The Notification Design of a Mobile User Interface

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Abstract. People often receive notifications through auditory, tactile, and visual forms. The purpose of this study is to explore the impact on the notification usability of the mobile device through different combinations of dimensions. The experiment was conducted adopting a 2 (visual presentation type) × 3 (notification dimension) design. We used semi-structured interviews, the Questionnaire for User Interaction Satisfaction (QUIS), and the subjective emotions questionnaire to help collect the users' preference for the notification types. The experimental results indicate that: (1) The most satisfactory notification is the vision + vibration dimension. (2) Whether the visual presentation was static or dynamic, the overall response of the vision + vibration dimension scores better. (3) There is a significant and positive correlation among each of the three parts of QUIS (Overall response, notification screen, Terminology & notification information). (4) Participants' subjective emotions are correlated with the judgment of the QUIS.

Keyword: Mobile notifications · Notification design · Vision · Vibration · Sound

1 Introduction

We often receive notifications from our mobile devices, and some untimely notifications may interrupt our daily lives. Notifications can be multi-dimensional. We receive notifications through auditory, tactile, and visual forms.

The current research on mobile notifications can be broadly summarized as shown in Fig. 1. It includes sound, vision, and vibration. Sound can subtly influence the mood of users and encourage the change of users from particular directions. Riccò et al. [6] also argued that sound is a reminder of multiple types of information, radically transforming the visual message. Enriquez, MacLean and Chita [4] found that vibrational stimuli have an impact on users' memories. In their experiment, users could consistently recall an arbitrary association between a vibrational stimulus and its assigned arbitrary meaning during a 45-min test period following a reinforced learning stage. In addition, some scholars have begun to conduct supplement this research study. Schlienger et al. [7] performed an experiment that tested combinations of graphics, animations, and sounds to improve detection and evaluation of changes occurring in the mobile user interface. They found that dynamic graphics help users

T. Z. Ahram and C. S. Falcão (Eds.): AHFE 2021, LNNS 275, pp. 939–949, 2021.
https://doi.org/10.1007/978-3-030-80091-8_112

identify the old and new values of changing positions, and that a sequential combination of sounds and dynamic graphics is the most efficient way to convey information to users.

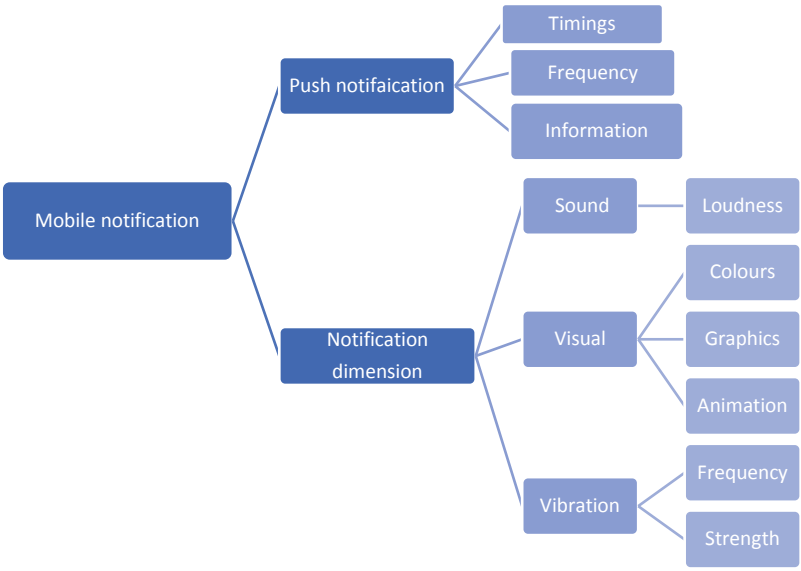

Fig. 1. The mobile notifications research design

Notifications are designed to have different information content. Mobile applications often provide notifications as feedbacks on the progress of the current task as the user operates the device. This study explored how to design notifications to help improve interface usability and enhance the users' interactive experience.

2 Experiment and Methods

The experiment was conducted by adopting a 2 (visual presentation type) × 3 (notification dimension) mixed factorial design. The levels of visual presentation type were static and dynamic. The levels of the notification dimension were vision, vision + sound, and vision + vibration. The variable of the visual presentation type is a between-subject variable and the notification dimension is a within-subject variable. We invited 60 participants to experience different mobile notifications via convenience sampling method. Their ages ranged from 19 to 40 years old. They had a considerable amount of experience using social applications.

The experimental application was created using "Xcode" and the visual part was designed using "Illustrator." The notification messages are for presenting the current progress to users. The visuals of the notification were designed as static and dynamic presentation types. The static presentation type was designed using a check mark with

text below (Fig. 2). The dynamic presentation type was designed using animated transitions. Participants will receive the notification when a task is successfully done. In both designs, the notification window will disappear automatically after 1.25 s. Participants can also click on the screen to close the window and return to the current user interface status.

Participants operated the experimental samples in a specific quiet room to complete the same tasks. These tasks made each participant experience three different types of notification (vision, vision + sound, and vision + vibration), but each participant only experienced one of the visual presentation types (static or dynamic).

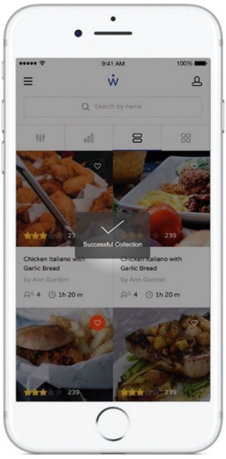

Fig. 2. The static presentation type

We used semi-structured interviews, the Questionnaire for User Interaction Satisfaction (QUIS), and the subjective emotions questionnaire to help collect user preferences for notification types. The three parts of the QUIS are related to the notifications (i.e., Overall response, Screen, Terminology and information). The questionnaire investigating participants' subjective emotions provides a number of psychological aspects on a 7-point Likert scale form to help investigate their user experiences and emotions, i.e., interruption of the notification (from 1 "no interruption feeling" to 7 "much circulation feeling"), the effectiveness of the notification (from 1 "least effective" to 7 "most effective"), concentration of the notification (from 1 "least concentrated" to 7 "most concentrated"), memory recollection of the notification (from 1 "no memory recollection" to 7 "much memory recollection"), and satisfaction with the notification (from 1 "most dissatisfied" to 7 "most satisfied"). A total of 50 valid questionnaires were analyzed by the mixed factorial ANOVA of the SPSS.

3 Results

3.1 The Overall Response of the Notification

Table 1 illustrates the results generated from the mixed factorial ANOVA regarding the visual presentation type and the notification dimension. The results indicated that there was no significant difference in the main effect of visual presentation type ($F = 2.98$, $P = 0.09 > 0.05$), but the main effect of the notification dimension showed a significant difference ($F = 9.67$, $P = 0.00 < 0.05$). The results of the post hoc comparison showed that participants considered their responses to vision + vibration ($M = 5.49$) to be the most satisfactory. Considering that the other notification types were greater than the median of 4 (vision + sound, $M = 5.12$; vision, $M = 5.01$), it means that the participants showed a good overall response to all of the notifications. The interaction effect (see Fig. 3) between the "visual presentation type" and "notification dimension" also showed statistically significant effects ($F = 3.31$, $P = 0.04 < 0.05$).

Table 1. The mixed factorial ANOVA of the feeling of the overall response.

Source	SS	df	MS	F	P	Post Hoc
Visual presentation type	4.73	1	4.73	2.98	0.09	
Notification dimension	6.26	2	3.13	9.67	0.00**	Vision + Sound = Vision < Vision + Vibration
Visual presentation type × Notification dimension	2.14	2	1.07	3.31	0.04*	

* means that $P < 0.05$, ** means that $P < 0.01$ and there is statistical significance

Figure 3 shows that when the visual presentation type of the notification is static, the overall response of vision + sound and vision is worse than dynamic. But whether static or dynamic, the overall response in the vision + vibration dimension shows a good score. Vibration provides participants with a better operating experience. This result is consistent with Bartram and Ware's (2001) study which suggested that motion has several advantages as a notification mechanism. It is significantly better than the traditional static codes of color and shape in designing icons used to attract a user's attention, especially in the periphery area.

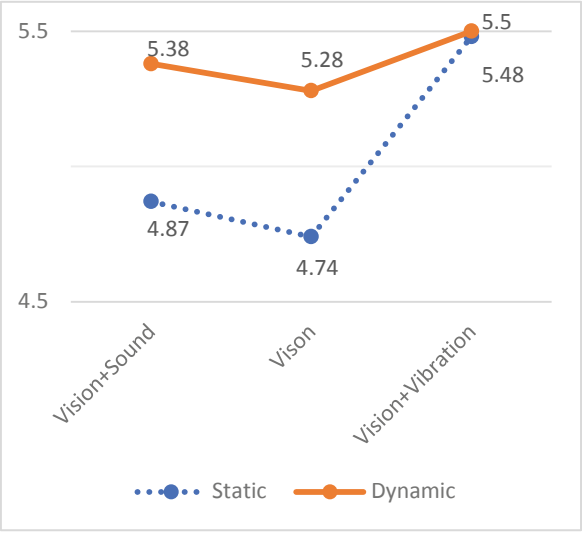

Fig. 3. The interaction diagram regarding the overall response of the notification.

3.2 Notification screen

Table 2 indicates that there was no significant difference in the main effect of visual presentation type ($F = 1.69$, $P = 0.20 > 0.05$), but the main effect of the notification dimension showed a significant difference ($F = 5.34$, $P = 0.006 < 0.05$). The results of the post hoc comparison showed that the visual ($M = 5.09$) dimension and vision + vibration ($M = 5.42$) showed significant differences ($P = 0.001 < 0.05$). Participants considered that the "vision + vibration" notification dimension makes the screen the most interesting, and the least was vision. Considering that the average value of various notifications is greater than the median of 4 (vision + sound, $M = 5.28$), the participants believed that the presentation of the notification screens highlighted the key points, and especially, the vision + vibration can be better focused on. The interaction effect between the "visual presentation type" and "notification dimension" showed no statistically significant effects ($F = 0.74$, $P = 0.47 > 0.05$).

Table 2. The mixed factorial ANOVA of the notification screen.

Source	SS	df	MS	F	P	Post Hoc
Visual presentation type	4.00	1	4.00	1.69	0.20	
Notification dimension	2.73	2	1.36	5.34	0.006**	Vision < Vision + Vibration
Visual presentation type × Notification dimension	0.38	2	0.19	0.74	0.47	

** means that $P < 0.01$ and there is statistical significance

3.3 Terminology and Notification Information

Table 3 indicates that there was no significant difference in the main effect of visual presentation type ($F = 0.43$, $P = 0.83 > 0.05$), but the main effect of the notification dimension showed a significant difference ($F = 3.61$, $P = 0.03 < 0.05$). The results from the post hoc comparison indicated that the participants consider that the vision + vibration ($M = 5.72$) notification dimension was the best way to be perceived and understood, while the vision ($M = 5.49$) dimension type was the worst. Considering that all of the kinds of notifications are greater than the median of 4 (vision + sound, $M = 5.53$), it means that the participants believed that the terminology and notification information provided by the notification interface were satisfactory, and during the operation, feedback on general notifications in the application can explain well the current progress. The interaction effect between the "visual presentation type" and "notification dimension" showed no statistically significant effects ($F = 0.58$, $P = 0.47 > 0.55$).

Table 3. The mixed factorial ANOVA of the terminology and notification information.

Source	SS	df	MS	F	P	Post Hoc
Visual presentation type	0.88	1	0.88	0.43	0.83	
Notification dimension	1.44	2	0.72	3.61	0.03*	Vision < Vision + Vibration
Visual presentation type × Notification dimension	0.23	2	0.11	0.58	0.55	

* means that $P < 0.05$ and there is statistical significance

3.4 The Correlation Analysis of the QUIS Results and Subjective Emotions

Based on the correlation analysis illustrated in Table 4, the results showed that there were differences in the correlation among different notification dimensions regarding the QUIS and emotions.

When the notification was via the vision dimension, the positive correlation between overall response and notification screen was significant, and they were highly correlated ($r = 0.712$). A significant positive correlation between the overall response and Terminology & information ($r = 0.682$) was also shown, and there was a significant positive correlation between notification screen and Terminology & information ($r = 0.698$). Both were moderately correlated. This indicates that the three parts of the QUIS questionnaire are positively correlated.

Notification interruption showed a negative correlation with the QUIS (Overall response $r = -0.394$, Screen $r = -0.390$, Terminology & information $r = -0.454$); they had a low correlation. This means that the lower the overall response, screen, and terminology & information scores, the more disruptive the notification is. The effectiveness of notification showed a positive moderate correlation with the QUIS (Overall response $r = 0.516$, Screen $r = 0.513$, Terminology & information $r = 0.620$), and a low negative correlation with the interruption ($r = -0.409$). The stronger the sense of interruption, the more effective the notification. There was no significant correlation

Table 4. Pearson's correlation analysis of the QUIS results and subjective emotions.

		Overall response	Screen	Terminology & information	Interruption	Effectiveness	Concentration	Memory	Satisfaction
Vision	***Overall response***	1	.712**	.682**	-.394*	.516**			.403**
	Screen		1	.698**	-.390*	.513**		.346*	.455**
	Terminology & infor-			1	-.454**	.620**		.382**	.558**
	Interruption				1	-.409**	-.293*		-.478**
	Effectiveness					1	.340*	.398*	.422**
	Concentration						1	.526**	.461**
	Memory							1	.508**
	Satisfaction								1
Vision + Sound	***Overall response***	1	.713**	.745**	-.443*	.437**	.334*		
	Screen		1	.713**	-.297*	.458**	.481**	.418**	
	Terminology &			1	-.286*	.564**	.511**	.356*	
	Interruption				1				-.497**
	Effectiveness					1			
	Concentration						1	.665**	.399**
	Memory							1	
	Satisfaction								1
Vision + Vibration	***Overall response***	1	.724**	.678**	-.333	.459**	.311**	.550**	.528**
	Screen		1	.647**		.302*		.415**	.390**
	Terminology &			1	.366**	.438**	.363**	.526**	463**
	Interruption				1	-.354*			-.445**
	Effectiveness					1	.284*	.379**	
	Concentration						1	.666**	.339*
	Memory							1	.561**
	Satisfaction								1

*Significantly different at 0.05 level ($P < 0.05$). **Significantly different at 0.01 level ($P < 0.01$).

between concentration and the QUIS, which means that the participants' concentration on the vision notification does not affect the operation experience; however, the negative correlation between concentration and interruption was significant (r = −0.293), and there was a significant positive correlation between concentration and effectiveness (r = 0.340); both had a low correlation. The participants showed more focus on the vision of notification; the more effective it is, the more disruptive it feels.

Participants' memory showed a positive correlation with the screen (r = 0.346), and with Terminology & information (r = 0.382), but there was no significant correlation with the overall response of the QUIS. Both the effectiveness of the vision notification and the participant's own concentration showed a positive correlation with memory (r = 0.398, r = 0.526). This shows that participants' memory of the notification is affected by screen presentation, the information terminology, and their concentration, where the more attractive the screen and information, the more the participants were impressed. Satisfaction indicates a negative correlation with interruptions and a positive correlation with other variables. In summary, when the notification was in visual type, participants paid more attention to the visual presentation. Experience and emotions affect each other, and these effects also determine the satisfaction score.

When the notification is via the vision + sound dimension, the positive correlation between overall response and notification screen was significant (r = 0.713). A significant and positive correlation also showed between overall response and Terminology & information (r = 0.745). Terminology & information and screen showed a significant and positive correlation (r = 0.713); they were highly correlated. Interruption showed a significant and negative correlation with the QUIS (Overall response r = −0.443, Screen r = −0.297, Terminology & information r = −0.286); there was a low correlation.

Effectiveness showed a significant positive correlation with the QUIS (Overall response r = 0.437, Screen r = 0.458, Terminology & information r = 0.564), and with Terminology & information it was moderately correlated; others had low correlations. The results are similar to the "vision" dimension. There was no significant correlation between effectiveness and interruption. Concentration showed a significant and positive correlation with the QUIS (Overall response r = 0.334, Screen r = 0.481, Terminology & information r = 0.511), with Terminology & information moderately correlated, while others had a low correlation. There was no significant correlation between concentration and interruption, and also no significant correlation with effectiveness.

Memory has a significant and positive correlation with the screen (r = 0.418), and is also positively correlated with Terminology & information (r = 0.354) and concentration (r = 0.665). There was a negative correlation between satisfaction and interruption (r = −0.497) and a positive correlation between satisfaction and concentration (r = 0.399); both had low correlations. This means that the sound dimension significantly affects the participants' interruption and concentration emotions, which in turn affects their satisfaction with the notification. The results confirm the effect of the sound dimensions on user emotions, which is consistent with the conclusions of Butz and Jung [1].

When the notification is via the vision + vibration dimension, the positive correlation between overall response and notification screen was significant (r = 0.724). A significant and positive correlation was also shown between overall response and

terminology & information (r = 0.678). Terminology & information and screen showed a significant and positive correlation t(r = 0.647). The results are consistent with the other notification dimensions above. The negative correlation between interruption and overall response was significant (r = −0.333). There was a positive correlation between interruption and terminology & information (r = −0.366) which is in contrast to the other two notification types. It was a low correlation, and there was no significant correlation between interruption and screen. This means that the clearer the terminology & information, the more disturbed the participants will be by the notification. In the vision + vibration dimension participants were more likely to perceive the notification because the vibration was added, so they preferred a simple image to textual information type, which helps simplify the recognition of the information.

Effectiveness showed a significant and positive correlation with the QUIS (Overall response r = 0.459, Screen r = 0.302, Terminology & information r = 0.438), and there was a significant and negative correlation between effectiveness and interruption. Concentration showed significant and positive correlations with the overall response (r = 0.311), Terminology & information (r = 0.363) and effectiveness (r = 0.284), and all were low correlations. The correlations between concentration and screen along with concentration and interruption showed no significance. Memory showed significant and positive correlations with the QUIS (Overall response r = 0.550, Screen r = 0.415, Terminology & information r = 0.526), but there was no significant correlation between memory and interruption. Satisfaction showed significant correlations with other variables apart from effectiveness, which is similar to the visual types.

4 Discussion

The QUIS results indicated that in mobile notifications, the vibration dimension can provide users with a good overall response. Participants consider that the "vison + vibration" dimension had a strong perceptibility and had less interference than the "vison + sound" dimension. The overall results indicated that the average score for all notification types was higher than the median of 4, indicating that the participants considered the notification type to be satisfactory. This study also found that in mobile interactions, users have a positive attitude toward applications that use notifications to present progress. Users consider the most favorite notification type to be the vision + vibration type. In terms of overall response, dynamic visual presentation is better than static presentation, and the dynamic animation transition is more interesting to users.

We further understand the impact of different prompting dimensions on participants through subjective questionnaires, and thus prove the reliability of the QUIS questionnaire. It was found that the results of the QUIS questionnaire was correlated with the subjective emotions.

In the single vision dimension, participants' concentration does not affect the results of QUIS, but when the notification dimension is vision + sound, there was a positive correlation between concentration and the QUIS, which means that the vision dimension affects participants' concentration and overall experiences. Concentration with interruption and effectiveness both showed a significant correlation in the vision

notification dimension, but they showed no significant correlation in the vision + sound notification dimension. The sound dimensions of the notification caused this difference. vision + vibration is special in that there is a significant positive correlation between the participants' memory and the effectiveness of the notification, but there is no significant correlation in the other two notifications.

In summary, participants showed a better response to the multiple notifications of vision + vibration, and the vision + sound notification was the least effective; this is in line with the results of Brewster et al. [3] and the Hoggan et al. [5], who found that the vibration dimension can increase users' interactive experience with the notification interface.

5 Conclusions

In this study, we explored the usability of mobile multiple-notification, evaluated the differences between notification dimensions through the QUIS questionnaire, and used subjective questionnaires to assist in understanding participants' subjective emotions of different notification designs. Through the experiment, this study found that:

1) The three parts of the QUIS (Overall response, Screen, Terminology & information) can effectively help investigate the usability of mobile notifications. The QUIS results indicate that the most satisfactory notification interface is the vision + vibration dimension, as participants consider that vibrations can improve the usability of the notification interface
2) When the visual presentation type of the notification is static, the overall response of vision + sound and vision is worse than that of dynamic, but whether static or dynamic, the overall response in the vision + vibration dimension shows a good score.
3) Participants consider the worst response to the notification dimension is vision + sound and the best is vision + vibration.
4) There is a significant and positive correlation among each of the three parts of the QUIS.
5) Participants' subjective emotions correlate with the judgment of the QUIS.

Warnock et al. [10] argued that there is no best combination of the notification dimensions, but there is the best modality for the situation. The mobile notification design should most appropriately be selected based on a number of factors such as message urgency, user impairment, and social context. Future research will further refine the different notification situations and context environments in order to understand the users' preferences for the combination of the mobile multiple-notifications, and to improve the usability of the notification interface interaction.

References

1. Butz, A., Jung, R.: Seamless user notification in ambient soundscapes. In: Proceedings of the 10th international conference on Intelligent user interfaces, pp. 320–322. ACM, January 2005
2. Bartram, L., Ware, C., Calvert, T.: Moving Icons: detection and distraction. In: INTERACT, vol. 1, pp. 157–165 (2001)
3. Brewster, S., Chohan, F., Brown, L.: Tactile feedback for mobile interactions. In: Proceedings of the SIGCHI Conference on Human factors in Computing Systems. ACM, pp. 159–162 (2007)
4. Enriquez, M., MacLean, K., Chita, C.: Haptic phonemes: basic building blocks of haptic communication. In: Proceedings of the 8th International Conference on Multimodal Interfaces, pp. 302–309. ACM, November 2006
5. Hoggan, E., Brewster, S.A., Johnston, J.: Investigating the effectiveness of tactile feedback for mobile touchscreens. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1573–1582. ACM, April 2008
6. Riccò, D., Belluscio, A., Guerini, S.: design for the synesthesia. Audio, visual and haptic correspondences experimentation. In: Proceeding of the 1th International Meeting of Science and Technology of Design, pp. 3–12 (2003)
7. Schlienger, C., Conversy, S., Chatty, S., Anquetil, M., Mertz, C.: Improving users' comprehension of changes with animation and sound: an empirical assessment. In: IFIP Conference on Human-Computer Interaction, pp. 207–220. Springer, Berlin, September 2007. https://doi.org/10.1007/978-3-540-74796-3_20
8. Warnock, D., McGee-Lennon, M., Brewster, S.: The impact of unwanted multimodal notifications. In: Proceedings of the 13th International Conference on Multimodal Interfaces - ICMI 2011, Alicante, Spain. ACM Press, pp. 177–184 (2011)
9. Warnock, D., McGee-Lennon, M., Brewster, S.: The role of modality in notification performance. In: IFIP Conference on Human-Computer Interaction, pp. 572–588. Springer, Berlin, September 2011. https://doi.org/10.1007/978-3-642-23771-3_43
10. Warnock, D., McGee-Lennon, M., Brewster, S.: Multiple notification modalities and older users. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1091–1094. ACM, April 2013