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Technology Acceptance and Hand Anthropometry (TAHA) Model: Insights from somatosensory technology

Pei-Lee Teh[a,]*, Pervaiz K. Ahmed[a], Ravindra S. Goonetilleke[b], Emily Yim Lee Au[b], Soon-Nyean Cheong[c], Wen-Jiun Yap[c]

[a]Monash University, Jalan Lagoon Selatan, Bandar Sunway, 47500, Malaysia
[b]Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
[c]Multimedia University, Persiaran Multimedia, Cyberhaya, 63100, Malaysia

Abstract

Somatosensory technology is an emerging technology used in applications such as home entertainment, medical and healthcare. It can track human hand movement and enable users to interact with digital devices or physical environment by using hand gesture(s). Effectiveness of somatosensory technology is determined by the compatibility between the technology's operational features and the anthropometric characteristics of the user's hand. Currently, only limited guidance is provided for designers and manufacturers in their development of consumer somatosensory technology products. Motivated by the shortfalls in the extant hand anthropometry literature, this study examines how hand anthropometry influences user technology acceptance. Drawing from Technology Acceptance Model (TAM), we develop Technology Acceptance and Hand Anthropometry (TAHA) model to investigate the impact of hand-size on user's somatosensory technology acceptance. A product trial experiment of 60 participants was conducted to test TAHA model. The results show that hand-size influences the relationship between perceived ease of use and behavioral intention to use somatosensory technology. Our findings have significant implications for hand anthropometry research and practice.

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Keywords: Hand anthropometry; Somatosensory technology; Technology acceptance model; Touchless system

* Corresponding author. Tel.: +603-55144971; fax: +603-55146192.
E-mail address: teh.pei.lee@monash.edu

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1. Introduction

There is a growing interest in the use of somatosensory technology in today's applications such as home entertainment, medical and healthcare. Somatosensory technology differs from other technology as it can track human hand movement and enable users to interact with digital devices or physical environment by using hand gesture(s). Effectiveness of somatosensory technology is determined by the compatibility between the technology's operational features and the anthropometric characteristics of the user's hand. Past research (see: [1], [2], [3], [4]) has examined hand anthropometry of different occupation groups including pianists, garment factory workers, agricultural and manufacturing employees. Some researchers (e.g., [5], [6], [7]) have studied hand anthropometry of different ethnic groups such as Hong Kong, United States, England and Japan females, Indian women and Bangladesh adults. Human factors research (see: [8], [9], [10]) has published on different hand models such as 3D-models of hand tool, optimization-based model and 3D hand gesture taxonomy. However, limited guidance is provided for the designers and manufacturers in the development of somatosensory consumer products. Motivated by the shortfalls in the extant hand anthropometry literature, this study examines how hand anthropometry influences user's somatosensory technology acceptance.

Technology Acceptance Model (TAM) has been long applied in research predicting technology usage. However, TAM research has not examined the impact of hand anthropometry on user's technology acceptance. In this study, we draw upon TAM to develop Technology Acceptance and Hand Anthropometry (TAHA) model to investigate the impact of hand-size on user's somatosensory technology acceptance.

2. Literature review

The study of anthropometry is the study of human body measurements to improve understanding human physical variations and assists in anthropological taxonomy [11]. Fransson and Winkel [12] and Blackwell et al. [13] highlight the importance of the relationship between hand anthropometry and handle size/shape in affecting individual's hand posture or grip strength. Other than a few select studies such as, hand anthropometry study on mobile phone keypad [14] and 3D hand gesture taxonomy [10], little empirical research on how hand-size influences user's somatosensory technology acceptance.

TAM posits that technology adoption behavior is determined by one's intention to use a specific technology, which is influenced by individuals' perceived ease of use and perceived usefulness of the system [15]. Typically, many researchers have restricted their study to investigate perceived ease of use and perceived usefulness in new technology acceptance research, thereby overlooking other controllable variables such as hand anthropometry and human anatomy. With increasing adoption of somatosensory technology consumer products in today's world, it is important to further our understanding of the impact of hand anthropometry on user's somatosensory technology acceptance. Given that hand-size variations exist between individuals, we expect that the relationships between perceived ease of use and behavioral intention, perceived usefulness and behavioral intention, and usability and behavioral intention, will be moderated by hand-size. Therefore, we propose:

- H1: The relationship between perceived ease of use and behavioral intention will be different depending on hand-size (i.e., small as compared to medium).
- H2: The relationship between perceived usefulness and behavioral intention will be different depending on hand-size (i.e., small as compared to medium).
- H3: The relationship between usability and behavioral intention will be different depending on hand-size (i.e., small as compared to medium).

3. Research methodology

3.1. Measures

Survey instrument used in this study is presented in Appendix A. Perceived ease of use and perceived usefulness were measured using items adapted from Davis [16], Venkatesh [17] and Chau [18]. Usability was operationalized using items modified from the instrument developed by Ryu et al. [19] and Bhuiyan and Picking [20]. Survey items of behavior intention were measured using one new item introduced in this study and two items from Venkatesh [17]. All survey items were assessed using a seven-point Likert scale from 1 (strongly disagree/very difficult) to 7 (strongly agree/very easy).

3.2. Sample

To test the hypotheses, we conducted an experiment with 60 students (30 females and 30 males) from a university in Malaysia. Participation was voluntary and anonymous. The participants read and signed an informed consent agreement prior to the experiment. The examination of hand characteristics was carried out based on the guidelines of Martin and Saller [21]. The relation between the length and the breadth of the hand is regarded as Hand index (characteristic 3). Hand length was measured by means of a ruler. All measurements were taken with the hand stretched out and laid flat, with the fingers straight. Participants with hand length below eight centimeters were categorized as small hand-size, while participants with hand length above eight centimeters were regarded as medium hand-size.

Table 1 shows the participants' demographic. Our research participants consisted of 30 males and 30 females. Seventy percent (*n*=42) of the participants were between 18 and 24 years old, and thirty percent (*n*=18) were between 25 and 34 years old. Forty-two participants were small hand-size and 28 were medium. The breakdown of technology adopter was as follows: 11.7 percent of innovators, 11.7 percent of early adopter, 33.3 percent of early majority, 23.3 percent of late majority and 20 percent of laggards.

Table 1. Participants' Demographic.

Variable	Classification	Frequency (*n*=60)	Percent (%)
Gender	Male	30	50
	Female	30	50
Age	18-24	42	70
	25-34	18	30
Hand-size	Small	32	53.3
	Medium	28	46.7
Consumer Types	Laggard	12	20
	Late Majority	14	23.3
	Early Majority	20	33.3
	Early Adopter	7	11.7
	Innovator	7	11.7

3.3. Data collection

The somatosensory technology/touchless system tested in this study was an in-house developed system, enabling users to interact with five home applications using hand gestures. The five home applications include accessing living room lights, movie on demand on the television, edutainment (games), kitchen e-cook book and digital photo albums. Each participants was facilitated by a research assistant who demonstrated the hand gestures (i.e., point-and-wait and palm-and-close) to generate commands for all five home applications. All participants were given five minutes for self-practice. To reduce fatigue, participants were given another two minutes rest time before running the test session. During the test session, each participant was required to complete five tasks involving the home applications using their hand gestures. After completing the experiment, each participant was asked to answer a survey questionnaire.

4. Results

4.1. Reliability, validity and factor analyses

Data analysis was performed using IBM SPSS. Reliability and validity of the scales were assessed using Cronbach's alpha (CA), composite reliability (CR) and the average variance extracted (AVE). As presented in Tables 2 and 3, all CA and CR values were greater than 0.80, meeting the value suggested by Nunnally and Bernstein [22] and Bagozzi and Yi [23]. For convergent validity (see Tables 2 and 3), the values of AVE for all variables were greater than the minimum value of 0.50 recommended by Fornell and Larcker [24]. Discriminant validity was established as all the square roots of AVE values were greater than the off diagonal values in the correlation table.

Factor analysis was conducted to check the construct validity. As presented in Tables 4 and 5, each items had good factor loadings and the values of Kaiser-Meyer-Olkin (KMO) were above 0.50. The numbers for the Bartlett test of sphericity were significant for all variables, with values ranging from 41.735 ($\text{Usability}_{\text{Model 2}}$) to 140.703 ($\text{Behavior intention}_{\text{Model 2}}$). All variables had eigenvalues of greater than 1. As a result, all variables (i.e., perceived ease of use, perceived usefulness, usability and behavioral intention) in Models 1 and 2 were significant to be analyzed in this study.

Table 2. Results of reliability and validity for Model 1. Bold values in the diagonal row are square roots of the AVE.

	Perceived Ease of Use	Perceived of Usefulness	Usability	Behavioral Intention
Perceived Ease of Use	**0.789**			
Perceived of Usefulness	0.686**	**0.869**		
Usability	0.621**	0.276	**0.926**	
Behavioral Intention	0.771**	0.779**	0.305	**0.938**
Mean	4.771	4.789	4.063	4.219
Standard Deviation	1.020	1.145	1.294	1.243
Cronbach's Alpha	0.876	0.891	0.914	0.932
Composite Reliability	0.908	0.925	0.948	0.957
Average Variance Extracted	0.623	0.755	0.858	0.880

Table 3. Results of reliability and validity for Model 2. Bold values in the diagonal row are square roots of the AVE.

	Perceived Ease of Use	Perceived of Usefulness	Usability	Behavioral Intention
Perceived Ease of Use	**0.825**			
Perceived of Usefulness	0.741**	**0.839**		
Usability	0.418*	0.453*	**0.882**	
Behavioral Intention	0.586**	0.750**	0.232	**0.987**
Mean	4.286	4.429	3.833	4.071
Standard Deviation	1.280	1.591	1.353	1.844
Cronbach's Alpha	0.904	0.859	0.851	0.987
Composite Reliability	0.927	0.905	0.913	0.992
Average Variance Extracted	0.680	0.704	0.778	0.975

Table 4. Results of factor analysis for Model 1.

	No. of Items	KMO	BTS	EV	Factor Loadings					
					Item1	Item2	Item3	Item4	Item5	Item6
Perceived Ease of Use	6	0.766	109.380***	3.741	0.873	0.818	0.708	0.693	0.809	0.820
Perceived of Usefulness	4	0.695	90.586***	3.020	0.946	0.865	0.837	0.823	Nil	Nil
Usability	3	0.747	64.627***	2.573	0.938	0.937	0.903	Nil	Nil	Nil
Behavioral Intention	3	0.749	75.283***	2.640	0.952	0.948	0.914	Nil	Nil	Nil

Note: *** $p < 0.001$; KMO=Kaiser-Meyer-Olkin; BTS=Barlett's Test of Sphericity; and EV=Eigen-values.

Table 5. Results of factor analysis for Model 2.

	No. of Items	KMO	BTS	EV	Factor Loadings					
					Item1	Item2	Item3	Item4	Item5	Item6
Perceived Ease of Use	6	0.853	97.664***	4.082	0.787	0.787	0.907	0.886	0.776	0.795
Perceived of Usefulness	4	0.581	108.299***	2.817	0.881	0.848	0.771	0.853	Nil	Nil
Usability	3	0.654	41.735***	2.333	0.901	0.938	0.801	Nil	Nil	Nil
Behavioral Intention	3	0.788	140.703***	2.927	0.986	0.987	0.990	Nil	Nil	Nil

Note: *** $p < 0.001$; KMO=Kaiser-Meyer-Olkin; BTS=Barlett's Test of Sphericity; and EV=Eigen-values.

4.2. Hypotheses testing

Stepwise regression analysis was performed to test Models 1 and 2. Tables 6, 7 and Figure 1 show the results of regression analysis. The predictors explained 71.3 percent and 56.2 percent of behavioral intention's variance in Models 1 and 2. For small hand-size participants, intention to use the touchless system was determined by perceived usefulness (β_1=0.473; p-value<0.01) and perceived ease of use (β_1=0.447; p-value<0.01). For medium hand-size participants, perceived usefulness (β_2=0.750; p-value<0.001) was the dominant factor predicting individuals' behavioral intention. Our findings showed non-significant usability-intention relationships (β_1=-0.179; p-value>0.05; β_2=-0.135; p-value>0.05) in Models 1 and 2. These results lend support to hypothesis H1 but not H2 and H3.

Table 6. Summary of the Models.

Model	R^2	Adjusted R^2	F-statistic	p-value
1	0.713[a]	0.694[a]	36.096	0.000***
2	0.562[a]	0.545[a]	33.332	0.000***

Note: *** $p < 0.001$; [a]Dependent Variable=Behavioural Intention; Model 1=Small Hand-size; Model 2=Medium Hand-size.

Table 7. Regression Analysis for Small Hand-size as Compared to Medium Hand-size.

Model		Non-standardized coefficients		Standardized coefficients		t-value	Sig.
1		*B*	SE	*B*			
	Predictor variables						
	(Constant)	-0.840	0.613			-1.369	0.182
	Perceived Usefulness	0.513	0.148		0.473	3.463	0.002**
	Perceived Ease of Use	0.545	0.166		0.447	3.274	0.003**
				B in			
	Eliminated variables						
	Usability				-0.179	-1.387	0.176
	Dependent variable: Behavioral Intention						
2	Predictor variables						
	(Constant)	0.224	0.707			0.316	0.754
	Perceived Usefulness	0.869	0.150		0.750	5.773	0.000***
				B in			
	Eliminated variables						
	Perceived Ease of Use				0.068	0.343	0.734
	Usability				-0.135	-0.922	0.365
	Dependent variable: Behavioral Intention						

Note: ** $p < 0.01$; *** $p < 0.001$; *B*=Beta Coefficient; SE=Standard Error; Model 1=Small Hand-size; Model 2=Medium Hand-size.

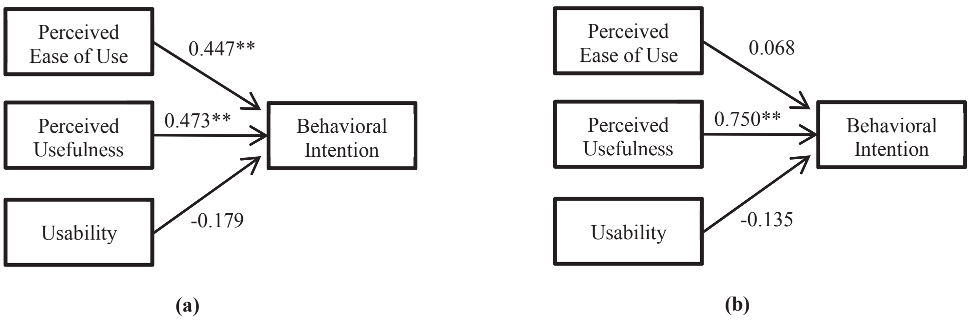

Fig. 1. (a) Results of Model 1; (b) Results of Model 2.

5. Discussion

The purpose of this study is to examine how hand anthropometry influences user's somatosensory technology acceptance. We found a significant difference in the relationship between perceived ease of use and behavioral intention in small hand-size as compared to medium hand-size. Perceived ease of use was a significant predictor of an individual's behavioral intention to use the somatosensory technology for small hand-size, while its relationship to usage intention was insignificant for medium hand-size. Our findings indicate that as the direct interaction between human and technology takes place human anthropometry/human anatomy will come to feature more and more as a key feature in the technology adoption decision. For individuals with small hand-size, they faced incompatibility to technology (i.e., lack of sensitivity or inability of the technology to read the signal) leads frustration to fatigue. When people with small hand-size are unable to access the digital appliance using hand gesture, they can break into frustration and fatigue.

Notably, for both small and medium hand-size, perceived usefulness was found to be a significant predictor of user's behavior intention to use the somatosensory technology. This indicates that once users begin to use a somatosensory technology, usefulness appears to be more significant overall in predicting behavioral intention.

In this study, usability was found to be non-significant in both small and medium hand-size. A possible explanation for this result is somatosensory technology is an enabler of smart home applications. Therefore, a user does not experience usability of somatosensory technology itself, but usability relates to what is being consumed (e.g., browsing digital photo album and playing edutainment).

6. Conclusion

Our study has important implications for theory and practice. From the theoretical aspect, this study expands our understanding of factors influencing somatosensory technology acceptance. Over the years, TAM research has led to numerous replications. However, research has not focused on understanding the influence of hand anthropometry on somatosensory technology acceptance. Given that somatosensory technology is operated by hand gesture, individuals cannot be considered as a homogeneous group with regard to somatosensory technology adoption. This study proposed and tested the TAHA Model, which presents an exposition of how hand anthropometry (i.e., hand-size) influences perceived ease of use, and thereby provides researchers and practitioners with a wider understanding of the dynamics underlying the change of perceived ease of use of somatosensory technology.

From a practical viewpoint, this study suggests hand anthropometry should be considered as one of the factors in designing applications for somatosensory technology. Technology system designers and developers need to formulate anthropometric guides with higher latitude to accommodate different hand anthropometry in the ergonomic design of somatosensory technology and applications.

This study has two research limitations. First, the subjects recruited in this study were Asians, and the results could differ with different ethnic groups such as Caucasians. In future, our model should be replicated across different ethics groups. Second, cross-sectional data was used in this study. Future work should conduct longitudinal analysis in order to strengthen the direction of causality.

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Appendix A. Survey Instrument

1. Perceived ease of use (1=strongly disagree; 7=strongly agree)
Item 1: Learning to operate the touchless system will be easy for the users.
Item 2: User will find it easy to get the touchless system to do what they want it to do.
Item 3: Users' interaction with the touchless system will be clear and understandable.
Item 4: User will find the touchless system to be flexible to interact with.
Item 5: It will be easy for users to become skillful at using the touchless system.
Item 6: User will find the touchless system easy to use.

2. Perceived usefulness (1=strongly disagree; 7=strongly agree)
Item 1: Using the touchless system would enable users to access home edutainment more quickly.
Item 2: Using the touchless system would enable users to access home control system more quickly.
Item 3: Using the touchless system would improve users' life.

Item 4: Users would find the touchless system useful in their life.

3. Usability (1=very difficult; 7=very easy)
Based on your experience in using the touchless system, what do you think about your experience with respect to:
Item 1: Accurate pointing
Item 2: Target selection
Item 3: Gesture-based interaction

4. Behavioral intention (1=strongly disagree; 7=strongly agree)
If the touchless system becomes available:
Item 1: I intend to use a touchless system at home.
Item 2: It is likely that the touchless system will be the medium I use at home.
Item 3: I predict I would use a touchless system at home.

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