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Research Article

Effects of Dexterity Level and Hand Anthropometric Dimensions on Smartphone Users' Satisfaction

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The usage of smartphones instead of simple mobile phones increases sharply in our era, especially among young people, because they do multiple tasks with single equipment. This study mainly focuses on smartphone satisfaction by combining hand measurements, smartphone users' survey results, and hand dexterity levels of corresponding users acquired from Minnesota Manual Dexterity Test (MMDT). Structural Equation Modelling (SEM) is used as a statistical tool to discover the potential direct and indirect relations among user satisfaction, hand dimensions, and dexterity scores. Results indicate that thumb length, hand length, and dexterity level of the users have notable effects on users' satisfaction with smartphones. Based on the results, a new approach that includes both gross motor skills and physical measurements is suggested to see hidden indirect relations with satisfaction.

1. Introduction

The increasing need for fast communication brings along the widespread use of the latest communication technologies. New forms of communication become mobile and they tend to coalesce into a single unit which is called smartphone. Numerous brands offer various smartphone models that have different technical features, physical designs, screen types, input devices, and so forth. People prefer different models of smartphones depending on their needs but it is quite hard to anticipate how they will be pleased with their smartphone. Smartphones have various features that are used in daily life such as standard phone calls, video phone calls, various instant messaging systems, advanced audio video recording technology, rapid Internet access, and various other features. Therefore, smartphone users have different expectations and purposes of using their devices. Their expectations and purposes of using affect their habits of the usage and the level of satisfaction. In the literature, there are numerous studies that have been conducted to measure user satisfaction and uncover information about the use of these devices.

Balakrishnan and Yeow [1] investigate the relationship between hand dimensions and short message service (sms)

satisfaction. They measured hand breadth, thumb length, and thumb circumference measurements of the participants and applied a questionnaire to measure sms satisfaction. As a result of the study, it is suggested that manufacturing customized mobile phones for people who have larger thumbs can increase customer satisfaction.

Zulkefly and Baharudin [2] study the extent of mobile phone use amongst university students. They use several questionnaires to determine family and personal factors affecting purposes of using the mobile phone and its features using. Choi and Lee [3] focus on smartphone interface simplicity in their study. They conduct an online survey among smartphone users to evaluate their smartphone's interface design in terms of simplicity. Park and Han [4] investigate the effects of touch key sizes and locations on one-thumb input on a mobile phone. They compare three different touch key sizes and twenty-five locations and use thumb length, thumb breadth, and hand length data of the participants. Lobo et al. [5] explain some guidelines which increase web usability of smartphones. Nitsche et al. [6] design an ergonomic user interface for a mobile search application by following a user centred design process which includes related questionnaires.

They finalize the study with usability tests for their ergonomic user interface concept.

Physical design of smartphones is also a crucial point for user satisfaction. Since smartphones may require use of two hands and different fingers depending on the activity, smartphone sizes, screen, and keyboard sizes have a critical importance for the ease of usage. Many researchers conduct studies about physical design and mobile phone sizes and hand anthropometrics.

Jain and Pathmanathan [7] investigate keypad design satisfaction of mobile phone users using questionnaires, mobile phone dimensions, and 20 different hand measurements of the participants. Bradley et al. [8] conduct a survey on 362 people to examine user capabilities on mobile phone related tasks.

According to most of the related studies' results, usability of devices and anthropometric features of the users are considered as critical points for design. These are supporting points to clarify the relationship between user expectations and device attributes. However, previous studies do not take into account the human capabilities that may affect overall user satisfaction on mobile devices. Essentially, it is very crucial to know approximate manual dexterity level of the target market for designing more appropriate devices. Although user capability is considered as a component of user satisfaction in some recent studies, there is still a gap in terms of considering motor skills of the users. This study fills this gap through using Minnesota Manual Dexterity Test (MMDT) as a part of the user satisfaction research.

Manual dexterity is a measurable characteristic and it is one of the indicators of human capabilities. Some tests are available to determine dexterity of one or two hands, but not both hands. Since smartphones may require use of both hands and several fingers, it is important to consider effect of user's manual dexterity on their satisfaction of use. Since using the smartphone is not totally the same as using conventional mobile phones, it often requires use of both hands and fingers besides thumbs. On the other hand, smartphones offer much more features related with screen size and keyboard; because of that, their dimensions are bigger. At this point, manual dexterity level of users and choosing the most appropriate smartphone model must be emphasized in terms of user satisfaction. People should decide their smartphone model considering their aims of use, hand dimensions, and manual dexterity level. This study tries to emphasize the relationships between these three aspects and satisfaction level of smartphone users.

In this study, dexterity level is considered as an indirect effect on the satisfaction, besides hand anthropometric dimensions that directly (or naturally) affect dexterity level. It is possible to use both direct and indirect effects with the help of Structural Equation Modelling (SEM) as an extension of Path Analysis (PA) [9] to determine variables influencing the outcome (satisfaction). SEM encompasses PA and both models use the same underlying idea of model fitting and testing [10]. However, SEM allows us to work with latent variables that are weighted values of some observed satisfaction indicators. Also, it takes into account measurement errors and allows using mediator in the model [11]. The

reason why SEM is preferred in this study is that it contains latent variables, contrary to PA, and it takes into account the measurement error, especially for independent variables, contrary to classical regression models.

The paper is structured as follows. Section 2 describes methods including user hand/finger dimensions, satisfaction, and dexterity test. The characteristics of the data and statistical analysis, basically PA and SEM, are defined in Section 3. Section 4 describes model settings and comparisons. Sections 5 and 6 include SEM result diagrams, conclusions, and future work, respectively.

2. Method

A multistage measurement process is designed to collect the data. The study is conducted with 36 participants. Firstly, each participant is asked to answer the questionnaire that includes questions about demographics, smartphone choices, habits, and satisfaction. Secondly, hand and finger dimensions of participants are measured. Finally, each participant performs the Minnesota Manual Dexterity Test.

2.1. Hand and Finger Dimensions. All hand and finger dimensions are measured for both right and left hands. However, not all of them are used in analysis part because there are high correlations between some of these measurements. Lafayette anthropometric tapes and small anthropometer are used for measuring the hand dimensions such as hand length, hand breadth, palm length, index finger length, index finger breadth, thumb length, and thumb breadth. Hand and finger dimensions (mm) are presented in Table 1.

2.2. Dexterity Test. Minnesota Manual Dexterity (MMD) Test includes several test methods. Two of them used in this study are the placing test performed by single hand and the turning test performed by two hands. Dexterity scores are determined based on task completion duration [12]. Both placing and turning tests are performed two times. Total trial times are used to determine percentile scale value that is provided by Examiner's Manual of the Minnesota Manual Dexterity Test. To obtain a composite score, the average of two percentile values is calculated. Analyses are implemented separately with placing, turning, and composite test scores.

Before starting the MMD test, each participant is informed about the tasks of the test and they are allowed to get familiar with the test equipment. After they performed both placing and turning tests, completion time of each task is recorded. Dexterity scores are provided in Table 2.

2.3. User Satisfaction Questionnaire. 1–5 Likert scale is used to measure satisfaction level of participants with their smartphones. Additionally, demographic information, the reasons for choosing their smartphones, daily usage preferences, usage habits, and satisfaction questions (Table 3) are asked in the questionnaire. To make the data collection process easier and to have more reliable results, all the participants are asked for their voluntary consent.

TABLE 1: Hand and finger dimensions (mm).

Subject number	Right hand length	Left hand length	Right hand breadth	Left hand breadth	Right palm length	Left palm length	Right index finger length	Left index finger length	Right index finger breadth	Left index finger breadth	Right thumb length	Left thumb length	Right thumb breadth	Left thumb breadth
1	174	172	74	73	91	91	70	70	15	15	50	50	18	19
2	182	182	83	81	99	101	75	75	15	16	57	57	19	19
3	183	186	84	80	103	102	70	71	17	17	65	65	21	21
4	180	182	94	93	94	94	74	74	18	18	55	55	23	23
5	189	190	84	85	108	108	72	73	16	16	59	67	21	21
6	166	166	76	75	93	93	67	68	16	15	58	58	20	20
7	186	187	82	82	104	105	74	73	18	17	67	64	23	22
8	175	175	73	71	99	99	70	69	15	15	64	61	18	18
9	177	177	77	78	100	100	71	71	16	16	66	65	20	20
10	168	169	80	80	95	95	66	66	17	17	58	57	21	21
11	174	174	79	80	99	99	65	65	15	15	65	64	20	20
12	174	174	78	78	97	97	71	68	16	16	61	61	21	20
13	196	197	87	86	113	112	76	77	18	17	67	68	23	22
14	181	181	85	85	102	103	72	72	16	17	66	66	21	21
15	187	186	89	88	107	107	75	75	17	17	66	65	21	22
16	175	176	82	82	99	100	69	69	16	16	65	65	22	21
17	180	181	83	83	101	100	73	73	17	17	64	65	22	22
18	172	172	75	73	92	92	72	73	15	14	62	61	18	18
19	166	165	73	73	91	91	67	66	14	13	59	59	18	17
20	198	197	96	96	110	110	80	79	18	17	70	70	22	22
21	181	181	95	94	93	93	76	77	18	18	60	60	22	22
22	173	173	80	81	98	98	66	66	16	16	66	65	21	21
23	177	179	84	83	97	97	67	68	15	15	65	64	21	20
24	189	189	82	81	104	104	74	73	15	15	66	66	19	19
25	166	165	73	72	94	94	63	63	14	14	62	62	17	17
26	175	175	79	78	102	102	67	68	15	15	65	65	20	20
27	185	184	83	85	102	102	77	76	15	15	62	63	20	19
28	187	187	82	82	105	105	72	72	16	16	65	64	20	20
29	173	172	74	74	93	93	73	73	16	15	61	62	19	19
30	169	168	75	74	92	92	70	71	16	16	62	63	19	19
31	188	188	83	84	106	106	73	72	17	17	65	66	22	22
32	185	185	80	80	103	104	70	71	17	18	64	65	22	23
33	189	188	84	84	109	109	74	74	18	18	68	69	24	23
34	172	172	74	73	96	96	68	68	16	16	64	63	19	19
35	171	172	73	73	92	92	73	73	15	15	63	63	17	17
36	178	178	85	85	97	96	69	68	16	16	66	66	22	21

TABLE 2: Minnesota Manual Dexterity Test results.

Subject number	(1) Placing test (sec)	(2) Placing test (sec)	Placing total (sec)	Placing percentile scale	(1) Turning test (sec)	(2) Turning test (sec)	Turning total (sec)	Turning percentile scale
1	67	63	130	25	67	54	121	1
2	60	58	118	60	52	48	100	40
3	57	49	106	95	40	35	75	99
4	68	61	129	25	50	49	99	50
5	54	54	108	90	55	48	103	31
6	63	56	119	60	61	45	106	20
7	58	54	112	85	49	45	94	69
8	65	55	120	60	56	44	100	40
9	66	54	120	60	58	44	102	31
10	63	58	121	60	64	51	115	3
11	66	61	127	31	60	58	118	2
12	58	59	117	69	63	50	113	3
13	69	66	135	10	53	50	103	31
14	67	61	128	31	52	48	100	40
15	60	58	118	60	56	55	111	10
16	59	56	115	80	48	45	93	75
17	60	56	116	75	49	48	97	60
18	69	63	132	20	47	46	93	75
19	64	58	122	50	52	46	98	50
20	56	49	105	95	55	52	107	20
21	63	60	123	50	58	56	114	5
22	67	65	132	20	57	52	109	15
23	69	62	131	20	40	41	81	97
24	57	53	110	90	55	50	105	25
25	67	70	137	5	49	46	95	60
26	61	56	117	69	59	51	110	10
27	64	60	124	40	58	53	111	10
28	66	64	130	25	63	48	111	10
29	60	53	113	85	51	46	97	60
30	68	64	132	20	51	50	101	40
31	63	60	123	50	57	50	107	20
32	70	62	132	20	54	50	104	31
33	60	55	115	80	49	48	97	60
34	71	65	136	10	58	47	105	25
35	60	57	117	69	60	54	114	5
36	70	60	130	25	53	46	99	50

3. Statistical Analysis

3.1. Data. The survey is conducted with 36 participants, the average age is 23 ranging between 19 and 34, and half of the participants are female. The main characteristics of the data are as follows: the average monthly income is 1007 (± 796) TL (Turkish Lira), while the average family income is 4000 (± 2153) TL. 83% of them are right-handed. The smartphones are used mostly for phone calls and instant messaging programs such as *Whatsapp*, *Tango*, with 39% and 25%, respectively. The brand and the price of the smartphone

are two most popular answers, with 39% and 27%, respectively, to the question of “*What is the most important feature for you while buying a smartphone?*” The dimension of the smartphone is generally the second or the third option for the participants while buying a smartphone.

The objectives of smartphone usage and the satisfaction questions are asked with 5 Likert points with *definitely dissatisfied* to *highly satisfied* scale in the survey. Cronbach’s Alpha for the reliability of these items is 0.849. The average scores of satisfaction questions are mostly higher than 4 and this shows that participants are satisfied with their smartphones.

TABLE 3: Satisfaction questions and rotated component matrix (rotation converged in 3 iterations).

Question codes	Question explanations	Component	
		Physical	General
M15	<i>I don't have difficulty in holding my phone with one hand.</i>		.628
M16	<i>I don't have difficulty in reaching keys with my thumbs.</i>		.549
M17	<i>I push neither incorrect nor multiple keys with my thumbs.</i>		.630
M18	<i>Even I need to be quick, I don't make mistakes in my transactions.</i>		.707
M19	<i>I don't feel strain in my hand, on my fingers or wrist while using my phone.</i>		.707
M20	<i>My phone's keyboard and keys have appropriate dimensions to be used comfortably.</i>	.637	
M21	<i>I am satisfied with my smartphone's dimensions.</i>	.913	
M23	<i>My phone's physical design doesn't cause any difficulty of use for me.</i>	.857	
M24	<i>I am generally satisfied with my phone.</i>	.937	
M25	<i>I like my smartphone.</i>	.888	
M26	<i>I am disappointed on my smartphone.</i>	.691	

Extraction method: principal component analysis.

Rotation method: Varimax with Kaiser normalization.

However, the participants state that “*it is possible to do some mistakes if they need to act faster,*” which is one of the indicators of physical dissatisfaction. The average score for the related question is 2.67, that is, the lowest score among all satisfaction scores. The average scores obtained from the answers of questions M16, M17, M19, and M20 (descriptions are placed in Table 3) are lower than 4, as well.

Data collection part also includes hand/finger measurements and Minnesota Manual Dexterity Test results mentioned in Sections 2.1 and 2.2, respectively. The raw data and/or related information can be obtained from the author via e-mail.

3.2. Analysis. By using *t*-test, it is concluded that there is no significant difference between right and left hand measurements with 5% confidence level. The analysis part proceeds with factor analysis. Participants answer several questions about their satisfaction in physical and general sense, and it is observed that the scores are split into two groups (Table 3). The first one is the physical satisfaction component, and the second one is the general satisfaction component. The final rotated component matrix of factor analysis is located at Table 3.

In the analysis part, it is aimed at keeping the number of variables limited, because of the sample size constraint. Additionally, since variables are highly correlated, two indicators for each factor are preferred. One is the physical satisfaction (F_1) composed of M16 and M17, and the other one is the phone size-general satisfaction (F_2) composed of M21 and M24. We implemented structural equation model (SEM) with two different types of indicators of satisfaction.

3.3. Path Analysis and Structural Equation Modelling. Path Analysis (PA), introduced by Wright [9], is a statistical tool to indicate direct and indirect relations between variables. The correlations among variables influencing the outcome are used to write structural equations in Wright's analysis. Blau and Duncan [13] introduce PA into social scientific research. The extensive research on PA is developed by Blau and Duncan [13] in the book *The American Occupational*

Structure. In their path models, they utilize occupational and educational outcomes in a sample of male adults and parents of them. In 1970s, PA gains its popularity among sociology, psychology, political science, economics, ecology, and other methods.

It is widely known that regression and correlation analysis are used to show relations between variables, but they are not quite enough to explain direct and indirect effects together. Pedhazur [14] emphasizes that “*PA is intended not to discover causes but to shed light on the tenability of the causal models a researcher formulates based on knowledge and theoretical considerations*” (p. 769).

Equations in Structural Equation Modelling (SEM) are known to be *regression-like*, because it is possible to use error terms which may not be independent of the other predictors like in regression models [15]. Maruyama [16] states that “*Regression for prediction does not provide logic consistent with SEM approaches. The set of uses of regression in which the particular predictors and their regression weights are of interest, called regression for explanation, define why SEM techniques are so valuable*” (p. 21).

Path diagram and path coefficients are two main tools for PA and also for SEM. Path diagram is the visual representation of the total effects of explanatory variables, and it consists of observed variables (rectangles) and latent variables (circles) connected by single-headed and double-headed arrows. It is mandatory to use double-headed arrows between exogenous variables which are assumed to have the variance explained by causes outside of the model. Conversely, endogenous variables' variances are assumed to be explained by exogenous variables and other endogenous variables.

Figure 1 depicts an example of a PA model. Variables 1 and 2 are exogenous variables, while variables 3 and 4 are endogenous variables. “*a*” and “*b*” are residuals and they are not correlated. The arrows are drawn from the variables assumed as causes to variables assumed as effects [14, 17]. Path coefficient located on the diagram is shown by p_{ij} with “*i*” subscript indicating the effect and “*j*” indicating the cause. r_{12} shows the correlation between exogenous variables. As it

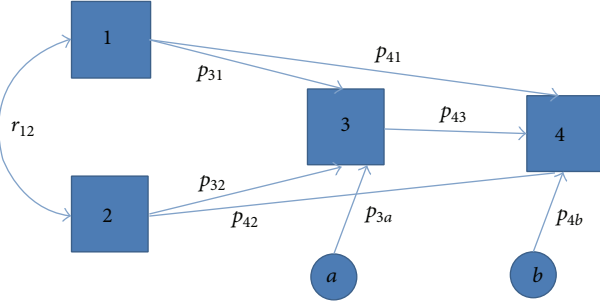


FIGURE 1: PA diagram example.

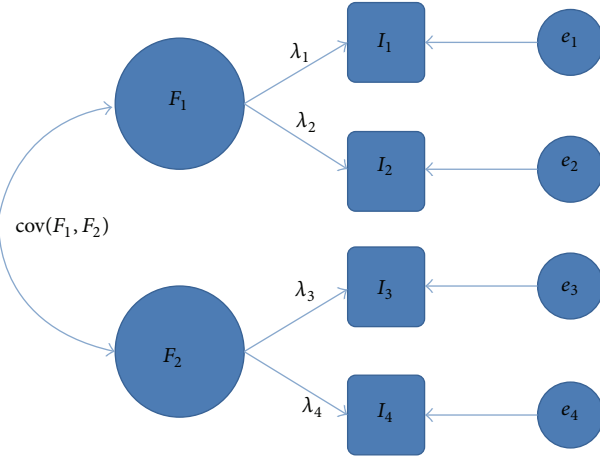


FIGURE 2: SEM diagram example.

is seen in Figure 1, all variables are observed (not latent) in PA.

Figure 2 depicts an example of a SEM model. There are 4 observed variables denoted by I_1 – I_4 that receive two paths going to them (the one from latent variable and the other one from their residual terms) and two latent variables denoted by F_1 and F_2 . e_i ($i = 1, \dots, 4$) is error term and it is possible to use correlations among errors for SEM, although it is not mandatory. The same as in the path diagram, the curved two-way arrows show the correlation between variables.

Model definition equations are main tools of SEM to see the relationship between observed and unobserved variables. Following Figure 2, the equations are written as follows:

$$\begin{aligned} I_1 &= \lambda_1 F_1 + e_1, \\ I_2 &= \lambda_2 F_1 + e_2, \\ I_3 &= \lambda_3 F_2 + e_3, \\ I_4 &= \lambda_4 F_2 + e_4, \end{aligned} \quad (1)$$

where λ_i , $i = 1, \dots, 4$, denotes the factor loadings estimated based on the observed data and e_i , $i = 1, \dots, 4$, denotes residual terms. Detailed implementations for variances and covariance are found in related text books such as [10, 16, 18] among others. It is essential for SEM to use a computational program because of its burden mathematical complexity. We

used AMOS [19] to implement our analysis. Programming languages such as AMOS use iteration for implementations, and it is crucial to check whether these minimization routines with iterations converge or not.

4. Model Setting and Comparisons

Before finalizing the model setting, a set of plausible models are tried. Maruyama's quote [16] "*attempting to impose a single path analytic solution to interpret makes no sense*" (p. 18) is a common view in PA and SEM literatures. Also, using too many unknowns in a SEM model leads to not having an unequally solvable model. So, it is not preferable to add all variables existing in the study while building the model. There is also one thing to be kept in mind while determining the number of variables which is the sample size, which is recommended to be more than ten times the number of free parameters [20, 21].

In this study, it is not so easy to increase the sample size because of the expense of data collection process. Additionally, since there are high correlations between satisfaction indicators, two main indicators for satisfaction for both latent variables are used. F_1 shows the physical satisfaction indicator, while F_2 shows the phone size-general satisfaction for the rest of the study. Also, placing percentile scores (PPS) and turning percentile scores (TPS) are added separately as mediators to the models, since placing task is completed with single hand, while turning test is completed with both hands. This discrimination makes using left hand measurements for left-handed participants and right hand measurements for right-handed participants important, even though we did not find any statistical differences between the measurements of hand sizes.

According to satisfaction indicators and turning/placing percentile scores, four different models are implemented (Table 4). In Models 1 and 2, physical satisfaction (F_1) is taken as latent variable. The mediator of Model 1 is TPS, while the mediator of Model 2 is PPS. In Models 3 and 4, phone size-general satisfaction (F_2) is taken as latent variable. The mediator of Model 3 is TPS, while the mediator of Model 4 is PPS. Also, each model is built in two different versions. The first one (A) omits mediator and correlations of errors as in classical regression model and the second one (B) is named as default model that includes both mediator and correlations. Each model includes hand length and thumb length of participants as exogenous variables (Table 4).

The first and the base model (Model 1-A, Table 4) does not include mediator or any covariance between independent variables and errors. The Chi-square test value of this model fit is 8.937 and probability value of the Chi-square test is 0.03 with 3 degrees of freedom (Table 4). An insignificant result at a 0.05 threshold is expected for a good model fit [22]. Therefore, in the base model, since p value is smaller than the 0.05 level, the null hypothesis is rejected that model fits the data. Contrary to classical methodology in statistics analysis in which it is aimed at rejecting the null hypothesis (usually alternative hypothesis reflects the

TABLE 4: Model comparisons.

Main models	Model 1		Model 2		Model 3		Model 4	
Model versions	A (*)	B	A (*)	B	A (+)	B	A (+)	B
Chi-square	8.937	0.5	8.937	0.172	41.578	5.716	41.578	2.903
Degrees of freedom	3	2	3	2	3	2	3	2
Probability level	0.03	0.779	0.3	0.918	0	0.057	0	0.234
RMSEA	0.238	0	0.238	0	0.606	0.230	0.606	0.114
AIC	22.937	26.5	22.937	26.172	55.578	31.716	55.578	28.903

A: without mediator and correlations of errors.

B: default model (with mediator and correlations of errors).

(*) Without mediator, the first cases of Model 1 and Model 2 are the same models. (+) Without mediator, the first cases of Model 3 and Model 4 are the same models.

difference or change), SEM usually concerns not rejecting the null hypothesis, since it shows the model fits the data well [10].

Another absolute fit statistic is root mean square error of approximation (RMSEA) which is sensitive to the estimated number of parameters in the model [23]. Hooper et al. [24] report that it is taken as “one of the most informative fit indices” [25] (p. 54) because of its sensitivity property. Revisiting Model 1-A, RMSEA value (0.238) is not counted as good for expected well-fitted data since the model with a RMSEA greater than 0.1 would not be preferable [26]. Another fit index which takes into account both the measure of fit and model complexity is Akaike information criterion (AIC) [27] that is reported in the model comparisons table (AIC = 22.937 for the first model).

One of the main benefits of SEM is that it allows researchers to work with indirect effects of variables in addition to direct variables. These indirect effects show the effects between two variables that are mediated by one or more intervening variables (mediators) [10]. In the default version of Model 1 (B) with two degrees of freedom, the null hypothesis is not rejected that model fits the data well (p value: 0.779). Also, RMSEA value is acceptable.

It is noteworthy that Chi-square values and RMSEA get smaller values for all models with mediators. Additionally, SEM with mediators provides better results for general satisfaction indicator which is considered in Model 3 and Model 4. It is observed that, including a mediator to the models with F_1 is not as effected as F_2 . It is an inevitable result because physical satisfaction is directly affected more by both hand and thumb lengths than the general satisfaction. This emphasizes the importance of mediator effect in indirect types of relations in SEM structures.

5. SEM Diagrams

The SEM diagrams of default version of four models (Model 1-B, Model 2-B, Model 3-B, and Model 4-B) with mediators and their comparisons are detailed in this section. The first theoretical model (Figure 3) depicts a mediated model, in which turning percentile scale modifies the effects of hand length and thumb length on F_1 which is a physical satisfaction indicator. It is pointed that hand and thumb lengths have direct effects, as well as having indirect effect on

satisfaction. Hand length has a direct and positive (positive means that when hand lengths get bigger, physical satisfaction gets higher) effect on satisfaction with 0.97 standardized regression coefficient. See Figures 3, 4, 5, and 6.

In Figures 3, 4, 5, and 6, the correlations between exogenous variables are specified with double-headed arrows. Since the same exogenous variables are used for each model, the correlations ($r_{12} = 0.45$) are all the same. The numbers on one-headed arrows indicate standardized regression coefficients. It is observed that the direct effect of hand and thumb lengths on physical satisfaction indicator is observed, in addition to the indirect effect which is the product of the path coefficients. For example, in Model 4-B (Figure 6), the direct effect of hand length on general satisfaction (F_2) is 0.61, while the indirect effect of hand length is $0.26 \times 0.55 = 0.143$.

6. Conclusion and Future Work

Smartphones are one of the most popular devices that are being used in daily life and requiring intensive human-machine interaction. Most of the consumers make their smartphone choices based on a few criteria. Usually, some technical features of smartphones and attractive appearance are being considered. This study attracts attention to the relationship between human attributes and satisfaction level of smartphones. Besides anthropometric dimensions, dexterity levels of participants are taken into account as a new approach and possible effects on smartphone satisfaction are inspected. Since motor skills of users are considered for the first time in this study, relevant findings provide a new viewpoint for smartphone satisfaction studies.

One of the main aims of this study is to investigate the satisfaction factors while selecting and using smartphones. For that purpose, first, hand anthropometric measurements of the participants were collected and then a multistage experimental study was conducted. Minnesota Manual Dexterity Test was utilized to make participants perform one-hand and two-hand dexterity tasks. A survey was conducted to assess satisfaction measurements. Based on survey results, it was possible to group the response under two main factors (physical satisfaction and general satisfaction). The factors in concern were hand anthropometric measurements and manual dexterity levels. Therefore, effects of these factors were investigated through detailed statistical analyses.

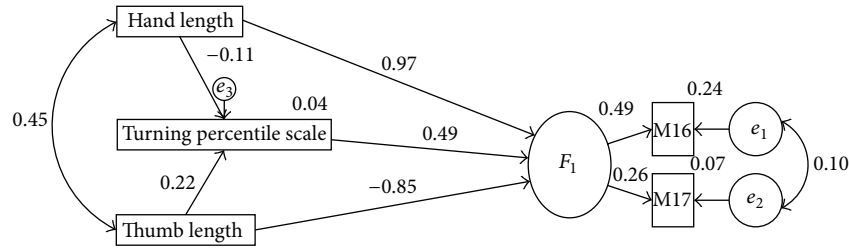


FIGURE 3: SEM diagram of Model 1-B.

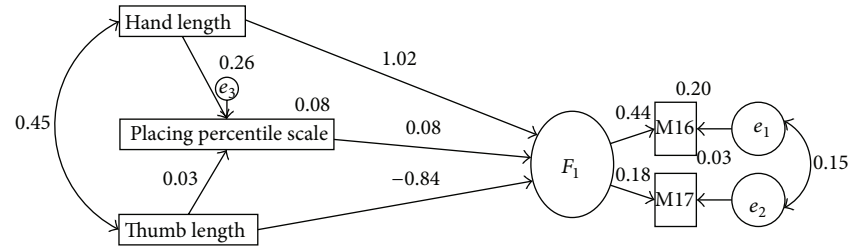


FIGURE 4: SEM diagram of Model 2-B.

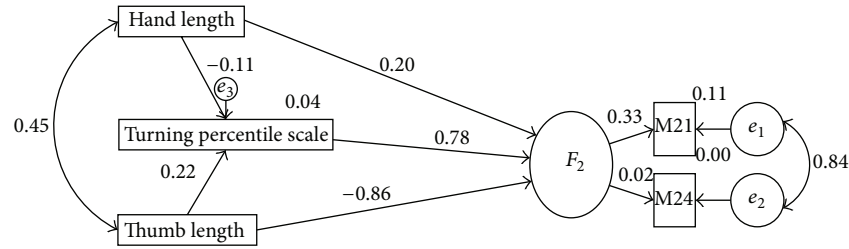


FIGURE 5: SEM diagram of Model 3-B.

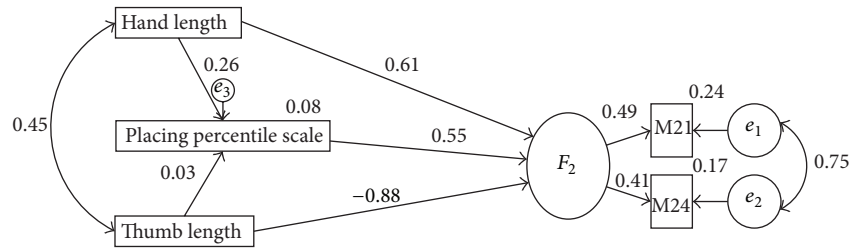


FIGURE 6: SEM diagram of Model 4-B.

Another aim of this study is to assess the effects of placing percentile scale and turning percentile scale as mediators. Therefore, SEM is used as a statistical tool that is an extension of multiple regression models. After finalizing data collection, several models were implemented with two different types of indicators of satisfaction, which were determined with factor analysis, for different types of dexterity test results. Measured variables were selected as exogenous variables, while two variables were selected to generate latent variables for two different satisfaction indicators. Even though the direct effects of hand and thumb lengths were smaller on general satisfaction than physical satisfaction, it was possible to obtain the indirect effects of these lengths on general satisfaction with the help of SEM.

SEM indicates that standardized regression coefficients (Figures 3, 4, 5, and 6) between hand/thumb lengths and

physical satisfaction (F_1) are higher than general satisfaction (F_2), since F_1 includes direct physical satisfaction questions that are “I do not have difficulty in reaching keys with my thumbs” and “I push neither incorrect nor multiple keys with my thumbs.” Additionally, there is a negative relation between thumb length and satisfaction for each model; users with longer thumbs are less satisfied physically with their smartphones than the users with shorter thumbs. This result may bring an idea for smartphone practitioners and manufacturers to produce the new generation smartphones with varied key sizes. As it is known that there is a difference between male and female thumb sizes, key sizes may be specified for genders.

As a conclusion, it can be stated that dexterity level and hand anthropometrics of the users affect smartphone satisfaction either directly or latently. Analyses results indicate

a critical importance of considering user attributes regarding dexterity and hand anthropometrics for both designers and consumers in the smartphone market.

Creating a more personal preference profile for users is an ongoing and natural extension of this study. Finding scientific evidence related to user-based factors for smartphone preferences would assist designers to invest more user friendly devices for their clients, especially in our era in which smartphones are tremendously popular and the sector of them are competitive indeed for designers and manufacturers. Future studies may consider different age groups. Further, other mobile devices used in daily life that require human-machine interaction may be studied. On the other hand, it is being planned developing a smartphone application to measure dexterity levels of potential users which will be applied prior to buying decision to help estimate prospective satisfaction level of them on the relevant smartphone.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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