3D Bio-printing in Medical Treatment: A Technology Acceptance Model

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***Abstract*--The 3D printing technology has been broadly applied in many industries. In medical science, 3D bio-printing is used for generating biological tissues and provides customized biological needs for patients. Nowadays, 3D bio-printing can print blood vessels, skin tissue, heart tissue, and artificial bones for surgical therapy or transplantation. The potentials of 3D bio-printing in medical science may create many business opportunities and greatly benefits patients. Although many successful cases have been reported in USA and UK, 3D bio-printing technology is relatively new in Taiwan. The question concerning how people in Taiwan approach the new technology or whether they would accept the new technology used in their medical treatments remains unknown. Thus, this study investigates the acceptance of 3D bio-printing applied in medical treatment from the perspectives of people in Taiwan. Two hundred forty nine adults (86 males, 163 females, average age 31) voluntarily completed an online survey. We used item analysis, factor analysis, and structural equation model (SEM) to build a TAM 3D bio-printing applied in medical treatment, which included perceived usefulness and confidence. This model may facilitate business in promoting 3D bio-printing in medical treatment, from which patients may gain benefits.**

I. INTRODUCTION

The growth of 3D printing industry is forecasted to 8.4 billion dollar by 2025 [1]. The rapid manufacturing of 3D printing speeds up the growth by skipping prototyping phase and go directly to making the end product; the fast and efficient printing of parts, such as car and house parts, contributes greatly to the value chain [2]. The customization feature of 3D printing expends the market by enabling end users to send self-designed or edited digital files the manufacturers for productions. For instance, Nokia Company released the 3D design files of its case to its customers, who may modify their specifications and receive the case with their own unique specifications [3].

In particular, 3D bio-printing application in medical field has grown rapidly in the past decade. Regenerative medicine and tissue engineering construct artificial tissue models as a revolutionary medicine in future [4]. Bio-ink-jet printing technology uses living cells as “ink” to “print” and hydrogels as “glue” to construct complex and customized architectures [5, 6]. 3D bio-printing can produce living cells, vessels, skin, bones, ears, tissues exoskeletons, stem cells, blood vessels, and organs for medical treatment [7-10]. The greatest advantage of 3D bio-printing is to produce custom-made tissues and organs that may largely solve the medical problems concerning tissue or organ failure due to aging, diseases, accidents, and birth defects as well as make a great contribution to the chronic shortage of human organs available for transplant [5, 8].

3D bio-printed market is anticipated to grow significantly. The demand of tissue and organ donations is huge, but the supply of these donations is facing serious shortage, only a small portion of people on the long waiting lists received organ transplants. The World Health Organization reports that about 28,000 transplants (33%) of 120,000 people on waiting lists are performed each year in the United States; internationally, less than 10% of the global demand for organ transplants is met [11]. 3D bio-printed organs with the features of fast manufacturing and low cost [7, 12] can supply many tissues and organs transplants and solve the problem of shortage.

The acceptance of a new technology in a market is critical to the successful application of the technology. For examples, studies about technology acceptance models (TAM) indicate that perceived usefulness and ease of use are the two major factors toward the acceptance of various technologies, including Web Course Tools (WebCT), a computerized system used in higher education institutions to support e-learning [13], healthcare information systems [14], making business decisions using Decision Support System (DSS), a computer system that can support multifaceted decision making and problem solving [15], and the use of smartphones [16]. In addition, individual factors, such as anxiety or confidence toward new and unfamiliar objects, may as well influence people’s behavior in adopting new technology; similar finding was reported in the study concerning employees’ acceptance and use of teleconferencing systems for work-related meetings [17].

However, whether the people in Taiwan would accept 3D bio-printing in medical treatment has not been examined so far. In particular, questions like whether people in Taiwan would perceive 3D bio-printing as safe and effective medical treatments, or if they’re anxious about the new technology, remain unanswered. Thus, this study proposed and built a technology acceptance model (TAM) of 3D bio-printing in medical treatment considering user perceived usefulness and individual factors (e.g. anxiety to new technology). Our hypotheses included H1: People perceived usefulness would be positively related to their acceptance of 3D bio-printing in medical treatment; and H2: People perceived confidence would be positively related to their acceptance of 3D bio-printing in medical treatment. **Figure 1** presents the research model: A technology acceptance model (TAM) of 3D bio-printing in medical treatment.

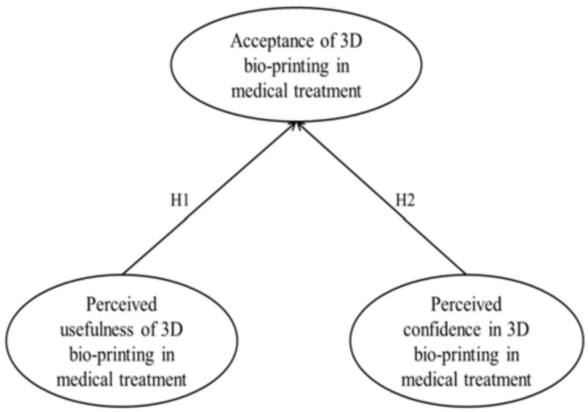

Figure 1 A technology acceptance model of 3D bio-printing in medical treatment

II. METHOD

A. Participants

Participants were invited through email and Facebook messages to fill out the online survey concerning their views of 3D printing in medical treatments. Participants were informed about the purpose of this study along with a brief description of 3D printing in medical treatments, including its concepts, unique features, successful cases, and potential benefits of 3D bio-printing applications in medical treatments. Then, participants were informed about with their rights and confidentiality of data. Participants must check the box indicating "Agree to participate in this study" in order to respond to items of the survey.

There were 255 participants voluntarily completed the online survey. After excluding six participants whose living area was not Taiwan, this study included 249 adults in Taiwan (age *mean* = 31.12, *SD* = 14.05, range 18 – 67). **Table 1** presents participants characteristics.

TABLE 1. PARTICIPANTS CHARACTERISTICS (N = 249)

		n	%
Age	18-20	29	11.6
	21-30	147	59.0
	31-40	11	4.4
	41-50	25	10.0
	51-60	21	8.4
	61 & older	16	6.4
Gender	Male	86	34.5
	Female	163	65.5
Student	Student	132	53.0
	Non-student	117	47.0
Affiliated institution	Medical institution	50	20.1
	Non-medical institution	199	79.9
Occupation	Student major in medical science and alike	93	37.3
	Student not major in medical science or alike	39	15.7
	Employee associated with medical institution and alike	106	42.6
	Employee not associated with medical institution or alike	11	4.4

B. Sources of items for technology acceptance model

Several technology acceptance models (TAM) were used to provide resources for generating initial items of using 3D bio-printing in medical treatment. Ngai, Poon and Chan [13] developed a TAM concerning the perceived ease of use and usefulness of Web Course Tools (WebCT), a tool used in higher education institutions to support e-learning. Pai and Huang [14] proposed a conceptual TAM about using healthcare information systems and identified two key factors, perceived usefulness and perceived ease-of-use. Dulcic, Pavlic and Silic [15] built a TAM concerning making business decisions using Decision Support System (DSS), a computer system that can support multifaceted decision making and problem solving; they found that the perceived usefulness and perceived ease of use were the core factors in using DSS. Joo and Sang [16] developed a TAM of the use of smart-phones and found that users' intrinsic motivations and extrinsic perceptions were the importance factors. Park, Rhoads, Hou and Lee [17] constructed a TAM in business settings concerning employees' acceptance and use of teleconferencing systems for work-related meetings; their results showed that both individual factors (e.g. anxiety and self-efficacy) and institutional factors (e.g. institutional support and voluntariness) were significantly associated with perceived ease of use, perceived usefulness, and actual use of the systems. Taken together, user perceived usefulness and ease of use are the two main factors of TAM. In the present study, we focused on the public view of 3D bio-printing in medical treatment, not specifically on the views of physicians who actually use 3D bio-printing technology; thus, we included the user perceived usefulness aspect and excluded the ease of use aspect.

Another consideration was user psychological responses to new technology. This study was used State-trait anxiety inventory (STAI) to form items of individual factors [18, 19]. STAI is a common measurement used to test the degree of anxiety; examples items of Trait anxiety include: "I worry too much over something that really doesn't matter" and "I am content; I am a steady person." In the present study, items were modified as "I'm afraid of using 3D bio-printing in medical treatment;" "I hesitate to use using 3D bio-printing in my medical treatment;" "I'm confused about using 3D bio-printing in medical treatment;" and "I worry that using 3D bio-printing in medical treatment may not meet the expected results." These items were used as reversed items toward the confidence in using 3D bio-printing in medical treatment.

All items were on a 5-point Likert scale with "1" indicating strongly disagree to "5" indicating strongly agree. Higher scores represented higher acceptance of using 3D bio-printing in medical treatment.

C. Model development procedure

Figure 2 presents the model development stages of the technology acceptance model of 3D bio-printing in medical treatment. Two researchers generated initial items from the items of TAMs and STAI [18, 19], then, selected and revised items suitable for the case of using 3D bio-printing in medical treatment to form the revised items. The revised items were distributed through online survey.

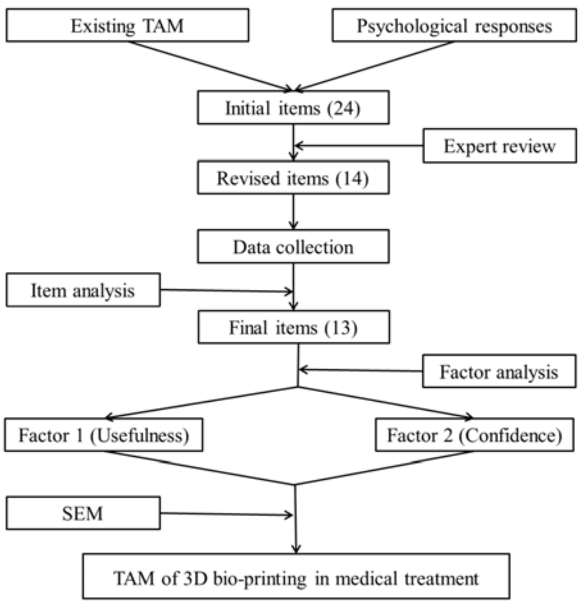

Figure 2 Stages of model development: A technology acceptance model of 3D bio-printing in medical treatment

D. Statistical analysis

The item analysis and factor analysis of SPSS (v. 19, Chicago, IL) were used to analysis survey data. Item analysis was applied to determine the internal consistence among the revised items. Based on results of item analysis, decisions concerning keeping or removing an item were made to form the final items. An item with corrected item total correlation ≧ .30 was kept; or an item with corrected item total correlation < .30 was deleted, one item at a time; reliability was recalculated after each deletion.

Factor analysis was used on the final items to identify latent variables with corresponding items loadings. The initial factor analyses used Principal Components Extraction method and the follow-up factor analyses used Principal Axis Factoring method with Varimax Rotation; significant Bartlett's test and KMO > 0.6. were criteria used.

Structural equation model (SEM) analysis of AMOS (v. 20, Chicago, IL) was used to build the acceptance model of 3D bio-printing in medical treatment. SEM examined the goodness-of-fits of maximum likelihood estimation of the overall model; the criteria included a non-significant value of Chi-square test, RMSEA < .05, incremental fit measures (AGFI, NFI, IFI, & CFI) > .90, , and parsimonious fit measures (PNFI, PCFI, & PGFI) > .50.

III. RESULTS

This section shows the results of items analysis and factor analysis, which identified two factors, perceived usefulness of and confidence in using 3D bio-printing in medical treatment. Then, we used structural equation model (SEM) to build a TAM of 3D bio-printing in medical treatment. Results supported both hypotheses; H1: User perceived usefulness was positively related to their acceptance of 3D bio-printing in medical treatment; and H2: User perceived confidence was positively related to their acceptance of 3D bio-printing in medical treatment.

A. Item analysis

Table 2 presents the revised items with squared multiple R. The results of item analysis on the 14 revised items indicated that Item 3 had a squared multiple correlations smaller than 0.3, which was then deleted to form the final items. Internal consistence reliability of the final items was high (Cronbach's alpha = 0.880).

TABLE 2. REVISED ITEMS WITH SQUARED MULTIPLE R

#	Item	Squared Multiple R	Keep (○) or remove (×)
1	I think that using 3D bio-printing in medical treatment would facilitate us to achieve certain medical treatment goals.	.576	○
2	I would be very happy to learn about the application of 3D bio-printing in medical treatment.	.379	○
3	I worry that using 3D bio-printing in medical treatment may not meet the expected results. (reversed item)	.261	×
4	It's rather practical to apply 3D bio-printing in medical treatment.	.637	○
5	I'm confused about using 3D bio-printing in medical treatment. (reversed item)	.447	○
6	I intend to recommend my relatives and friends to use 3D bio-printing in medical treatment.	.569	○
7	I intend to use the 3D bio-printing in the near future.	.603	○
8	Using 3D bio-printing in medical treatment can shorten the time of treatment.	.609	○
9	I hesitate to use using 3D bio-printing in my medical treatment. (reversed item)	.562	○
10	Using 3D bio-printing in medical treatment is beneficial to patients.	.671	○
11	The concept of using 3D bio-printing in medical treatment is easy to be accepted.	.549	○
12	3D bio-printing in medical treatment can be widely and flexibly applied in various conditions.	.522	○
13	I'm afraid of using 3D bio-printing in medical treatment. (reversed item)	.593	○
14	Overall, I believe that using 3D bio-printing in medical treatment benefits the health of human being.	.646	○

B. Factor analysis and the TAM of 3D bio-printing in medical treatment

We applied factor analysis with principal components and varimax rotation abstract method on the final items to identify latent factors to build the model. **Table 3** shows the factors and factor loadings of the TAM of 3D bio-printing in medical treatment. The model was significant (*KMO* = 0.900, χ^2 = 1282.885, *df* = 78, *p* = 0.000) with two factors; one factor named perceived usefulness of 3D bio-printing in medical treatment had 34.767% of cumulative variance (Cronbach's alpha = 0.879); the other factor named confidence in 3D bio-printing in medical treatment had 53.714% of cumulative variance (Cronbach's alpha = 0.756); all items collectively were accounted for 53.714% of cumulative variance of the model (Cronbach's alpha = 0.880).

C. Structural equation model

This study examined the goodness-of-fits of maximum likelihood estimation of the overall model and information observations in three types: absolute fit measures, incremental fit measures and parsimonious fit measures. The model's indices of absolute fit measures (χ^2 = 54.315, *df* = 52, χ^2/df = 1.045, *p-value* = 0.386, *GFI* = 0.968, *RMSEA* = 0.013), incremental fit measures (*AGFI* = 0.945, *NFI* = 0.959, *IFI* = 0.998, *CFI* = 0.998), and parsimonious fit measures (*PNFI* = 0.639, *PCFI* = 0.665, *PGFI* = 0.553) were all within acceptable range and indicating a good fit of the internal structure of the model. Table 4 presents the standardized total effects of 3D bio-printing in medical treatment. Our results supported both hypotheses; H1: User perceived usefulness had 0.466 total effects on and was positively related to their acceptance of 3D bio-printing in medical treatment; and H2: User perceived confidence had 0.655 total effects on and was positively related to their acceptance of 3D bio-printing in medical treatment (**Figure 3).**

TABLE 3. FACTORS AND FACTOR LOADINGS OF TAM OF 3D BIO-PRINTING IN MEDICAL TREATMENT

#	Item	Loading	Factor name	Rotation sums of squared loadings		
				Total	% of variance	Cumulative %
4	It's rather practical to apply 3D bio-printing in medical treatment.	0.805	Perceived usefulness of 3D bio-printing in medical treatment	4.520	34.767	34.767
8	Using 3D bio-printing in medical treatment can shorten the time of treatment.	0.790				
10	Using 3D bio-printing in medical treatment is beneficial to patients.	0.738				
1	I think that using 3D bio-printing in medical treatment would facilitate us to achieve certain medical treatment goals.	0.689				
14	Overall, I believe that using 3D bio-printing in medical treatment benefits the health of human being.	0.679				
12	3D bio-printing in medical treatment can be widely and flexibly applied in various conditions.	0.669				
7	I intend to use the 3D bio-printing in the near future.	0.646				
6	I intend to recommend my relatives and friends to use 3D bio-printing in medical treatment.	0.565				
2	I would be very happy to learn about the application of 3D bio-printing in medical treatment.	0.520				
11	The concept of using 3D bio-printing in medical treatment is easy to be accepted.	0.453				
13	I'm afraid of using 3D bio-printing in medical treatment. (reversed item)	0.788	Perceived confidence in 3D bio-printing in medical treatment	2.463	18.946	53.714
9	I hesitate to use using 3D bio-printing in my medical treatment. (reversed item)	0.786				
5	I'm confused about using 3D bio-printing in medical treatment. (reversed item)	0.783				

TABLE 4. STANDARDIZED TOTAL EFFECTS: TAM OF 3D BIO-PRINTING IN MEDICAL TREATMENT

# Item	Standardized total effects
Factor 1: Perceived usefulness of 3D bio-printing in medical treatment	0.466
1 I think that using 3D bio-printing in medical treatment would facilitate us to achieve certain medical treatment goals.	0.608
2 I would be very happy to learn about the application of 3D bio-printing in medical treatment.	0.393
4 It's rather practical to apply 3D bio-printing in medical treatment.	0.720
6 I intend to recommend my relatives and friends to use 3D bio-printing in medical treatment.	0.641
7 I intend to use the 3D bio-printing in the near future.	0.659
8 Using 3D bio-printing in medical treatment can shorten the time of treatment.	0.761
10 Using 3D bio-printing in medical treatment is beneficial to patients.	0.773
11 The concept of using 3D bio-printing in medical treatment is easy to be accepted.	0.600
12 3D bio-printing in medical treatment can be widely and flexibly applied in various conditions.	0.632
14 Overall, I believe that using 3D bio-printing in medical treatment benefits the health of human being.	0.743
Factor 2: Confidence in 3D bio-printing in medical treatment	0.655
5 I'm confused about using 3D bio-printing in medical treatment. (reversed item)	0.589
9 I hesitate to use using 3D bio-printing in my medical treatment. (reversed item)	0.756

13 I'm afraid of using 3D bio-printing in medical treatment. (reversed item)	0.801

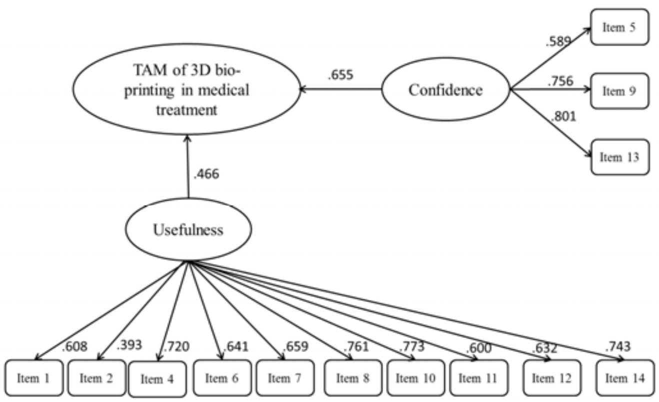

Figure 3 TAM of 3D bio-printing in medical treatment with standardized total effects

IV. DISCUSSION

This study built a TAM of 3D bio-printing in medical treatment (**Figure 3**). Our results supported both hypotheses. H1: User perceived usefulness was positively related to their acceptance of 3D bio-printing in medical treatment (34.767% cumulative loadings, 0.466 total effects). This finding is in line with previous findings that perceived usefulness is an important factor toward the acceptance of technology [13-16]. H2: User perceived confidence was positively related to their acceptance of 3D bio-printing in medical treatment (53.714% cumulative loadings, 0.655 total effects). This finding agrees with the view that individual factors (e.g. anxiety and self-efficacy) were associated with their behavior about acceptance of technology [17-19].

This model may facilitate business in promoting 3D bio-printing in medical treatment, while maximize the benefits toward patients. Our findings also show that user perceived confidence had higher cumulative loadings and total effects than user perceived usefulness. These findings highlight the important influence of individual factors on the acceptance and use of technology. Marketing strategies should focus more on enhancing user confidence, while introducing the usefulness of 3D bio-printing in medical treatment.

This study contributes to the field of 3D bio-printing application in biomedical innovation by constructing an acceptance model of a new technology and pointing out the importance of people perception of the 3D bio-printing technology in medical treatments. Previous studies in biomedical innovation rarely consider patient psychological aspects toward new technology. This model including people perceptions, usefulness and confidences, may enhance the acceptance and promotion of the successful application of the new technology of 3D bio-printing.

Technology management of 3D bio-printing is critical, as the impacts of biotechnology are profound and multi-dimensional, including current and future, regional and global, as well as medical industrial competitiveness and economic development [20, 21]. Leaders of bio-medical governmental departments, health institutions, and industries should work together to establish national-level strategies and regulations for the technology management of 3D bio-printing in order to meet the needs of the new technology's rapid development. Technology management strategies are critical in shaping and guiding the development of 3D bio-printing industry in the field of medical treatment [22].

This model may be implemented in different countries by conducting surveys to further understand the acceptance of 3D bio-printing technology; various cultures may impact the degree of accepting new technology in different ways. As 3D bio-printing technology applied in medical treatment most likely will progress prosperously, this model may also be repeated to observe the changes of people's acceptance of 3D bio-printing in a country.

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