THE EFFECTS OF PERCEIVED BARRIERS AND PERCEIVED ENJOYMENT ON USERS' INTENTION TO USE 3D PRINTER TECHNOLOGY

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ABSTRACT

The main purpose of this study is to investigate the intention of consumers to use desktop 3D printers with taking into account the dimensions of perceived barriers and enjoyment. This study contributes to the early understanding of Turkish consumers' intention to use desktop 3D printers. According to the results of the research; the effect of the perceived enjoyment on intention to use of 3D Printer was positive and the effect of the perceived barrier on intention to use was negative. When the results are anticipated in terms of 3D Printer ownership; the perceived enjoyment in user group who have 3D Printer was lower than the group who do not have, whereas risk perceptions stems from barriers was higher for this group.

Keywords: 3D Printer, Perceived Barriers, Perceived Enjoyment, Additive Manufacturing, Third Industrial Revolution

INTRODUCTION

3D printer technology use additive manufacturing method unlike the classical manufacturing method where traditional production tools such as lathe, drill, saw are used, thus complex and nested models such as bearings can easily be produced with less cost (Wallenius & Decade, 2014). Although 3D printing technology is still in its infancy, it's rapidly developing especially in the manufacturing industry as an alternative method for mass production. This new production technology calls third industrial revolution. This revolution leads to a more economical production in a smaller number and requires much lower input of labour. It's expected that industrial machinery, aerospace, automotive, medical & dental devices, and consumer products are five leading manufacturing industries that will use 3D printer technologies more intensively. Within 20 years, it's predicted that products of 3D Printers will constitute half of the total production (Leering, 2017; The Economist, 2012). Along with the remarkable improvement in the manufacturing industry, 3D printers seem to be very popular among end users with allowing customers to produce simple or complex objects in their homes with their desktop 3D printers. Reports show that the number of desktop 3D printers sold in 2017 hit the half million. According to the estimations, within 2020 1.5 million 3D Printer will be sold, and global desktop 3D printing market is expected to reach $7.2 billion market size by 2019 (Adams, 2017; Alliedmarketresearch.com, 2018). In this respect, examining the factors that affect the consumers' intention to use 3D printers as a new technology is valuable. Depending on the fact that previous research on this topic is extremely limited, this study attempts to provide original contribution to the relevant literature.

LITERATURE REVIEW

Technology Adaptation Model (TAM) is simple, powerful and the most widely applied model for determining users' acceptance and utilization of new technologies. Basically, it states that perceived usefulness and perceived ease of use have significant effect on intention to use new technologies (Bagozzi & Warshaw, 1989; Davis, 1989). The basic TAM model and extended versions have been used for many different technologies such as; on-line shopping (Vijayasarathy, 2004), consumer acceptance of online banking (Pikkarainen et al., 2004), mobile commerce (Wu & Wang, 2005), usage of e-Learning (Calli et al., 2013) and willingness to adopt wireless Internet via mobile devices (WIMD) (Lu et al., 2003). As a relatively a new subject, there are not enough academic studies related with intention to use or acceptation of the desktop 3D printer technology by end users in literature. However, there are some important studies that have investigated organizational adoption of 3D printing in manufacturing industry such as; Yeh and Chen (2018) examined the organizational perspectives and critical success factors influencing the adoption of 3D printing. Within the scope of this study four dimensions and thirteen criteria were examined; these dimensions are Technology, Organization, Environment and Cost. Although the results show that cost is the most important factor, differences have emerged among the departments in determining the critical success factors. Schniederjans and Yalcin (2018) developed a new model that consists of seven dimensions from five widely used adoption theories for new adoption model specific to 3D-printing technology in manufacturing organizations within the USA. Other studies that investigated the subject of 3D printer adaptation in the manufacturing industries are as

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follows; impact of 3D printing technologies on business models (Rayna & Striukova, 2016) and top-management 3D printing adoption (Schniederjans, 2017).

During the literature review stage of this research only one academic study has been found on the adaptation / intention to use of the desktop 3D printers by end user (customer). An empirical academic study which integrated with Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT) states that perceived ease of use, perceived usefulness, perceived compatibility and perceived enjoyment are the main forces behind users' intentions to accept 3D Printing technology (Wang et al., 2016). Results of this study also shows that younger people are more likely to be early adopters of 3D printers. In another study conducted by desk research methodology suggests six main technological characteristics to be used for better understanding of the challenges of selling consumer level 3D printers. These are; the form of the printer, the frame, the build platform, the extruder and hot-end, the movement, and the computer-printer interface (Harm-Jan, Ulusemre, & Xin, 2018). This study was conducted from a more technical perspective and demonstrated 3D Printers' technological characteristics from the viewpoint of consumers without considering the antecedents of intention to use 3D printer or its adaptation. In this respect; it makes significance to conduct research about consumers acceptance and use of 3D printer as a new technology and to investigate the antecedents impacting on consumers' intention to use 3D Printer.

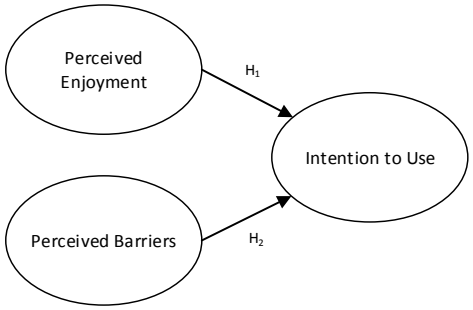
CONCEPTUAL FRAMEWORK

While there are a numerous of specific factors thought to be effective on the consumer's intention to purchase 3D Printer; such as ability to print colour, materials for frame, power outage protection, etc. (Harm-Jan et al., 2018), but it is quite difficult to measure all variables in an empirical study. For this reason, this research which was described as an exploratory study mainly focused on the two general factors which are believed to be the major influencers of the intention to use/adoption of 3D Printer. Specifically, the effect of perceived barriers and perceived enjoyment on the intention to use Desktop 3D Printer were investigated in this study.

Ram and Sheth (1989) defined the concept of innovation resistance and investigated on the factors causing consumers to resist on innovations. Innovation resistance was explained as the resistance of consumers to new innovations depending on the fact that innovations necessitate changes in routines and established status quo or they contradict with the beliefs and ideas. This resistance stems from both functional barriers and psychological barriers including norms of the individuals and perceived image of the innovative product. In the case of functional barriers, product utilization patterns, value of the product and risks regarding the product utilization are among this kind of barriers (Ram & Sheth, 1989). From the aspect of risk barrier, risk is defined as a situation where the probabilities of outcome are not well known. If a new technology is not sufficient to give the consumer the expected outcome, it will lead to loss on the consumer in different aspects such as financial, psychological, physical or social (Im, Kim, & Han, 2008). Ram and Sheth (1989) proposed a similar categorization and claimed that there are four types of risks associated with the adoption of innovations compromising; ***physical risk***, ***economic risk***, ***functional risk*** and ***social risk***. For this research, short interviews were conducted with experts using 3D printers, long production time and cost (machine & filament) dimensions were expressed as effective factors against on intention to use technology by them. In the market there are different 3D Printers for different budgets. Cost would be high when plug & play system is purchased but cost is reduced when printer is assembled by user. Yeh & Chen (2018) has found that cost is very important factor for the adoption of 3D printing in manufacturing industry. In the interviews, the duration of production process has been expressed as an important barrier especially for industrial purpose by experts.

This study also explores the impact of ***perceived enjoyment*** on the intention to use 3D Printer. Davis et al. (1992) indicated that users' intentions to use computers in the workplace are affected by the degree of enjoyment they experience in using the computers on their own and the result of this study suggested that enhancing enjoyability may increase the adoption of unproductive systems. According to Venkatesh et al. (2002) perceived enjoyment which is defined as intrinsic motivation in research served as an important predictor of intentions to use the technology, and also Wang et al. (2016) discovered a positive effect of perceived enjoyment on intention to use 3D printer and defined this dimension as perceived to be fun or enjoyable. End-user has both become the producer and the consumer in the new era that has evolved with 3D Printer technology as a result of democratization of design and production. Moreover, co-production of products also affect the consumers' attitudes (Clark, Calli, & Calli, 2014). Within the scope of the study, the emotional state of the consumer especially perceived enjoyment in the production process is thought to be important on the intention to use 3D Printers.

Figure 1 Conceptual Model



RESEARCH METHODOLOGY

Online survey method was mainly used in the study. Particularly, in order to discover perceived barriers against intention to use 3D Printer, experts using 3D printers were asked to state their opinions before the preparation of online survey. Regarding the construction of the questionnaires, findings from the interviews and the studies of Sun & Zhang (2006), Im et al. (2008) and Martins et al. (2014) were taken into account. 3D Printer is a novel technology thus this study is an exploratory research in its nature (Malhotra, 2004). Depending on the fact that the number of desktop 3D Printer users either for hobby or business purposes is unknown, it was important to access owners of 3D Printers in a convenient manner. Hence, convenience sampling as a non-probability sampling technique was used for reaching 3D printer owners with 3D Printer groups in Facebook. In this respect, it is not possible to generalize the results of this study. As shown in figure 1, two hypotheses (H_1:The positive effect of perceived enjoyment on intention to use, H_2: The negative effect of perceived barriers on intention to use) will be tested within the scope of the research.

Descriptive Statistics

The survey was conducted in July 2018 and a total of 463 participants constituting 409 (88,3%) male and 54 (11,7%) female respondents were reached. 74,7% of the participants were in the age group of 18-29, and 67,4% of the participants defined their education level as university. In terms of monthly income, 50.3% of the participants stated that they had monthly income of 1.300 TL or less. 60.5% of the respondents stated their profession as a student. Finally, 258 respondents (55.7%) stated they had a 3D printer.

Data Analysis and Results

Confirmatory Factor Analysis (CFA) was conducted for validation and reliability of the measurement model before the conceptual model was tested. The findings presented in Table 1, 2 and 3 were obtained. Three items representing perceived cost, time and performance barriers in the conceptual model were removed because of non-significant results. These items were; "*It is probable that 3D Printer would frustrate me because of its poor performance", "I think it takes a long time to produce with a 3D printer*", "*It is probable that 3D Printer would not be worth its cost".*

Table 1: Factor Scores of the Measurement Model

Factors	Item in The Questionnaire	Standardized Regression Weights (λ)	Error Variance ε = (1- $\lambda^{2)}$
Perceived Enjoyment	I find 3D Printer is fun to use	,797	,366
	I feel happy when using 3D Printer	,804	,354
	I think the production with 3D printer is enjoyable.	,791	,374
Perceived Barriers	I don't feel myself ready for this technology right now.	,796	,366
	I do not think I can use this technology because I find it too complicated.	,692	,521
	It is unclear whether 3D Printers will be a useful technology.	,607	,631
Intention to Use	I predict I would use 3D Printer in the future	,860	,260
	I would recommend using 3D Printer to my friends.	,862	,256
	I predict I would use 3D Printer in the future	,724	,476

** The standardized regression coefficients (λ) of all the items in the table are significant at p <0.001.*

The findings in Table 1 give the standardized regression coefficients (λ) and error variances (1- λ^2) which demonstrate the link between each item and the relevant factor. The fit indices of the model in Table 2

also reveal that the model is well adapted to the given data (Byrne, 2010; Schumacker & Lomax, 2004; Schermelleh-Engel, Moosbrugger, & Müller, 2003) Thus, it can be concluded that Perceived Enjoyment, Perceived Barriers and Intention to Use factors are well represented by the items shown in Table 1.

Table 2: Fit Indices of the Measurement Model

χ2 /df	GFI	AGFI	CFI	RMSEA
2,929	,952	,911	,959	,046

To test the reliability and validity of each construct, Cronbach α, Average Variance Extracted (AVE), Composite Reliability (CR) and correlations between the factors were considered, these values are given in Table 3. Cronbach α and CR results above the critical value of 0.70 and AVE value above 0,50, indicate that the factor structure is reliable (Fornell & Larcker, 1981; Hair, C. Black, Babin, & Anderson, 2014). The AVE value of the perceived barrier factor was found to be below 0,50. However, values that are slightly below 0,50 are acceptable when the other criteria of construct reliability are provided (Fornell & Larcker, 1981). Therefore, it is possible to express that all factor structures are reliably represented by the items that they are composed of.

Table 3: Factor Correlation Matrix & Validity & Reliability of Construct

	Cronbach α	C.R.	AVE	Intention to Use	Perceived Enjoyment	Perceived Barriers
Intention to Use	0,847	0,858	0,669	**0,339**		
Perceived Enjoyment	0,833	0,840	0,636	0,513	**0,263**	
Perceived Barriers	0,715	0,743	0,494	-0,582	-0,330	**0,339**

The formula used is: $CR= (\Sigma\lambda)^2 /(\Sigma\lambda)^2 + \Sigma\varepsilon$; $AVE= \Sigma\lambda^2 / \Sigma\lambda^2+\Sigma\varepsilon$

The diagonal of the correlation matrix is composed of the largest values of the squares of the correlations between the relevant factor and the other factors, while values below the diagonal represent the correlation coefficients between the related factors. The conservative approach to the discriminant validity compares the estimated AVE scores with squares of the inter-factor correlations. It is possible to say that the discriminant validity is provided when the AVE scores of each structure are larger than the largest values of the squares of the correlations between factors (Fornell & Larcker, 1981; Hair et al., 2014). Convergent validity has been tested via CR and AVE to show the relationship of each item with its associated factor. Hair et al. (2014:632) stated that the conditions of AVE> 0.50 and CR> 0.70 should be met for convergent validity. As seen in Table 3, as all factors (perceived barrier acceptable limit) provided these requirements, conclusions regarding the existence of the convergent validity can be put through. The hypotheses suggested in the research model have been tested with Structural Equation Modeling (SEM). The fit indices of the research model are illustrated in Table 4. Findings indicated that the research model fits well with the current data.

Table 4: Fit Indices of the Research Model

χ2 /df	GFI	AGFI	CFI	RMSEA
3,561	0,941	0,893	0,943	0,053

Research hypotheses have been interpreted by taking those who have 3D Printer and who do not into account. Table 5 represents SEM results for both groups. According to both groups, two hypotheses of the research were supported. In general, the effect of perceived enjoyment on intention to use of 3D Printer was positive and the effect of perceived barrier on intention to use was negative based on the analyses. When the results are evaluated in terms of 3D Printer ownership; the perceived enjoyment in user group who have 3D Printer was lower than the group who do not have, whereas risk perceptions stems from barriers was higher for this group.

Table 5: Results of 3D Printer Ownership Status

3D Printer Owners						
Dependent Construct		**Independent Construct**	**Standardized Regression Weights**	**S.E.**	**C.R.**	**P<**
Intention of Use	←	Perceived Enjoyment	,319	,088	3,876	,001
Intention of	←	Perceived Barriers	-,414	,241	-3,675	,001

3D Printer Owners						
Dependent Construct		**Independent Construct**	**Standardized Regression Weights**	**S.E.**	**C.R.**	**P<**
Use						
Non-Owners of 3D Printer						
Dependent Construct		**Independent Construct**	**Standardized Regression Weights**	**S.E.**	**C.R.**	**P<**
Intention of Use	←	Perceived Enjoyment	,488	,091	6,649	,001
Intention of Use	←	Perceived Barriers	-,397	,137	-5,033	,001

CONCLUSIONS

Despite the growing interest in 3D printing technology, a limited number of studies has investigated consumers' intention to use desktop 3D printers. This study aimed to explore the antecedents of intention to use 3D Printer so as to extend the current theoretical and empirical knowledge. First of all, the results of the research revealed significant positive effect of perceived enjoyment on the intention of using the 3D printer which supports the results of Wang et al., (2016). In the case of respondents who do not own 3D Printers, the effect of the factor of enjoyment is slightly higher than the user group which might stem from a belief coming from expectations before experiencing the production with 3D Printers. However, user group have more realistic conclusions regarding the usage of the printers as they know the production process. Marketing strategies can be produced accordingly, for instance media messages can more focus on the enjoyment aspect of 3D Printers to enhance the amount of the sales. On the other hand, the negative impact of the barrier factor on intentions to use was lower among the group that do not have 3D Printers. The level of risk perceptions of respondents not having 3D Printers was lower as they have not encountered and experienced 3D Printers, and they did not have enough experience to have an insight of probable adverse events associated with the usage of printers. The cost and time questions expressed by means of perceived barriers factor did not reveal a significant result in this research. The reason for this is thought to be that questions are not fully understood by the respondents or these dimensions have not significant effect on intention to use 3D Printer for desktop users. This effect must be taken into consideration in future studies.

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