Modus Operandi: The Implications from Redesigning Moded Experiments in Multitouch User Interfaces

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ABSTRACT

Evaluation of moded interaction techniques is essential in determining the optimal strategy to switch between the modes of a user interface. Performance can be evaluated when each technique is used to complete a given set of changing mode sequences. However, there have been limited variations in the patterns adopted by past studies, because all of their mode sequences were consistently presented in chunks of only 5 tasks at a time. Our study addresses the identified gap by expanding the chunk size by at least 10 times and diversifying the independent variables (i.e. patterns). Although we found that Persist outperforms User-Maintained Interaction technique overall, patterns with a clear presence of dominating mode are ideal for the latter (and supported locking feature) to thrive. Our findings show how an experimental modification can augment the existing understanding of moded interaction.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**

KEYWORDS

Experiment design; touch-based; mode-switching; moded interaction.

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1 Introduction

A moded system is one in which a given input can generate different output, depending on what the currently active mode is. This system design has been adopted in both computer and non-computer devices like Vim editor and sewing machine due to the benefits of gesture polymorphism [1]: “making the interface more powerful without making it more complex” [3]. The challenge of moded interaction is the lack of contextual awareness that negatively affects users’ interpretation of the system behavior, contributing to moded errors [7]. Furthermore, since the switching of modes can occur very frequently, it is important to manage its complexity such that moded errors and time consumption are kept to a minimum, especially when there are more than 2 modes involved [8]. This can be done by evaluating different techniques to identify the optimal one that can maximize the interface usability. While prediction-based [9] is theoretically cost-free from the user’s perspective and hence an ideal interaction technique, its accuracy is preventing it from being adopted, hence we focus on more practical techniques like Persist and User-Maintained Interaction (UMI).

Firstly, Hinckley et al. defined Persist as a technique that keeps the selected mode active until the user chooses a new mode [4]. This is by far the most frequently adopted technique in mainstream applications we can find today. For instance, selecting the pen tool on a sketch app will persist the pen mode until the user selects a different tool (e.g. brush tool) to persist the new mode. Since Persist offloads the mode-maintenance responsibility to the system, instead of the users, a mismatch between the users’ and system’s mental model often occurs, resulting in moded errors, which adversely affect the user experience of moded interaction in general [12].

Secondly, UMI activates a mode as long as the user maintains a force onto an element of the system (e.g. button, lever, etc.). For instance, only while a piano pedal is being pressed, will the keys played have a sustained effect. Subsequently, upon releasing the pressed pedal, the keys played will automatically produce the original sound without any effect. Li et al. proposed pressing the barrel button of a pen and using the non-dominant hand (NDH) as a mechanism to trigger the mode in a UMI way [6]. This kinesthetic feedback afforded by UMI makes it a better technique [10] because the mode-maintenance responsibility is now dependent on the user, instead of the system. This is how mode ambiguity and moded error can be minimized to enhance the overall user experience.

Past studies commonly refer to UMI as ‘quasimode’ [9] or ‘spring-loaded’ [4] and augment its functionality by adding a locking mechanism [2] so that the user no longer needs to keep exerting any effort in maintaining a particular mode.

Three independent studies [4, 6, 11] had conducted evaluations and consistently revealed that UMI performs relatively better than other techniques, but why is it that Persist still prevails as the default technique in today’s moded tablet activities like sketching and typing? This discrepancy between theoretical and practical performances of these techniques motivated our study to explore more varied patterns of mode-switching behavior that real-world uses and situations are likely to require. For instance, these studies designed their experiment tasks to be completed in sets of 5 simple tasks that may or may not require switching of modes, thus raising the issue of how and why the results could possibly differ if we significantly expand the set size to facilitate experiments of longer and more varied mode sequences. Analyzing such results could bring about new insights that can complement the existing landscape of moded interaction, especially when the interactivities commonly offered today are becoming increasingly complex and lengthier.

2 Experiment

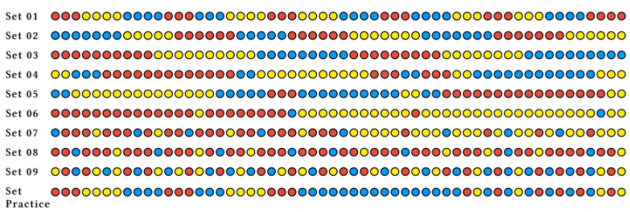

Figure 1: 10 sets of mode sequences were designed to evaluate between Persist and UMI. Red, yellow and blue colors represent the 3 different modes.

None of the 3 studies incorporated the locking mechanism [2] into the *UMI* technique used in their evaluation in which the user is able to “lock” a temporary mode (i.e. the mode requiring a sustained effort such as keeping pressed) as a primary mode in UMI in case a frequent or dominant appearance of a mode could benefit a switching of primary-secondary mode relationship in UMI. This is a good opportunity to include locking in our experiment because of 2 reasons: Firstly, no quantitative studies had been done to confirm or support the effectiveness of locking as an additional feature to *UMI*. Secondly, the length (i.e. 10 times longer than previous studies) of the patterns used in our study warrants the inclusion of locking so that the burden of holding continuously can be transferred from the user to the system while still pertaining the benefits of UMI. This is especially relevant in today’s contexts where mainstream messaging applications like WhatsApp and Telegram, where the initially user-maintained voice-recording feature is supported with an optional locking, which comes in handy in lengthy recordings. Hence, we re-designed the conventional experiment to better accommodate the latest development of both Persist and UMI techniques while switching between 3 modes.

2.1 Design

Fig. 1 depicts the complete mode sequences belonging to 10 different sets (1 practice, 9 experimental) designed for the experiment. Table 1 highlights how our study varied both repetition and alternation factors in each set. Set 01 to 05 were designed to reflect an increasing number of consecutive circles of the same mode, which we defined as Repetition Frequency (RF), while maintaining the almost equal distribution of 3 modes, as reflected in the Yellow-Blue-Red (YBR) Ratio. This allows us to determine the extent that the length of mode repetition affects the preference to lock while using *UMI* technique. For Set 06 to 08, we varied the number of outliers as well as the number of dominating modes. Set 09 is probably the most complicated among the rest of the sets as there are no consecutive repetition of modes and the distribution across the 3 modes is almost equal. The last set is a practice set which is an amalgamation of the key characteristics portrayed by Set 01 to Set 09. Each set can be completed by clearing the provided sequence, one circle at a time.

Table 1. Key characteristics of mode sequence patterns.

Set	Characteristics	Set	Characteristics
01	RF = 3 to 4 YBR Ratio =1:1.05:1.05	06	1 outlier in subsets of 16 2 dominating modes YBR Ratio = 23:2:31
02	RF = 5 to 7 YBR Ratio = 1:1.05:1.05	07	≤ 3 outliers in subsets of 8 2 dominating modes YBR Ratio = 3:1:3
03	RF = 8 to 10 YBR Ratio = 1:1.05:1.05	08	≤ 3 outliers in subsets of 8 1 dominating mode YBR Ratio = 1:1:5
04	RF = 11 to 13 YBR Ratio = 1:1.05:1.05	09	RF = 1 YBR Ratio = 1:1.05:1.05
05	RF = 14 to 16 YBR Ratio = 1:1.05:1.05	Prac-tice	First 24 = Set 01 Next 16 = all blue Last 16 = Set 09

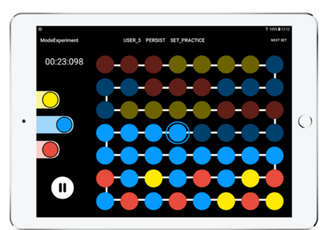

Figure 2. Screenshot of a practice set in a snake layout

A simple interactive tablet application was developed to test these patterns (Fig. 2). As shown in the figure, the sequence of colored circles was ordered in a ‘snake’ layout to avoid troubling the user when sweeping through the rows. Each colored circle can be cleared by matching its color with that of the outer ring, which is controlled by the 3 mode buttons on the left side of the screen. Upon correct matching, the colored circle can subsequently be tapped to be greyed out as complete (in Fig. 2, the user has tapped half the set) and the outer ring will jump to the neighboring circle. Different sound effects are played as feedback informing whether circles are triggered correctly.

For Persist, we selected a traditional yet scalable variation of the implementation, where there will be a button for each mode and the corresponding mode will be persisted upon pressing the button. Shown at the left edge of the screen in Fig. 2, there are 3 horizontal bars in yellow, blue and red color. Each of these bars is a mode button. The longer length of the bar represents the persisted mode and only one mode can be persisted at a time. For UMI, the difference is that each button will only activate the corresponding mode as long as the user holds onto the mode button. Upon releasing it, the mode will automatically return to the primary mode (i.e. previously persisted mode). As mentioned previously, the locking mechanism was incorporated into this implementation of UMI to provide each of the three modes equal opportunity to be made a primary mode on demand. Having experimented with different interaction finger gestures such as sliding to trigger the locking [2], in this study we used double-tapping due to the clear speed advantage that can be observed.

2.2 Apparatus, Participants and Procedures

The application was developed using Android Studio and installed on an 8-inch Samsung Galaxy Tab S2 tablet running Android OS 7. Screen and audio recordings were made to document both the session's interaction details as well as the verbal feedback expressed by each participant. We recruited a total of 20 participants (11 female and 9 male between 17 and 32 years old, mean age 23.7, SD = 4.14) who had prior experience using multitouch tablets. None of the participants had color vision deficiency and hence had no difficulties differentiating between the 3 mode colors. Each participant completed a total of 20 sets (10 sets per technique) in a randomized order to counterbalance any bias from the order effect of the 9 patterns. Half of the participants had to complete the first 10 sets using Persist technique while another half used *UMI* to ensure that the order of techniques does not affect any of the results collected. 5-minute breaks were allowed between the 2 techniques to prevent the accumulation of fatigue. At the beginning of each technique, participants started with a practice set to familiarize themselves with the new technique and strategize on how to balance the speed-accuracy tradeoff. The best-performing participant was rewarded $20 for minimizing both time and error.

After completing the required circle-tapping tasks, each participant rated their experience for each technique based on 4 different aspects: ease of use, accuracy, speed, and fatigue. We used a 5-point Likert scale where "1" means very low and "5' means very high for ease of use, accuracy, and speed while the points are reversed for fatigue. This is so that we can consistently associate bigger numbers as more positive attributes.

3 Results

We used two-way ANOVA to find out if there are significant main effects of *Technique* and Set on quantitative data like time and error rate. If Mauchly's test showed a violation in the sphericity hypothesis, Greenhouse-Geisser was then applied to correct both the p-values and reported degrees of freedom. If interaction between *Technique* and *Set* is significant, simple main effect of *Technique* will be analyzed instead. For subjective preferences, we used Friedman's test without post hoc analysis.

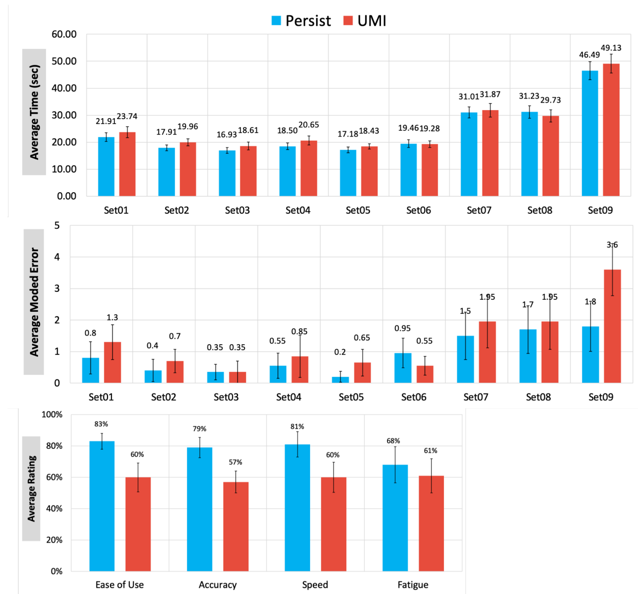

Figure 3. The average duration spent (top), moded error incurred in each set (middle) and subjective ratings (bottom). Error bars show 95% confidence interval.

With respect to time, each participant spent on average 25.11 seconds completing each set using both techniques. ANOVA showed significant interaction between *Technique* and *Set* ($F_{4.83,91.79} = 3.66, p < 0.01$). Hence, simple main effect revealed that Persist is consistently faster ($p < 0.05$) than UMI in Set 01, 02, 03, 04, 05, and 09. This is interesting because regardless of low (Set 09) or high RF (Set 01 to 05), Persist has an advantage over UMI. With respect to error rate, participants incurred an average of 1.12 moded errors out of the 56 circles to be tapped. A two-way ANOVA also revealed significant interaction between *Technique* and *Set* ($F_{3.87,73.49} = 3.06, p < 0.05$). In addition, simple effect revealed that on average, Persist (1.8) incurred less faster ($p < 0.05$) mistakes than UMI (3.6) in Set 09 only (See Fig. 3). With respect to subjective preferences, Persist was consistently rated more favorable than UMI with at least 20% difference for ease of use, accuracy and speed, and 7% difference for fatigue level (see Fig. 3). Friedman's test found a significant difference between Persist and UMI in ease of use ($\chi^2(1) = 8, p < 0.005$), accuracy ($\chi^2(1) = 11.27, p < 0.001$), and speed ($\chi^2(1) = 6.25, p < 0.05$), but not for fatigue level.

4 Discussion and Future Work

The overall result of Persist technique consistently performed better than UMI, may be contradicting against past experimental results at first glance, especially when our Set 09 is of the same alternating pattern used in the previous studies. However, it can in fact be supplementary because the mode patterns used in our study are of a much longer length, and more diverse than just consecutively alternating, hence reflected interesting nuances between the two techniques that have not been highlighted before.

For instance, one of the reasons why participants preferred Persist over UMI was due to its consistent model of interaction regardless of the presented patterns. P3 commented that "*I don't have to remember which mode is the primary one (while using* Persist*)*". For every colored circle encountered that is different from the previous one, the mode button must be re-selected to persist the new mode, prior to tapping the target circles. This consistency simplified the mode-selection process and made it an effortless experience despite costing additional taps. On the other hand, UMI's locking mechanism not only facilitated easy reversal of mode relationship between primary and secondary but also resulted in the unequal treatment of modes. P8 said that she had to "*constantly check if the incoming target mode is already the primary mode or not. If yes, there is no need to press the mode button. Else, it has to be pressed before the colored circle can be tapped.*" A mental if-else decision like this was what slowed down participants' performance while using UMI.

However, as we compared the performances of both techniques across the different sets, we could find instances where UMI was perceived to be more desirable than Persist. For instance, although P7 said that "*holding (a mode button temporarily) is a hassle*", he agreed that "*it does give more control of what is happening or what mode is currently active*". P1, P10 and P18 also commented that "*locking one mode means that there is one less mode that (he has) to control*". One of them was directing all his attention to the selection and holding of 2 temporary modes while simultaneously relying on his automatic response to release the same button when the incoming target is a primary mode. Most of the participants shared the same sentiment that patterns depicted by Set 06, 07 and 08 are where UMI has an advantage over Persist and hence would prefer using it. As shown in Fig. 3, participants spent less time in Set 08 and incurred less moded error in Set 06, as compared to when they used Persist. The observations made sense because these sets were characterized by the presence of one or two dominating modes and singular outliers that can benefit from UMI's temporary activation of mode and locking feature.

Since the design implemented in this study is a generalized abstraction of moded interaction, future development should incorporate a more realistic environment (e.g. role-playing games that switch between multiple weapons) to evaluate the techniques. Furthermore, it would also be interesting to investigate the net effect of locking and other trigger mechanisms of it.

5 Conclusion

This study explored how a modification of mode-switching patterns in experimental design can bring about new perspectives of Persist and UMI techniques. The results showed that each technique has its own strengths and weaknesses depending on the pattern of mode sequences. The performance across time, moded error and subjective preferences favor Persist more than UMI. However, patterns with clear dominating mode show that UMI (and its locking feature) could definitely come in handy. We plan to conduct more studies with varying patterns and interaction techniques to further confirm, identify opportunities and design implications for future applications.

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