Analysis of Discomfort Factors in Smartphone Use

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Abstract

We are facing security threats over the Internet that users are not aware of, such as malware infection as well as unauthorized access. We look into user interfaces which cause discomfort so that users can be more aware of security risks. Despite of our efforts on security protections, risk to encounter dangers is increasing by use of smartphones. This paper reports our research progress on discomfort factors with use of smartphones; we conducted a questionnaire survey and found factors that are supposed to cause discomfort when using smartphones obtained from the results of exploratory factor analysis. Through exploratory factor analysis, we came up with five factors that contribute to the discomfort feeling. In addition, we describe the verification results of the difference for each factor according to smartphone OSs (iOS/Android) and the smartphone usage period.

1. Introduction

Computer and Internet users are exposed to threats such as virus infection, unauthorized access, and phishing scams. These opportunities are expected to increase as smartphone use and IoT spread. The problem that users are unaware of security threats has been pointed out [1]; they do not take countermeasures. It is important that users maintain awareness to avoid security threats and risks. We have surveyed discomfort factors when using personal computers and designed risk-aware interfaces using discomfort feelings [2]. However, the spread of smartphones in recent years has been remarkable. In the 2016 “household ownership rates for ICT devices” in Japan, the personal computer rate was 73.0% and that of smartphones was 71.8%. In addition, in “Internet usage by device” for 2016 in Japan, 58.6% used personal computers and 57.9% used smartphones; there is little difference between personal computers and smartphones [3]. Furthermore, “Attack aimed at smartphones and smartphone applications” has drawn attention as a new threat in “10 Major Security Threats 2017” [4]. Under such circumstances, we consider assisting user awareness to avoid security threats and risks a necessary target when using smartphones. This research’s long-term goal is to design a smartphone interface that utilizes the "discomfort feeling" when using a smartphone. We expect that there are unique discomfort elements in smartphones due to differences in operability to computers, usage situation, etc. We find it unlikely that discomfort factors when using smartphones are consistent with such factors when using computers. In addition, familiarity with operation depending on the years of use, smartphone operability, and the threat encountered by the differences in OS may affect the discomfort feeling when using smartphones.

This paper reports the result from a user survey on discomfort factors when using smartphones and compares that with when using computers. In addition, we describe the result of analyzing differences in discomfort factors with smartphone OSs and the smartphone use period.

The next section presents previous research and related work on “risk-aware interface.” Section 3 reports our user survey on feeling discomfort in smartphone use. Section 4 reports the results of factor analysis, and Section 5 describes the differences in discomfort factors between computer use and smartphone use. Section 6 describes differences in the discomfort factors of smartphone OS and smartphone usage period. Section 7 discusses the application of “discomfort interface.” The final section concludes the paper and presents future work.

2. Related Work

Previous research has investigated risk-aware interfaces. For example, one system displays vulnerable software in computers as graffiti on the desktop [6] and a smartphone interface uses Nudge to detect phishing [7].

In previous research, Oikawa [5] collected discomfort elements and identified the factors of discomfort through a questionnaire survey and factor

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analysis to investigate what factors caused discomfort among computer system users. Seven factors that contribute to discomfort were presented as follows.

Factor 1) Time consuming:
Looking for things that are difficult to find or inputting information using a keyboard or a mouse.
Factor 2) Information seeking:
A situation in which users attempt to find information that is difficult to locate.
Factor 3) Message:
Messages that interrupt user activity.
Factor 4) Unexpected operation:
System malfunctions that users do not expect or intend.
Factor 5) Difficulty in seeing:
The sense of sight provided by a physical aspect.
Factor 6) Time delay:
Wait time and system delays.
Factor 7) Noise:
The sense of hearing for a particular sound.

Previous research studies have created prototype interfaces that give users discomfort to be aware of security risks and human errors and have verified focusing on the use of "discomfort feeling" by users when using computers [2][9]. This study is aimed at interface design using the factors of "discomfort feeling" by users when using smartphones.

3. Questionnaire Survey on Feeling Discomfort with Smartphone Use

3.1. Create a questionnaire

Based on the discomfort factors of forty-six elements created by investigating discomfort when using a computer system, we examined discomfort elements during smartphone use. The common discomfort elements in smartphone use were modified versions of the discomfort elements for computer use. For example, "The computer screen suddenly goes dark" was modified to “The smartphone screen suddenly goes dark.” The discomfort elements concerning keyboard and mouse operation were corrected to "tap" and the element “You come across a website that uses too much Flash” was excluded from questions because it hardly applies when using smartphones, so we adopted 45 elements from the discomfort elements in computer use.

Furthermore, we added eleven elements from a preliminary survey in which we asked 18 women undergraduates and graduate students about subjects for comments about situations and events that caused them to feel discomfort in “smartphone use,” “Internet use,” and “daily life.” Finally, we created a questionnaire that consisted of 56 discomfort elements.

We measured the degree of discomfort caused by each discomfort element using a questionnaire survey. We asked subjects to rate each discomfort element using the five levels of the Likert scale. The five levels went from calm (one point) to acute discomfort (five points) and we collected a dataset of 105 elements from women undergraduates and graduate students.

We conducted exploratory factor analysis on the data and modified the questionnaire. Considering correlation and relevance between elements after analysis, we excluded 13 elements and the other 13 elements were gathered into six. We added 11 elements at the preliminary survey that we collected into six elements. Then, we added four new elements to finally create 40 question sentences.

3.2. Questionnaire survey implementation

We conducted this survey using 40 questionnaire items modified based on the results of the preliminary survey analysis. We conducted this February 15 and 16, 2018, using the survey company's Web questionnaire system. As with the preliminary survey, our evaluation used a five-level Likert scale. We added three questions related to smartphone use "smartphone OS (iOS/Android)," "years of use," and "frequently used smartphone functions" in the questionnaire. For comparison with previous studies, we limited the survey subjects to 412 college students (122 males and 290 females). We conducted our analysis on 403 respondents (116 males and 287 females), excluding three people who chose "I do not have a smartphone/I do not use it" in the question about the smartphone OS and six people who marked the same rating for 37 of the 40 questions. Among the 403 respondents, 297 people were iOS users and 106 used Android. Regarding the use period, 55 people responded less than one year, 69 people responded one to two years, 69 people responded two to three years, 62 people responded three to four years, 50 people responded four to five years, 50 people responded five to six years, 33 people responded six to seven years, 13 people responded seven to eight years, and two people responded more than ten years.

4. Factor Analysis Results

We performed exploratory factor analysis for the 403 data points using the maximum likelihood method, Promax rotation. We used IBM SPSS Statistics v23 for factor analysis. For calculating the average value and the standard deviation value from the evaluation of each question item, we confirmed the ceiling effect in three items, Q1S04 (Ave 4.02, SD 1.02), Q2S16 (Ave 4.24, SD 1.02), and Q2S17 (Ave 3.94, SD 1.10). Among these three items, we excluded Q2S16 that was particularly high and reanalyzed 39 items. We conducted our analysis assuming five factors judging from the attenuation state of the eigenvalue obtained from the initial solution and the possibility of interpretation. Thus, we excluded the two items (Q1S07 and Q2S19) for which the loading factor was <.300 and finally conducted factor analysis again on 37 items. Table 1 shows the factor pattern matrix after rotation and commonality.

The cumulative contribution ratio that accounts for the total variance of 37 items with five factors before rotation was 48.01%. The items that showed high values for commonality after rotation are Q1S03 (.517) for the first factor, Q2S15 (.519) for the second factor, Q2S17 (.531) and Q2S14 (.504) for the third factor. Since Q1S05 (.285) of the first factor and Q2S10 (.278) of the second factor became 0.3 or less, these were considered exclusion targets; however, they were analyzed from the possibility of interpreting each factor. Through examining the reliability of each factor, "Cronbach's alpha" in the Fifth Factor was 0.553, which was somewhat low, but since both were > 0.5, this was judged as reliable.

We show the factor name and each feature for the five extracted factors as follows.

Factor 1) Stumbling by system or network:
Discomfort caused by operation delay or system downtime due to hardware malfunction or poor Internet connection status.

Factor 2) Operation trouble and difficulty seeing:
Discomfort due to input and output not being performed smoothly.

Factor 3) Unintended operation or display:
Discomfort due to getting unintentional results and performing intended operations.

Factor 4) Sudden changes:
Discomfort due to extra demands.

Factor 5) Understanding of the application:
Discomfort due to insufficient understanding or inadequate understanding regarding application use.

Discomfort factors when using a smartphone differed from those when using a computer in both number and interpretation.

5. Differences in Discomfort Factors between Computer Use and Smartphone Use

There are fewer factor solutions that we can extract as discomfort factors when using smartphones compared to discomfort factors when using computers. We consider this one of the reasons that excluding or consolidating question items based on the correlation coefficient and interpretation reduces the number of items.

Regarding the factor solution, we can judge that three is a reasonable number according to the attenuation state of the eigenvalue obtained from the initial solution. In this case, we can interpret that the first factor is related to "discomfort concerning the process (including Internet connection)," the second factor is related to "output method discomfort," and the third factor is related to "discomfort concerning input method and contents." However, since Q1S15 (factor loading 0.397) and Q1S17 (factor loading 0.395) are subject to deletion, all excluded items including the ceiling effect item (Q2S16) become additional items for the smartphone, thus we adopted a five-factor solution. Among the five factors, although the fifth factor’s reliability is low, "Understanding of the application" is a new interpretation that is dissimilar to factors when using a computer. We think that we may be able to increase reliability by digging deeper.

Regarding the contents of items in the factors, as a result of comparing between using the computer and using a smartphone, the items "Difficulty in seeing," "Time delay," and "Unexpected operation" when using a computer were also extracted to the same factor when using a smartphone. However, items of "Time consuming" and "message" when using a computer were distributed to a plurality of factors when using a smartphone.

Items extracted as the factor “Difficulty in seeing” when using a computer were extracted as the factor “Operation trouble and difficulty in seeing” when using a smartphone. This included items related to "Multi-touch" and "Copy & Paste" that were newly added here, we think that factors related to input and output were extracted as one factor.

Items related to the "Time delay" and "Unexpected operation" factors that were extracted when using the computer were included in the "Stumbling by system or network" factor when using a smartphone. We think that the factors of discomfort due to malfunctions in the smartphone and Internet connection were strong influences.

Table 1. Factor Pattern matrix (N = 403)

Item		Fator 1	Factor 2	Factor 3	Factor 4	Factor 5	communality
Q1S20	You can not connect to the Internet.	.695	-.036	.109	-.122	-.015	.473
Q1S21	There is a communication restriction or speed limit.	.695	.010	.054	-.046	-.056	.474
Q1S03	The operation is slow because the performance of the smartphone is not good.	.688	-.094	.090	.076	.010	.517
Q1S01	It takes time to start up or shut down or restart the smartphone.	.624	.152	-.198	.127	-.021	.492
Q1S18	The smartphone's battery is about to run out when going out	.592	.211	-.120	-.223	.180	.470
Q1S19	It takes time to display pages on the Web or in the application.	.578	.091	.042	.070	-.029	.449
Q1S04	The smartphone suddenly restarts or stops moving.	.561	-.164	.209	.006	.129	.436
Q1S06	If an error message is displayed for the operation you performed and you can not complete the operation	.534	-.156	.045	.075	.234	.398
Q1S02	When the smartphone operates slowly because that processing is beneficial, such as during virus scans and updating.	.416	.120	-.144	.280	.015	.383
Q1S05	The screen of the smartphone suddenly goes dark.	.413	-.225	.215	-.013	.182	.285
Q1S17	Fingerprint authentication or face authentication is unresponsive.	.375	.152	-.071	.013	.284	.377
Q2S09	You were asked for ID or password.	.041	.703	-.098	.046	-.118	.438
Q2S18	Something requires pinching with two fingers or multi-touch (operating with two or more fingers simultaneously) .	-.131	.578	-.007	.172	-.083	.332
Q2S11	When registering personal information, there are many input items.	.131	.515	.175	-.013	-.064	.439
Q2S06	You read small size letters.	-.170	.509	-.044	.002	.279	.347
Q2S07	You read a long sentence and a web page that has many contents and is vertically long.	-.003	.504	.032	.065	.067	.340
Q2S13	Kanji conversion is not done as desired.	.032	.481	.157	.120	.046	.454
Q2S01	It is hard to find out what kind of information is on the screen.	.006	.473	.113	-.068	.258	.466
Q2S08	You enter long URL (web page address).	.007	.472	.074	-.071	.168	.348
Q2S15	Copy and paste is difficult.	.076	.428	.319	-.002	.053	.519
Q2S10	You forget the necessary password.	.127	.421	.086	-.115	.037	.278
Q2S02	You do not know if the information posted on the web page is accurate.	-.060	.406	.175	.065	.167	.376
Q2S04	It is difficult to see the background of the web page and the color of the text.	-.061	.374	.185	-.031	.342	.478
Q2S17	Unintentionally tapping ads.	.089	.083	.739	-.001	-.251	.531
Q2S05	You see sentences or images that make you feel bad.	-.088	.132	.531	-.012	.164	.441
Q2S14	You can not tap the place you want.	.190	.242	.464	-.131	.014	.504
Q2S03	Ads is displayed on the screen.	.037	.297	.430	.073	-.208	.346
Q1S15	Suddenly big sounds and movies are played from the smartphone.	.065	-.145	.378	.212	.278	.363
Q2S12	Entry of information that you do not want to enter when entering personal information is included in essential items.	-.091	.303	.364	.018	.091	.350
Q1S09	Software (application) is updated and installed without permission.	-.074	-.095	.204	.501	.138	.302
Q1S08	When a message notifying about software or application updates is displayed during work.	.142	.027	.065	.467	-.003	.327
Q1S13	It is necessary to find or switch the desired application with multiple applications open.	.040	.188	-.222	.418	.174	.330
Q1S16	Suddenly vibration is transmitted from the smartphone	-.201	.125	-.020	.409	.331	.327
Q1S11	You need to use or install another application to use certain functions in the application.	.132	.013	.286	.359	.011	.345
Q1S14	It is difficult to find applications and files you want to use.	.248	.054	-.194	.150	.468	.381
Q1S12	It is difficult to understand how to use the application.	.187	.099	-.123	.069	.431	.307
Q1S10	An application was unintentionally started (calling, the camera was running, etc.)	.011	-.004	.196	.177	.370	.320
	eigenvalue	10.639	2.497	1.862	1.492	1.275	
	contribution rate(%)	28.755	6.748	5.032	4.033	3.445	
	accumulated contribution rate(%)	28.755	35.503	40.536	44.569	48.014	
	Cronbach's alpha	0.868	0.87	0.773	0.652	0.553	

Three of the four items for the "Information seeking" factor when using a computer are sorted out as items of "Operation trouble and Difficulty in seeing." Both are items that can reasonably be interpreted as related to visual difficulty.

As items related to sound and moving images were consolidated into one item, we expected that the "Noise" factor when using the computer would not be extracted. We expected to newly add the relevance for "vibration," but it was extracted as a different factor, no correlation was found, and the result differed from the prediction.

By modifying question items, items corresponding to the "Message" factor when using a computer decreased from five to two and items corresponding to the "Information seeking" factor decreased from seven to four. We extracted two items for the "Message" factor as different factors when using a smartphone. We thought that the item "When a message notifying about software or application updates is displayed during work" was influenced by the "troubles" caused by the request to close the message display. Another item "When the smartphone operates slowly because that processing is beneficial, such as during virus scans and updating" belongs to the "Message" factor when using a computer. As the meaning of the item content is related to Internet connection malfunction and smartphone performance, it can be said that it was allocated as a more reasonable interpretation factor.

For the "Time consuming" factor extracted as the first factor in computer use, one of the 11 items was excluded, but all items were distributed other than the "Stumbling by system or network" factor when using smartphones.

Next, we describe the following ten newly added items as smartphone discomfort elements.

Factor 1)

- (Q1S21) There is a communication restriction or speed limit
- (Q1S18) The smartphone's battery is about to run out when going out
- (Q1S17) Fingerprint authentication or face authentication is unresponsive

Factor 2)

- (Q2S18) Something requires pinching with two fingers or multi-touch (operating with two or more fingers simultaneously)
- (Q2S15) Copy and paste is difficult

Factor 3)

- (Q2S17) Unintentionally tapping ads

Factor 4)

- (Q1S16) The smartphone suddenly transmits vibrations

Factor 5)

- (Q1S10) An application was unintentionally started (calling, the camera was running, etc.)

Excluded from analysis)

- (Q2S16) An advertisement is displayed in a place to tap (excluded due to the ceiling effect)
- (Q2S19) The scroll direction goes opposite to the usual direction (excluded during analysis due to factor loading)

In the elements that constitute discomfort factors when using smartphones, we added eight new items that were peculiar to smartphones. All factors included these items and looking at the factor level, the result was not that smartphone-specific factors were extracted, but we considered that discomfort elements peculiar to smartphones affected all factors.

6. Differences in Discomfort Factors According to Smartphone OS and Use Period

The smartphone operability and encountered threats differ depending on the OS (iOS/Android) and use period, so we considered that the user's acceptance of discomfort when using their smartphone also differs. We verified the hypothesis that "discomfort factors differ depending on the OS and usage period" by conducting variance analysis using the factor scores for each item with five factors.

Thus, the primary effect of OS ($F(1, 399) = 6.756$, $p = .009$) was significant at the 1% level for "Stumbling by system or network." Both the primary effect ($F(1, 399) = 3.287$, $p = .071$) in the use period and the interaction between the OS and use period ($F(1, 399) =. 029$, $p = .865$) were insignificant. Regarding the other factors, none of the primary effects of the OS, the primary effect of usage period, or the interaction between OS and usage period were significant (Table 2).

Table 2. Result of an analysis of variance

Factor	OS / Usage Period	F-number	p-value
1	OS	6.756	.009
	Usage Period	3.287	.071
	OS * Usage Period	.029	.865
2	OS	2.396	.122
	Usage Period	.330	.566
	OS * Usage Period	.623	.430
3	OS	.309	.579
	Usage Period	.611	.435
	OS * Usage Period	.029	.866
4	OS	1.270	.260
	Usage Period	2.366	.125
	OS * Usage Period	.000	.986
5	OS	2.818	.094
	Usage Period	.209	.648
	OS * Usage Period	.015	.903

7. Discussion

We described an application plan for each of five discomfort factors extracted at this time to construct a risk-aware system using discomfort interfaces when using smartphones.

Regarding the "Stumbling by system or network" factor, we can conceive of creating interfaces that make you feel stuck with factors other than applications that cause operation delays, or temporary network shutdowns.

Regarding the "Operation trouble and difficulty in seeing" factor, we can conceive of creating interfaces such as operation range expansion, increasing the number of operations or inputs, and scaling characters more than usual.

Regarding the "Unintended operation or display" factor, we can conceive of arranging the advertisements to positions where they are easy to tap or to play sound and video.

Regarding the "Sudden changes" factor, we can see how interfaces for displaying notifications and messages and those for adding vibration during operation can be implemented. Regarding smartphone vibrations, there is a possibility that strong vibrations during the drag operation may discomfort the user [8].

Regarding the "Understanding the application" factor, we can conceive of placing it in a position such that finding or understanding the application is difficult.

8. Conclusions

As this paper reports, we conducted a questionnaire survey on user subjectivity and examined the discomfort factors for smartphones from the analysis. The results of the questionnaire survey on feeling discomfort during smartphone use revealed two factors: "Stumbling by system or network" and "Understanding the application" differ from computer use discomfort factors. In addition, although we did not extract factors unique to smartphones, all five factors included newly added discomfort elements that were peculiar to smartphones. Meanwhile, the hypothesis "the difference in OS causes different discomfort factors" only applied for the first factor; comparing items to determine the differences they make is a future task.

In future work, we need to implement smartphone interfaces based on factors extracted in this paper and verify user discomfort and the effects on awareness. Differentiation from the existing warning interfaces and familiarization problems are also future tasks.

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