the many advantages of personalized 3D printing, it is not used much for fashion items. Thus, this paper explores the variables influencing consumers' acceptance level. Venkatesh, Morris, Davis and Davis (2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) as an acceptance model. The UTAUT model identifies performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC) as direct determinants of behavioral intention (BI) and use behavior (Venkatesh et al., 2003). Based on these variables, Venkatesh, Thong, and Xu (2012) developed UTAUT2. This model added new variables to the model such as hedonic motivation (HM) and price value (PV).

PE has been used as an alternative to perceived usefulness from Technology Acceptance Model (TAM). PE is defined as users' belief of the system's benefits toward their job performance (Venkatesh et al., 2003). PE has one of the highest values of BI (Chiu, Fang, & Tseng, 2010b; Chiu, Huang, & Yen, 2010a). EE is the

preceived ease of use from TAM (Venkatesh et al., 2012). EE and BI have a positive relationship (Martins, Olivera, & Popovic, 2014; Nistor, Baltes, Dascălu, Mihăilă, Smeaton, & TrăuşanMatu, 2014). SI indicates the tendency of an individual believes others should be using the new technology (Venkatesh et al., 2003; Venkatesh et al., 2012). According to SI, these important other people will create a positive effect on the consumer adoption of the new technology.

FC can be defined as the level of an individual's belief that an organization and technical infrastructure exists to support the system and FC affects BI (Venkatesh et al., 2003). HM can be described as the enjoyment or happiness obtained from using the technology (Venkatesh et al., 2012). HM contributes significantly to BI of the technology (Brown & Venkatesh, 2005). PV can be defined as consumers' cognitive perception of the benefits of the technology and the monetary cost of using it (Venkatesh et al., 2012).

These variables were influenced by consumer characteristics such as age, gender, experience, voluntariness, and intention to use new technology (Venkatesh et al., 2003). When it comes to new technologies, older consumers, compared to younger consumers, have more difficulty grasping new or complex information, and this can affect their learning about new technologies (Morris, Venkatesh, & Ackerman, 2005). Therefore, older consumers find it important that the new technologies have available, adequate support (Hall & Mansfield, 1975). However, in the early stages of using a new technology, younger men tend to exhibit a greater tendency to seek novelty and innovativeness than the older (Chau & Hui, 1998).

Regarding the gender differences, men tend to depend on FC less than women when considering the use of new technologies, whereas women are more prone to placing emphasis on external support factors (Hennig & Jardim, 1977; Rotter & Portalian, 1969; Venkatesh & Morris, 2000). Also, women are more likely to pay attention to the prices of products and services then men (Slama & Tashchian, 1985).

Another variable that can affect the relationship between facilitating conditions and BI is experience. Experienced consumers do not need additional support due to their abilities to quickly become familiar with the technology and communicate its features and instructions to other users (Alba & Hutchinson, 1987). Similarly, a meta-analysis indicated that less experienced users tend to rely on facilitating conditions more than experienced users (Notani, 1998).

3. Attitude Toward Using Technology

Attitudes are defined as an assessment of influence and impact on a given task (Ajzen & Fishbein, 1977). In other words, Attitudes Toward Using Technology (ATUT) show the extent to which users like or dislike the use of technology. In the use of new technology, for example, an indicator affecting desired behavior is intention. Also, desired behavior is intention, which can specify an individual's willingness and how much effort will be put into carrying out an action (Ajzen & Fishbein, 1980). According to Venkatesh et al. (2003), ATUT can significantly affect BI. Therefore, in this study, we connect ATUT to enjoyment, liking, and fun that consumers associate with the use of 3D printing technology.

Hartmann and Vanpoucke's (2017) findings showed that UTAUT2 is a positive measure of user acceptance and that SI and EE are good predictions of "intention to use" for early-stage technology. However, their results also suggested significant differences in prerequisites, depending on the level of participation by users and the DIY mind frame (Hartmann & Vanpoucke, 2017). Following that UTAUT2 framework, Halassi, Semeijn, and Kiratli (2019) suggested that FC, HM, and a DIY mentality are key determinants of consumer acceptance and UI of 3D printing technology (Halassi et al., 2019). Gao, Shi, Guo, Kuang, and Xu's (2015) research about wearable-technology acceptance demonstrated that PE, HM, EE, and SI are positively linked to individuals' intention to adopt medical wearable devices. Chang, Lou, Cheng, and Lin's (2015) results suggested that FC significantly affect use behavior, PE and SI influence on

BI, but not EE. Regarding NU, Abosag, Ramadan, Baker, and Jin (2019) suggested that consumers' NU has an effect on SI (Abosag et al., 2019).

4. Need for Uniqueness

Another variable that has been considered in this research is NU, which represents the extent to which an individual is motivated to appear special and different from others (Tian & Bearden, 2001). The concept of consumers' NU first came from Snyder and Fromkin's (1980) theory of uniqueness. Consumers' NU should reflect both self-image and social image. A consumer may use a new product or technology to enhance self-image and social image (Grubb & Grathwohl, 1967). NU can also be connected to consumer behavior and SI (Grubb & Grathwohl, 1967). Therefore, the personality traits of potential consumers may affect how they perceive technology and their intentions to use a new technology.

5. Hypotheses

Based on the literature review, the following hypotheses are related to the UTAUT variables, NU, and use of 3D printing technology to create personal clothes:

H1: There are differences in the PE (H1a), EE (H1b), SI (H1c), FC (H1d), HM (H1e), PV (H1f), and ATUT (H1g) of 3D printing technology to create personal clothes with different demographic characteristics (e.g., age, gender, marital status, and ethnicity).

H2: There are differences in the PE (H2a), EE (H2b), SI (H2c), FC (H2d), HM (H2e), PV (H2f), and ATUT (H2g) of 3D printing technology to create personal clothes with different 3D printing experiences (item and fashion item).

H3: There are differences in the PE (H3a), EE (H3b), SI (H3c), FC (H3d), HM (H3e), PV (H3f), and ATUT (H3g) of 3D printing technology to create personal clothes with a different level of NU in fashion.

H4: There are differences in the NU in fashion with different demographic characteristics (e.g., age, gender, marital status, and ethnicity) (H4a) and 3D printing experience (item and fashion item) (H4b).

H5: People with higher PE (H5a), EE (H5b), SI (H5c), FC (H5d), HM (H5e), PV (H5f), and ATUT (H5g) are more likely to have higher UI to create their own clothes using a 3D printer.

H6: People with higher PE (H6a), EE (H6b), SI (H6c), FC (H6d), HM (H6e), PV (H6f), and ATUT (H6g) are more likely to have higher PI to create their own clothes using a 3D printer.

6. Modified UTAUT Model for 3D Printing Technology

According to the hypotheses, the modified UTAUT for using 3D printing technology to create personalized clothes has been structured as seen in Figure 1. The first row is the variables dividing the sub-groups of participants according to their demographic characteristics (H1), 3D printing experience (H2), or NU (H3-H4). The variables on the second row are the UTAUT variables (PE, EE, SI, FC, HM, PV, and ATUT), and the independent variables to the variables on the third row could affect UI (H5) and PI (H6). Several researchers have suggested positive relationships among the UTAUT variables, as well as UI and PI (Chiu et al., 2010a; 2010b; Martins et al., 2014; Nistor et al., 2014).

III. Methods

1. Sampling and Analysis Methods

An online survey was conducted to test the hypotheses with a purposive sample, which comprises participants who are 18 years or older; live in the United States, which is the location of the largest 3D printing market in the world (Kearney, 2018); and to know what 3D printing is. Information about the survey was uploaded to a website, which contained the survey tool. Participants who were interested in participating in this study started the questionnaire by clicking the accept button and had the option to withdraw whenever they

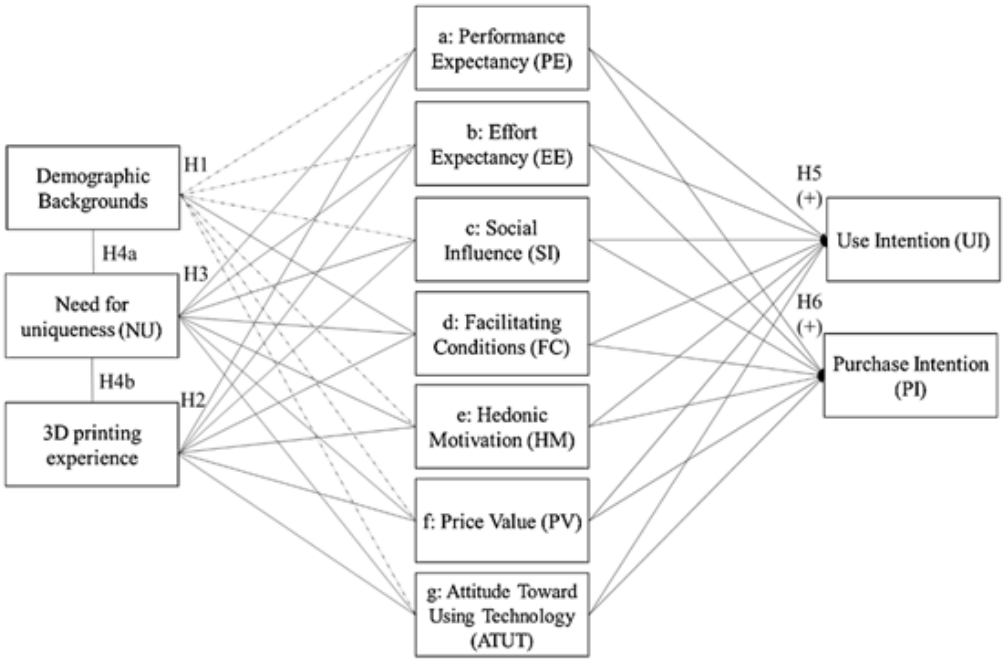

Figure 1. A Research Model of Modified UTAUT for 3D Printing Technology to Create Own Clothes

wanted by leaving the webpage. The collected data was analyzed using SPSS 25.0 with descriptive analysis methods, Welch's *t*-tests and ANOVA for uneven groups with Schefft's ad-hoc tests, and multiple linear regression tests. A series of Welch's *t*-tests and ANOVA were performed to investigate the differences among the sub-groups of different demographic characteristics (H1), experiences (H2), and NU (H3-H4) and performed a multiple linear regression to test the relationships among the UTAUT variables and UI (H5) and PI (H6).

2. Measurement Scales

The Cronbach's alpha values were calculated to measure internal consistency. They ranged from .785 to .904; above .70 indicates high internal consistency (Hallberg & Schaufeli, 2006) (Table 1). The measurement scales of the UTAUT variables were borrowed from the following references: UI, PI, PE, EE, SI, ATUT, FC, HM, and PV. The effect of the participants' demographic characteristics (e.g., age, gender, marital status, and ethnicity) and NU on those UTAUT factors were investigated.

IV. Results and Discussion

1. Sample Characteristics

The total number of participants were 324; they consisted of 192 men (59.26%) and 132 women (40.74%) with a mean age of 30.79 (SD=8.64; range=18-69) (Table 2). The United States is leading in the 3D printing market, and 54% of Americans working in technology or innovation-related fields are skilled users of 3D printing (Anderson, 2017). About 57.72% of major consumers of 3D printers in the U.S. market are in their 20s and 27.16% in their 30s (Kearney,2018).Among the participants, 51.23% are married and 48.15% are single. More than 50% in the demographic makeup were Caucasian, followed by Asian (26.23%) and African American (9.57%). About 85% of

Table 1. Measurement Scales and Cronbach's Alpha Values

Category	Sub-category			Cronbach's alpha
Use intention (UI)	Using 3D printing to make my own clothing is a good idea.	UI1	Holzmann, Schwarz, & Audretsch (2020); Venkatesh *et al.* (2012)	.880
	I intend to use 3D printing to make my own clothing.	UI2		
	I predict I would use 3D printing to make my own clothing.	UI3		
	I plan to use 3D printing to make my own clothing.	UI4		
	I will always try to use 3D printing to make my own clothing.	UI5		
Purchase intention (PI)	Purchasing 3D printing to make my own clothing is a good idea.	PI1	Holzmann *et al.* (2020); Venkatesh *et al.* (2012)	.904
	I intend to purchase 3D printing to make my own clothing.	PI2		
	I predict I would purchase 3D printing to make my own clothing.	PI3		
	I plan to purchase 3D printing to make my own clothing.	PI4		
	I will always try to purchase 3D printing to make my own clothing.	PI5		
Performance expectancy (PE)	I would find 3D printing useful to create my own clothing.	PE1	Venkatesh *et al.* (2012)	.825
	3D printing enables me to accomplish making my own clothes more quickly.	PE2		
	3D printing increases my productivity in making my own clothes.	PE3		
Effort expectancy (EE)	Learning how to use 3D printing to make my own clothing is easy for me.	EE1	Venkatesh *et al.* (2012)	.879
	My interaction with 3D printing to make my own clothing is clear and understandable.	EE2		
	I find 3D printing to make my own clothing easy to use.	EE3		
	It is easy for me to become skillful at using 3D printing to make my own clothing.	EE4		
Social influence (SI)	People who are important to me think that I should use 3D printing to make my own clothing.	SI1	Venkatesh *et al.* (2012)	.892
	People who influence my behavior think that I should use 3D printing to make my own clothing.	SI2		
	People whose opinions that I value prefer that I use 3D printing to make my own clothing.	SI3		
Attitude toward using technology (ATUT)	Using 3D printing to make my own clothing is a good idea.	ATUT1	Holzmann *et al.* (2020); Venkatesh *et al.* (2012)	.866
	3D printing makes creating my own clothing more interesting.	ATUT 2		
	3D printing to make my own clothing would be enjoyable.	ATUT 3		
	I would like work with 3D printing to make my own clothing.	ATUT 4		
Facilitating conditions (FC)	I have the resources necessary to use 3D printing to make my own clothing.	FC1	Venkatesh *et al.* (2012)	.855
	I have the knowledge necessary to use 3D printing to make my own clothing.	FC2		
	3D printing to make my own clothing is compatible with other systems I use.	FC3		
	I can get help from others when I have difficulties using 3D printing to make my own clothing.	FC4		
Hedonic motivation (HM)	Using 3D printing to make my own clothing is (will be) fun.	HM1	Venkatesh *et al.* (2012)	.785
	Using 3D printing to make my own clothing is (will be) enjoyable.	HM2		
	Using 3D printing to make my own clothing is (will be) very entertaining.	HM3		

Table 1. Continued

Category	Sub-category			Cronbach's alpha
Price value (PV)	3D printing to make my own clothing is reasonably priced.	PV1	Venkatesh *et al.* (2012)	.866
	3D printing to make my own clothing is a good value for the money.	PV2		
	At the current price, 3D printing to make my own clothing provides a good value.	PV3		
Need for uniqueness (NU)	When dressing, I have sometimes dared to be different in ways others are likely to disapprove.	NU1	Garrison (2015); Tian & Bearden (2011)	.889
	I often dress unconventionally even when it's likely to offend other.	NU2		
	Concern for being out of place doesn't prevent me from wearing what I want to wear.	NU3		
	If someone hinted that I had been dressing inappropriately for a social situation, I would continue dressing in the same manner.	NU4		
	When I dress differently, I'm often aware that others think I'm peculiar, but I don't care.	NU5		
	I give up wearing fashions I've purchased once they become popular among the general population.	NU6		
	When a style of clothing I own becomes too commonplace, I usually quit wearing it.	NU7		

Table 2. Sample Characteristics of Demographic Backgrounds

Category	Sub-category		No.	%	Rank
Gender	Male		192	59.26	1
	Female		132	40.74	2
Age	10s		3	0.93	6
	20s		187	57.72	1
	30s		88	27.16	2
	40s		33	10.19	3
	50s		8	2.47	4
	60s		5	1.54	5
Marital status	Single		156	48.15	2
	Married		166	51.23	1
	Other		2	0.62	7
Ethnicity	American Indian or Alaskan Native		23	7.10	4
	Asian or Pacific Islander		85	26.23	2
	Black or African American		31	9.57	3
	Hispanic or Latino		13	4.01	5
	White / Caucasian		164	50.62	1
	Prefer not to answer		8	2.47	6
Use experience	Have been used a 3D printer	Yes	276	85.19	1
		No	48	14.81	2
	Have been worn/used 3D printed items	Yes	286	88.27	1
		No	38	11.73	2
	Have been worn 3D printed fashion items	Yes	70	21.60	2
		No	254	78.40	1

participants had used a 3D printer before, and 88% have worn/used printed items or and among them, 21.60% were fashion items.

Regarding their 3D printing experiences, 88.69% of the participants used 3D printed products, 3.57% more than those who have personally used a 3D printer. The high percentage of experiences with 3D-printed items supports why many companies offer 3D printing services such as Shapways, i.materialise, and Thingiverse (Karthik, 2020). There are more consumers using 3D-printed products than those using the 3D printer itself (Lee & Choi, 2017).

However, according to a report by Cell Robox®, published jointly with research firm OnePoll, a survey of 1,000 U.S. consumers found that one in three Americans is considering buying a home-ready personal 3D printer; 65% of consumers considering buying 3D printers were interested in creating and printing customized products for their homes (McCue, 2014). The high percentage of consumers intending to purchase 3D printer shows the possibility that the use of 3D printers at home for personalization can become popular.

Despite the wide ranges of user experience and purchase intention of 3D printing, 3D-printed DIY fashion is still in its infancy due to limitations in printing materials and technologies in the fashion industry, compared to other areas such as engineering and architecture.

2. Results of UTAUT and NU

The mean value of each factor of UTAUT was above 4.5 and ranged from 4.85 to 5.31 (Table 3). Participants had high perceptions of the UTAUT independent factors and dependent factors of UI and PI on using a 3D printer to create their own clothes. The participants agreed that they have a NU in fashion (M=4.97, SD=1.66). According to previous research, fashion opinion leaders have a strong need for differentiation from others and score higher than fashion followers on measures of general NU (Goldsmith & Clark, 2008; Snyder & Fromkin, 1980; Workman & Kidd, 2000).

3. H1-H2: Differences among Demographic Characteristics on UTAUT

The results from the t-tests and ANOVA partially supported H1 and fully supported H2. H1. Regarding the differences among sub-groups with different demographic characteristics on UTAUT factors, men and women were significantly different in FC ($t=.807$, $p \leq .05$). Men, compared to women, had better conditions to use a 3D printer to make their own clothes. This can be due to men's greater willingness than women to put more effort into overcoming difficulties to achieve their goals. On the other hand, women tended to focus more on the extent of effort involved and the process to achieve their objectives (Hennig & Jardim, 1977; Rotter & Portugal, 1969; Venkatesh & Morris, 2000). Therefore, in terms of a new technology—in this case, 3D printing—men rely less on FC and women tend to give more attention to external supporting factors. However, there was no significant difference in UTAUT factors among people with different demographic characteristics such as age, marital status, and ethnicity.

H2. There were significant differences among people with varying levels of experience with 3D printed items and fashion items. Participants who had used a 3D-printed item showed higher perceptions on all the UTAUT factors than participants who had not used one: a) PE ($t=3.702$, $p \leq .05$), that is, they had more positive expectancies of the 3D printing functions; b) EE ($t=3.406$, $p \leq .05$), they thought that using a 3D printer to make their own clothes was easy; c) SI ($t=5.390$, $p \leq .01$), they were more susceptible to use a 3D printer to make their own clothes from others; d) FC ($t=4.898$, $p \leq .001$), they were in a better environment to use a 3D printer; e) HM ($t=1.361$, $p \leq .01$), they perceived the use of a 3D printer to make their own clothes as fun, enjoyable, and entertaining; f) PV ($t=5.448$, $p \leq .01$), they perceived making their own clothing with a 3D printer as reasonable in price; and g) ATUT ($t=3.038$, $p \leq .05$).

Participants with experience in using/wearing 3D-printed fashion items also showed higher perceptions on all the UTAUT factors than those without this

Table 3. Results of UTAUT and the Need for Uniqueness

Category	Sub-category	Mean (SD)	Total Mean (SD)
Use intention (UI)	UI1	5.23(1.41)	5.10(1.55)
	UI2	5.10(1.52)	
	UI3	5.16(1.50)	
	UI4	5.10(1.62)	
	UI5	4.94(1.67)	
Purchase intention (PI)	PI1	5.18(1.42)	5.05(1.60)
	PI2	5.00(1.60)	
	PI3	5.09(1.65)	
	PI4	5.03(1.60)	
	PI5	4.88(1.72)	
Performance expectancy (PE)	PE1	5.25(1.44)	5.20(1.46)
	PE2	5.16(1.46)	
	PE3	5.18(1.44)	
Effort expectancy (EE)	EE1	5.18(1.50)	5.12(1.51)
	EE2	5.08(1.48)	
	EE3	5.08(1.52)	
	EE4	5.12(1.53)	
Social influence (SI)	SI1	4.84(1.76)	4.85(1.76)
	SI2	4.89(1.76)	
	SI3	4.82(1.76)	
Attitude toward using technology (ATT)	ATT1	5.23(1.52)	5.24(1.52)
	ATT2	5.32(1.51)	
	ATT3	5.23(1.47)	
	ATT4	5.22(1.53)	
Facilitating conditions (FC)	FC1	4.90(1.73)	5.03(1.63)
	FC2	5.06(1.62)	
	FC3	4.99(1.56)	
	FC4	5.21(1.56)	
Hedonic motivation (HM)	HM1	5.35(1.40)	5.31(1.44)
	HM2	5.31(1.47)	
	HM3	5.29(1.43)	
Price value (PV)	PV1	4.94(1.62)	5.01(1.61)
	PV2	5.00(1.56)	
	PV3	5.07(1.66)	
Need for uniqueness (NU)	NU1	4.98(1.63)	4.97(1.66)
	NU2	4.89(1.69)	
	NU3	5.17(1.54)	
	NU4	5.03(1.59)	
	NU5	5.06(1.53)	
	NU6	4.84(1.82)	
	NU7	4.82(1.75)	

7-Likert scale: 1=strongly disagree to 7=strongly agree

experience: a) PE (t=3.843, p≤.01), b) EE (t=4.917 p ≤.01), c) SI (t=7.616, p≤.01), d) FC (t=5.903, p≤.01), e) HM (t=1.010, p≤.01), f) PV (t=7.454, p≤.01), and g) ATUT (t=2.907, p≤.01). Moreover, those who used 3D-printed fashion items showed higher UI (t=5.630, p ≤.01) and PI (t=6.893, p≤.01) than those without 3D-printed fashion item experiences.

In terms of NU, the participants who had used a 3D-printed item (t=4.742, p≤.05) and a 3D-printed fashion item (t=7.503, p≤.001) pursued more NU than

people without the 3D-printed item or fashion item use experiences. This is supported by previous research, which has shown that experience can also influence the relationship between FC and BI. Greater experience can lead to better knowledge about the technology and easier user learning, thus reducing user dependence on external support (Alba & Hutchinson, 1987). Also, a meta-analysis showed that users with less experience or familiarity with the new technology depend more on FC (Notani, 1998).

4. H3-H4: Differences in NU on UTAUT

Regarding the NU, H3 was partially supported and H4 was fully supported. H3. Participants who had a greater NU had higher perceptions on all UTAUT factors (.000 ≤p≤.005) except PV (Table 4). Thus, the target consumers of 3D printers for creating their own clothes are people with a high NU. The mean average for PV was 5.01 (SD=1.61), which showed that all participants, whether they had a high or low NU, considered the PV of 3D printers to make their own clothes as reasonable. This may be due to the belief that a 3D printer can make an unlimited number of clothes after purchase. H4. There were differences in NU according to 3D-printed item and fashion item use experiences (.000≤p≤.023). If a participant had 3D printing experience, they were more likely to display NU in their fashion sense.

5. H5-H6: Relationships among UTAUT Variables and UI and PI

The multiple linear regression tests, which categorized PE, EE, SI, FC, HM, PV, and ATUT as independent variables

Table 4. Results of Independent T-test and ANOVA

Category	Hypotheses	Group	Sub-group	Mean	SD	*t*-value	*p*-value
PE	H2a	3D printed item use	Yes	5.31	1.17	3.702	.022
			No	4.34	1.54		
	H2a	3D printed fashion item use	Yes	5.37	1.07	3.843	.000
			No	3.87	1.70		
	H3a	Need for uniqueness	Low	4.28	1.50	-5.644	.001
			High	5.42	1.08		
EE	H2b	3D printed item use	Yes	5.22	1.21	3.406	.041
			No	4.32	1.56		
	H2b	3D printed fashion item use	Yes	5.33	1.09	4.917	.000
			No	4.32	1.61		
	H3b	Need for uniqueness	Low	4.04	1.49	-6.670	.003
			High	5.38	1.09		
SI	H2c	3D printed item use	Yes	5.04	1.46	5.390	.002
			No	3.36	1.82		
	H2c	3D printed fashion item use	Yes	5.24	1.23	7.616	.000
			No	3.35	1.93		
	H3c	Need for uniqueness	Low	3.14	1.76	-8.954	.000
			High	5.26	1.25		
FC	H1d	Gender	Male	5.08	1.26	.807	.028
			Female	4.96	1.48		
	H2d	3D printed item use	Yes	5.19	1.22	4.898	.000
			No	3.78	1.70		
	H2d	3D printed fashion item use	Yes	5.30	1.12	5.903	.000
			No	4.02	1.67		
	H3d	Need for uniqueness	Low	3.81	1.53	-7.294	.005
			High	5.32	1.13		

Table 4. Continued

Category	Hypotheses	Group	Sub-group	Mean	SD	*t*-value	*p*-value
HM	H2e	3D printed item use	Yes	5.35	1.13	1.361	.006
			No	4.97	1.65		
	H2e	3D printed fashion item use	Yes	5.35	1.06	1.010	.000
			No	5.14	1.64		
	H3e	Need for uniqueness	Low	4.65	1.65	-3.719	.000
			High	5.47	1.01		
PV	H2f	3D printed item use	Yes	5.19	1.28	5.448	.005
			No	3.64	1.67		
	H2f	3D printed fashion item use	Yes	5.36	1.10	7.454	.000
			No	3.71	1.72		
ATUT	H2g	3D printed item use	Yes	5.34	1.20	3.038	.014
			No	4.48	1.67		
	H2g	3D printed fashion item use	Yes	5.38	1.08	2.907	.000
			No	4.72	1.79		
	H3g	Need for uniqueness	Low	4.36	1.72	-4.803	.000
			High	5.46	1.06		
			High	5.38	1.08		
NU	H4b	3D printed item use	Yes	5.10	1.20	4.742	.023
			No	3.88	1.51		
	H4b	3D printed fashion item use	Yes	5.27	.99	7.503	.000
			No	3.76	1.58		

Table 5. Results of Multiple Linear Regression Analysis of UTAUT

Depen -dent	Hypotheses	Independent	*B*	Constant *B*	*β*	*t*-value	*p*-value	VIF	Adjusted R^2	Durbin-Watson
UI	H5a	PE	.050	.273	.050	1.137	.000	3.557	.828	1.873
	H5b	EE	.148		.149	3.274		3.864		
	H5c	SI	.237		.297	6.720		3.634		
	H5d	FC	.212		.225	4.521		4.610		
	H5e	HM	.026		.024	.581		3.306		
	H5f	PV	.005		.005	.121		3.540		
	H5g	ATUT	.325		.328	7.226		3.851		
PI	H6a	PE	.217	-.157	.201	5.083	.000	3.557	.860	1.829
	H6b	EE	.156		.148	3.588		3.864		
	H6c	SI	.256		.300	7.516		3.634		
	H6d	FC	.253		.252	5.608		4.610		
	H6e	HM	.008		.007	.195		3.306		
	H6f	PV	.039		.041	1.041		3.540		
	H6g	ATUT	.098		.093	2.269		3.851		

and UI and PI as the dependent variables, determined significant relationships among those factors and supported H5 and H6 (Table 5). H5. The variance inflation factors of all predictor variables were below 4.610; values lower

than 10 indicate no multicollinearity issues (Freund, Wilson, & Sa, 2006). There were all positive relationships among the variables. If the independent variables (PE, EE, SI, FC, HM, PV, and ATUT) were higher, the participants demonstrated more UI for a 3D printer to create their own clothes (R2Adjusted=.828, p≤.001). H6. Similarly, participants with higher PE, EE, SI, FC, HM, PV, and ATUT showed higher PI for a 3D printer to create personal clothes (R2Adjusted=.860, p≤.001).

V. Conclusion

This study explored the potential of personalized fashion designs using 3D printing technology by attempting to further understanding on the relationships between the UTAUT, the need for uniqueness, and demographic characteristics on technology adoption. The study's major results were, first, regarding the differences in UTAUT factors among sub-groups with varying demographic characteristics, men and women were significantly different in facilitating conditions. Men had better conditions to use a 3D printer to make their own clothes than women. Thus, when it comes to using a new technology—in this case, 3D printing—men rely less on facilitating conditions and women tend to give more attention to external supporting factors. These results indicate that the future development of the 3D printing market should focus on considering women's tendencies to make 3D printing more user-friendly to female consumers. This could be achieved by making existing 3D CAD software, 3D printing operation software, methods of inserting and extruding filaments to be easy to use without needs of reading the instructions.

Second, there was no significant difference in UTAUT factors among people with different demographic characteristics such as age, marital status, and ethnicity. However, there were significant differences among people with different 3D-printed items use experiences. Those who had experience with 3D-printed items also showed higher perceptions on all the UTAUT factors, use and purchase intentions than those without this previous experience. Therefore, consumers with 3D printed fashion item use experiences are more likely to use 3D printers to create their personalized clothes. This shows that the experience and exposure to the 3D printing is important to increase the adoption level of the 3D printing to create their own clothes. Marketers and retailors in 3D printing market can provide trial chances of using 3D printers and 3D printed items to consumers.

Third, the people who had experienced 3D-printed items showed more needs for uniqueness than people who had not experienced 3D-printed item or fashion items. Also, the need for uniqueness has a positive influence on consumers' intention to use 3D printing technology for making personal clothes. Thus, the potential target group of 3D printers for creating own clothes could be people with a high need for uniqueness who have more tendency of 3D printed item use experiences. The emphasis on the uniqueness of fashion items could attract more consumers, and the consistent developments of unique textures, colors, material types that affect the design outcomes could also maintain existing experienced consumers.

Fourth, this study showed that all participants, whether they had a high or low need for uniqueness, perceived the price value of the 3D printer to make their own clothes is important. The reasonable price would be the key drive to popularize this technology in fashion, so it is recommended to developers and marketers/retailers to make the 3D printer be reasonable in price.

Next, regarding the relationships among UTAUT variables, as well as use intention and purchase intention, there were all positive relationships between the variables. If the independent variables of all UTAUT were higher, the participants were more likely to express use and purchase intentions for a 3D printer to create their own clothes. Thus, it is important to make the 3D printing to create their own clothes to be useful, fun and interesting, socially acceptable, easy to use, and prepare infrastructure to support the use of 3D printing This may be achieved by providing open-sources or education opportunities that anyone can participate, and future technology improvements can include the development of various 3D printing materials that meet consumer tastes

and preferences and the development of interfaces.

This study analyzed the potential for the popularization of 3D printing technology to create their own fashion items and explored consumers' willingness to embrace and use personal fashion designs. However, due to the uneven number of sub-groups, future studies should make a comparison using balanced groups. Future studies can investigate other variables that might affect the acceptance rate of 3D printing for fashion items and compare their differences among people in diverse demographic such as different countries and other personal characteristics.

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