CIS400/401 Final Report - Designing Rhythm Game Interfaces for Touchscreen Devices

Dept. of CIS - Senior Design 2011-2012

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ABSTRACT

As touchscreen devices become increasingly popular, rhythm games and other interactive software applications are expected to support touch-driven user interfaces. This study focused on the evaluation of the timing accuracy and game enjoyability of various rhythm game interface designs for touchscreen devices. This was accomplished through the development of a rhythm game prototype for Android tablets, "Beats2 Prototypes". The prototype app demonstrated various gameplay user interfaces and collected usage data for quantitative and qualitative comparisons.

1. INTRODUCTION

Over the past few years, touchscreen devices have become increasingly common in the consumer market. According to a report in the March 2010 publication of *Information Display*, consumer-device manufacturers are rapidly adopting touch-input technologies, with revenues increasing *10x* and unit production *3x* faster than the display industry [1]. With the adoption of this new input paradigm comes the natural expectation of increased software support for new touch-focused interfaces, allowing for faster and more natural human-device interactions [2].

One area that touchscreen support can be leveraged is in the design of rhythm games. A *touchscreen* is a specialized display that receives user input through physical contact from a finger or stylus. *Rhythm games* are a genre of music-based games in which the player performs specific actions in response to audio and visual cues. Rhythm games often focus the the player's beat recognition abilities, aided through visual patterns that match the rhythm of the song. These visual patterns consist of a series of *note* objects that appear or move across the screen. Interaction with these notes would typically involve hand actions occuring in the *hitbox* area, a pre-defined area for interaction. In non-touchscreen rhythm games, such actions may be the pressing of a button; in a touchscreen scenario, such actions would be either *soft button* touches, defined as virtual buttons interacted by through tap, or *touch-input gestures*, defined as touch events with predefined timing and path properties. The performance of the player is reflected by their *timing accuracy*, measured by the time difference between the timestamp of the touch event and the expected time for that note.

The success of a rhythm game depends on two main factors: 1) game mechanics that allow players to best maximize their timing accuracy, and 2) a gameplay experience that is perceived as enjoyable. Both factors are strongly influenced by the gameplay's *interface design*, defined as the placement and movement patterns of the game's note and tapbox elements. In this study, gameplay with a specific style of interface design is referred to as a rhythm game *Mode*. The interface designs must also be designed to accomodate to the input method of the hardware it will be applied to. In this study, the target hardware were large touch-screen devices such as multi-touch tablets running the Android OS. Through the development of an Android rhythm game prototype and collection of user gameplay data and feedback, this study compared the timing accuracy and game enjoyability of various different rhythm game interfaces for touchscreen devices.

2. RELATED WORK

Wiimote + Dance Game

In their study, "Understanding Visual Interfaces for the Next Generation of Dance-Based Rhythm Video Games," Charbonneau et al. presented their experimental study of comparing game interfaces for *RealDance*, a dancing game prototype that uses the Wiimote. Three interfaces were compared: "Timeline", "Motion Lines", and "Beat Circles." The results of their studies showed that both "Motion Lines" and "Beat Circles" were significantly more efficient than the traditional "Timeline" interface in dance games [4].

External Multi-Touch Panel + Turn-based Strategy Game

In their study, "A Study on Multi-Touch Interaction for Game," Yong-Chul Kwon and Won-Hyung Lee created a multi-touch panel using FTIR technology and tested ot with a turn-based strategy game. In doing so, they created guidelines for multi-touch user interface designs and also argues that touch interfaces can be more comfortable and sensitive than traditional mouse and keyboard input given that the game interface is designed for multi-touch technology [5].

iPad + Real-Time Strategy Game

In their study, "One-handed interface for multitouch-enabled real-time strategy games," Crenshaw et al. designed a new touch-based interface for single-handed usage of large-sized touch devices. They first designed a real-time strategy game with a touch-based interface and surveyed participants with it. Their study showed that porting traditional desktop

games to iOS require the development of a user interface specifically aimed at touchscreen interfaces.They argue that well designed multi-touch user interfaces can lead to faster and more accurate response times due to the larger area and less targetting precision required of gestures over traditional buttons [6].

3. STUDY OVERVIEW

This study compared rhythm game interfaces through the following three stages:

1. *Design* various simplified rhythm game interfaces with categorized properties
2. *Prototype* app development of a rhythm game that test the various interfaces
3. *Evaluation* of the interfaces through collecting user data and feedback

3.1 Design

In the *Design* stage of the study, existing commercial rhythm games for various hardware platforms were analyzed and categorized based on common game interface properties. These properties were then used to create simplified rhythm game interfaces.

Designs

The results of analyzing commercial rhythm games are shown in Figure 29 in the *Appendix*. Based on the generalized styles from the analysis, eight simplified interface designs were drafted and categorized as shown in Figure 28 in the *Appendix*. These interface designs were defined based on 1) the mobility of tapbox and note elements, and 2) the movement behaviours of elements within game area.

Three element mobility categories were chosen for the interface designs:

1. Moving notes and fixed hitboxes
2. Moving hitboxes and fixed notes
3. Fixed notes and fixed hitboxes

Four movement behaviour categories were chosen for the interface designs:

1. Top to bottom
2. Centre to corners
3. Corner to centre
4. Fixed grid points

Comparisons

These eight interface designs encompass the majority of interface designs used by the rhythm games analysied in Figure 29. Mode #1 closely matches all the rhythm games under the "Falling Notes" style, particularly *Dance Dance Revolution*. Mode #2 is similar to the games under the *Spreading Notes* style but more emphasized in the spreading aspect. In those games, objects approach from a central area in the horizon up top to a row near the bottom; in Mode #2, the objects approach from the horizon in the centre of the screen to the four corners. Mode #3 is similar to *Gitaroo Man Lives!*'s "Focusing Notes" style but with four focus points instead of one. Mode #4 closely matches *jubeat*'s "Grid" style. Mode #5 matches *DJMax Technika*'s "Sliding Hitbox" style. Mode #8 is similar to *Osu! Tatakae! Ouendan!*'s "Appearing" style but restricts objects into a grid instead of allowing any location. This was done to reduce the complexity of the game and the player's possible reaction delay from an object appearing in an unexpected location.

There are currently no rhythm game with an interface similar to Mode #6 nor #7; however, the two styles were included as the reverses of #2 and #3 respectively. The "Streaming Notes" and "Sliding Cursor" styles were not covered in this study. This is because 1) they only operate on one dimension, and 2) the complexity of their gameplay comes from visual recognition of the object subtypes, a factor that is eliminated from this study through only using a single graphic for all notes objects and a single graphic for all hitbox objects.

3.2 Prototype

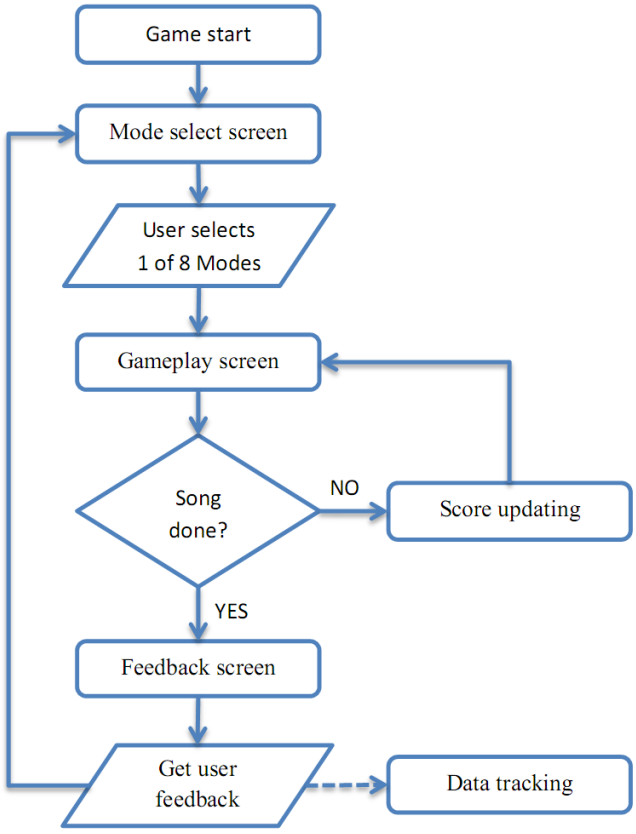

Figure 1: Gameflow diagram for the prototype app, "Beats2 Prototypes".

In the *Prototyping* stage of the study, the designed rhythm game prototype was created implementing the designs drafted in the previous *Design* stage as eight selectable "Modes". Figure 1 shows the overall gameflow diagram of the final prototype app, "Beats2 Prototypes". The following are more detailed descriptions of each stage:

Game Start

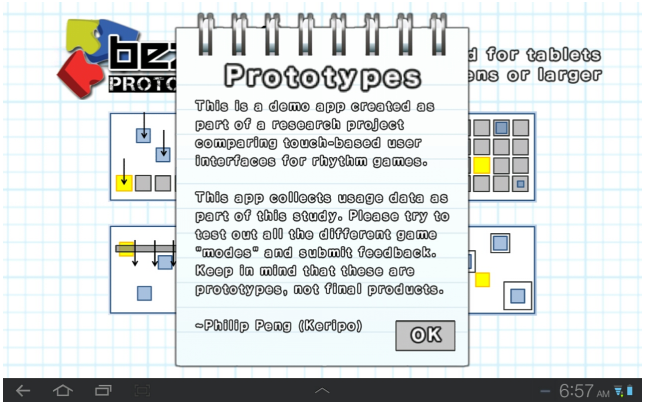

Figure 2: Screenshot of the data collection message.

The prototype app is an Android app that can be launched from the Android tablet or phone's apps list. It was written for the cross-platform *Unity3* game engine (see the *Technical Resources* section for more details), so a *Unity*-branded splash screen will display on start. After the splash screen, a short message will appear notifying the user than s/he is participating in a study which will collect usage data from them (see Figure 2). After closing the disclaimer, the user will be at the "Mode Select" screen.

Mode Select

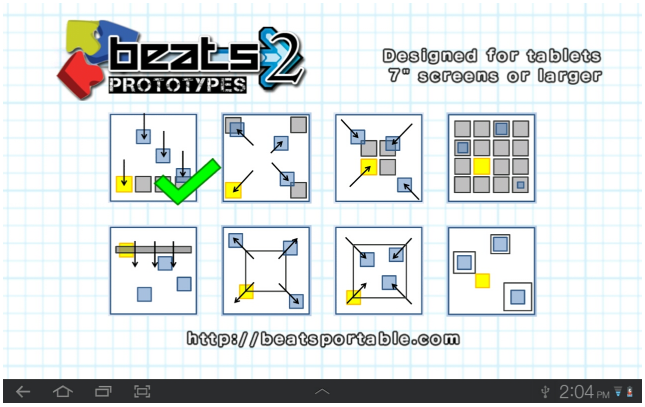

Figure 3: Screenshot of the "Mode Select" screen.

In the "Mode Select" screen, all eight Modes will be displayed via their respective representative icons (see Figure 3). Tapping on any of the icons will start the game featuring the respective Mode's interface design. For the user's convenience, gameplay history is kept for the duration of the session (launch to exit) and previously played Modes are indicated via an overlayed checkmark.

Gameplay

After a Mode has been selected, the "Gameplay" screen loads (see Figure 4 and 5). For all eight Modes, the same common backend and data is used. The background song used was the rhythm game *Beatmania IIDX 16: Empress*'s popular dance song "smoooooch" by composer "kors k" [7]. The song was chosen for its strong, easy-to-recognize rhythm

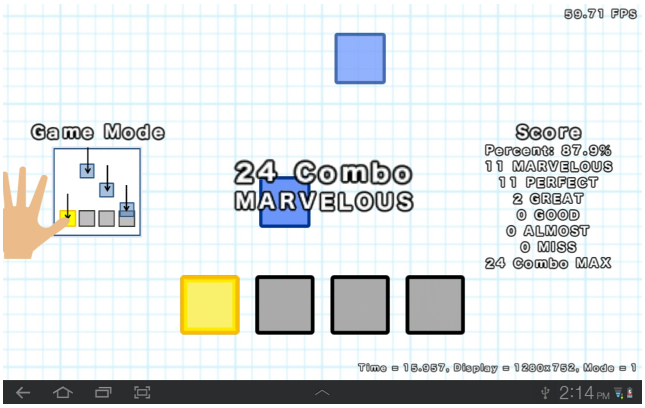

Figure 4: Screenshot of Mode #1's "Gameplay" screen.

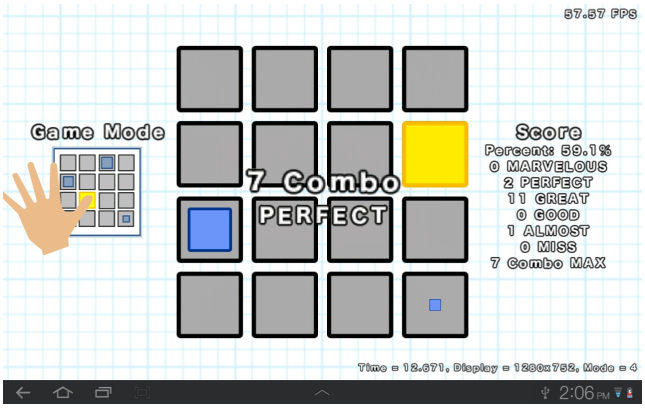

Figure 5: Screenshot of Mode #4's "Gameplay" screen.

and steady, high tempo (177 BPM). The notes pattern data was generated using Karl O'Keeffe's open source program, *Dancing Monkeys*, which generates note patterns with extremely high precision [8].

For all Modes, interface elements other than the notes and hitboxes were kept consistent. The left side of the screen featured the icon of the current Mode with an overlayed hand graphic indicating the suggested hand placement (explicit instructions would affect the "Intuitive" feedback metrics - see the *Evaluation* section). The right side of the screen featured the current percent score and timing accuracy chart. The top right corner featured a live "frames-per-second" counter for debugging purposes. The bottom right corner featured a text label containing the current music time, the screen dimensions, and the current Mode, also for debugging purposes. The entire middle of the screen is an open square area in which the selected Mode's respective interface design is implemented. The only exceptions to this consistency are the location of the current combo and current accuracy text labels for Mode #3, for which they were shifted underneath the hitbox area a bit to avoid obstructing view.

Score Updating

While the game is running, notes are constantly loaded from the pre-generated notes pattern data and notes/hitbox properties updated. Whenever a note is hit, a score update event is triggered based on the timing accuracy of the note hit. Each note has its own corresponding expected time value (in milliseconds) which is compared to the current music time. The time difference is then compared against the chart in Figure 6 to evaluate the qualitative timing accuracy value. For example, a time difference of 100ms (late) would map to a "PERFECT" note hit whereas 125ms would map to a "GREAT" note hit.

Accuracy Value	Timing
INACTIVE	< -300ms
ALMOST	-300ms
GOOD	-210ms
GREAT	-150ms
PERFECT	-90ms
MARVELOUS	-30ms
PERFECT	40ms
GREAT	120ms
GOOD	200ms
ALMOST	280ms
MISS	400ms

Figure 6: Timing chart used to evaluate a note hit's timing accuracy value.

If the accuracy value is "INACTIVE", the note hit is ignored, otherwise, a respective counter is incremented. For accuracy values of "GREAT", "PERFECT" or "MARVELOUS", the combo counter is incremented. For other non-"INACTIVE" values, the combo counter is reduced to zero. If the note ever reaches the "MISS" range, the miss event is automatically triggered (combo reduced to 0 and the "MISS" counter increases). Note that the accuracy value intervals in the positive range are greater than in the negative range to account for the observed tendency of users to hit notes slightly later.

The absolute value of the time difference is then added to a cummulative time difference sum and divided by the cummulative notes hit count to calculate the new percent score. A "MISS" is given the time difference of 400ms. Note that because the percent score is calculated with the raw time differences, two game playthroughs may have the same accuracy value counter numbers but slightly different percent scores.

After the accuracy value has been processed, the combo and accuracy text labels overlaying the middle of the screen and timing accuracy chart on the right side of the screen are then updated to reflect the new game statistics.

Feedback

Figure 7: "Feedback" overlay.

Once the song is complete, the "Feedback" screen/overlay is displayed. The overlay presents an interface where the user can select a 1-5 star rating for each of the five feedback metrics ("Challenge", "Intuitive", "Unique", "Fun", and "Overall" - see the *Evaluation* section for more details). Once all five of the categories have been rated, the "Submit" button becomes activated. Clicking on the "Submit" button will trigger tracker data sending, then bring the user back to the "Mode Select" screen.

Data Tracking

Upon the start of the gameplay, a "Started" event would be tracked and sent to *Lumos*. Upon the completion of the gameplay, a "Completed" event would be tracked and the percent score, combo max value, and the entire timing accuracy chart's values would also be sent. Once the user completes the "Feedback" screen and taps the "Submit" button, the feedback ratings will also then be sent. Each tracked data is sent separately instead of together in the case that not all tracked data is available (e.g. the user exits the app without leaving feedback ratings). See the following *Evaluation* section for more details on the data itself.

3.3 Evaluation

In the *Evaluation* stage of the study, the rhythm game prototype was published on *Google Play*, the official app store for Android from Google [9]. A popular, previously published rhythm game, *Beats, Advanced Rhythm Game*, was used to advertise the prototype [10]. The prototype app targetted tablet devices due to the facts that 1) Android tablets usually feature large multi-touch displays [12] for which interface design has a significant effect, and 2) Android tablet use is on the rise [11]. For comparison purposes, data collection was also done for Android phones, which feature a significantly smaller touchscreen.

To collect user data that can be used for this study, the app implemented a data tracker that uses a free metrics tracking service by *Lumos* (see the *Technical Resources* section for more details). Data was collected for quantitatively metrics (usage and gameplay statistics) and qualitative metrics (feedback ratings) for each individual Mode (#1-8) and platform (tablet and phone).

Usage Statistics

Usage statistics measured quantitatively:

- Game Started count
- Game Completed count
- Feedback Submitted count

The usage statistics reflects on the overall prototype itself. Comparing the "Game Started" counts between the different Modes compares the popularity of each Mode relative to each other. A Mode that looks interesting at first look or is found to be interesting after the first playthrough will have a higher "Started" count. Comparing the "Completed" count to the "Started" count reflects on how well the Mode meets the user's expectations in interest level. A Mode that is boring and is not enjoyable to the user may not be played through to completion. The "Feedback Submitted" count can be used to calculate the percent of users who played through the Mode and was willing to provide feedback. These percentages can also be used as a rough measure of the accuracy of the results of this study.

Gameplay Statistics

Gameplay statistics measured quantitatively:

- Percent Score value
- Combo Max count
- MARVELOUS count
- PERFECT count
- GREAT count
- GOOD count
- ALMOST count
- MISS count

The gameplay statistics reflect on the timing accuracy of the Mode being studied. A Mode with an interface design that is well suited for fast touch-based user input (e.g. playing rhythm games on a touchscreen devices) will inherently have gameplay statistics indicating high timing accuracy. The "Percent Score" value is a raw measure of this timing accuracy. The "Combo Max" count is correlated to the general consistency of timing accuracy. The specific accuracy value breakdown of hits gives a better picture of median average timing accuracy as "Percent Score" can be greatly skewed if the "MISS" count is high. Since Mode #1's "Falling Notes" style is very common amoung currently available rhythm games, it is expected to have high familiarity amoung users and can be used as a baseline for comparison.

Feedback Ratings

Feedback ratings measured on a 1-5 star scale:

- Challenge
- Intuitive
- Fun
- Unique
- Overall

These feedback ratings reflect on the game enjoyability of the Modebeing studied.

The "Challenge" rating measures the difficulty of the gameplay. A high "Challenge" rating would imply that the user found the Mode's interface design difficult to use and react to, leading to low timing accuracy. A high "Challenge" rating could be either desirable or not depending on whether users see the difficulty as a nuisance or an added twist to the game; thus, this rating should be evaluated together with the "Fun" rating.

The "Intuitive" rating measures the learning curve of the gameplay. A high "Intuitive" rating would imply that the user found the interface easy to learn and easy to use. A user interface that feels natural and intuitive is usually highly desirable in games and allows for easier mastery (i.e. improved timing accuracy).

The "Fun" rating measures the direct enjoyability of the gameplay. Enjoyability is influenced by a number of possible factors depending on the user. For games where the goal is to have users enjoy spending time playing the game, a high "Fun" rating is desirable.

The "Unique" rating measures the novelty of the gameplay. In a competitive market where games often try to copy ideas off each other, originality and uniqueness can sometimes play an important factor in making a game stand out. A high "Unique" rating implies the user found the Mode very different from the rest, possibly as a new interface never used before. A unique game can draw many new users; however, it cannot predict the long-term success of the game.

The "Overall" rating measures the reception of the gameplay as a whole. A high "Overall" rating would imply that the user found the gameplay under that Mode to be suitable for a successful rhythm game, with all factors accounted for.

4. RESULTS

The following are results collected from the *Evaluation* stage of the study. For each Mode, the average accuracy values are presented as pie charts for tablets and phones separately (see Figure 30 in the *Appendix* for the complete data set), with the colour legend matching the colours used in timing diagram of Figure 6. For analysis purposes here, a "X% accuracy" refers to the combined percentage of accuracy values of "PERFECT" and "MARVELOUS".

The average feedback rating values are also presented as bar charts with tablet and phone data beside each other (see Figure 31 in the Appendix for the complete data set). The analysis, however, focused mainly on tablet data as most of the interfaces were not designed for the small screens of phones (defined in this study as having a screen size of under 5" across). Specifically, the destination layout aspect is no longer an influential factor when the entire span of the screen is consistently in the user's viewing angle, thus requiring little change in focus.

In the last subsection, overall results were compared and Modes analyzed relative to each other. These results were then used to make general conclusions for each interface design in the *Conclusion* section. Note that all analysis is only based on tablet results.

Mode #1: Falling Notes

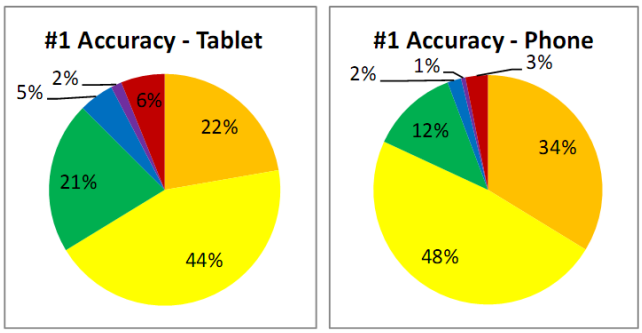

Figure 8: Mode #1 accuracy data.

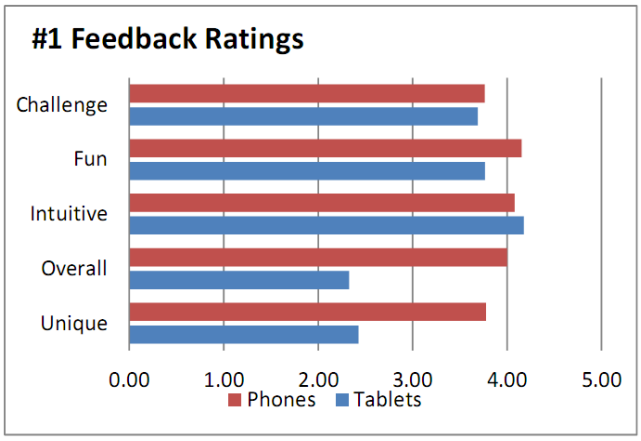

Figure 9: Mode #1 feedback data.

Mode #1 uses the "Falling Notes" style that is most common in rhythm games (see Figure 29), so it can be used as a target baseline for the other Modes to try to match. Visual focus was at a fixed row of hitboxes, with notes moving along linear paths from the peripheral vision. The linear, overall single-dimensional direction of motion allows for more focus on accurate timing. As expected, accuracy was high at 66%.

Mode #1 received extremely low "Unique" and "Overall" ratings at 2.43 and 2.33 respectively. These low ratings can be attributed to the commonality of the style in rhythm games.

Mode #2: Spreading Notes

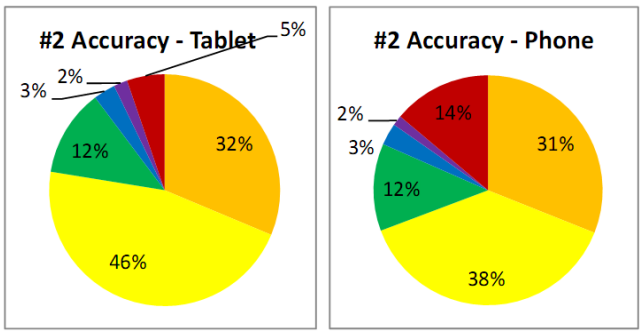

Figure 10: Mode #2 accuracy data.

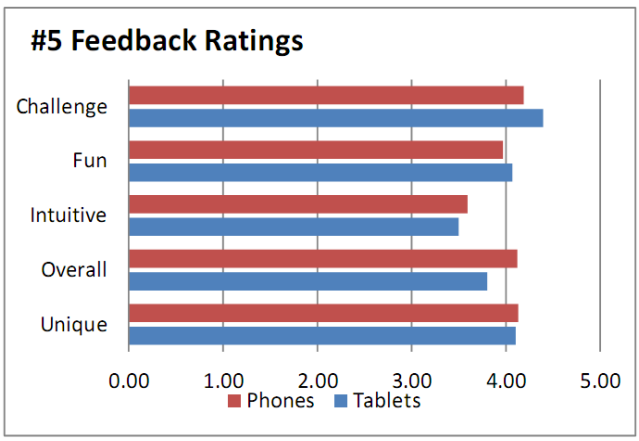

Figure 11: Mode #2 feedback data.

Mode #2 changes the visual focal points (from all on one side in Mode #1) to the four corners of the screen. Since notes appear and move out from the centre, however, users could instead focus mainly there if the four corners still lie within peripheral vision (which is currently true for most touchscreen sizes). In addition, the corner hitbox placement means the hands can be placed around the perimeter of the tablet itself to avoid obstructing view of the notes. These positive factors are reflected in the results of an extremely high 78% accuracy (surpassing Mode #1).

Mode #2 received strong ratings of almost 4.00 in all categories.

Mode #3: Focusing Notes

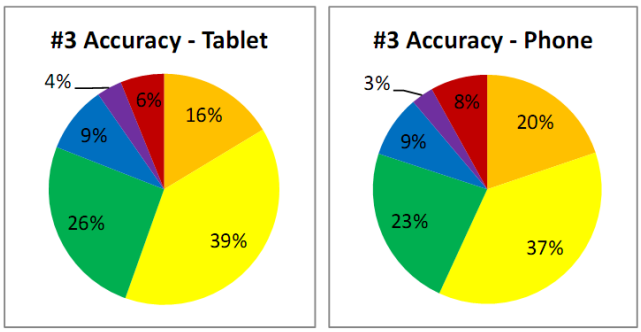

Figure 12: Mode #3 accuracy data.

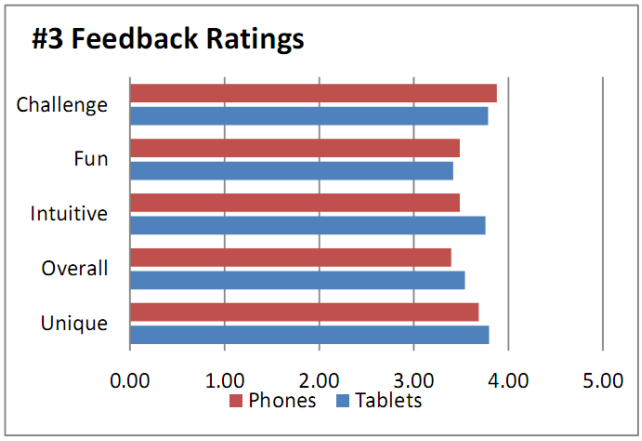

Figure 13: Mode #3 feedback data.

Mode #3 is the opposite of Mode #2 in terms of focal position, with notes moving from the corners to a central location. While there is the advantage of tapping fingers only needing to travel short distances between hitboxes, the rest of the hand obstructs the screen. This disadvantage most likely explains the mediocre accuracy of 55%.

Mode #3 received relatively low ratings overall, with a low "Fun" rating of 3.42.

Mode #4: Grid

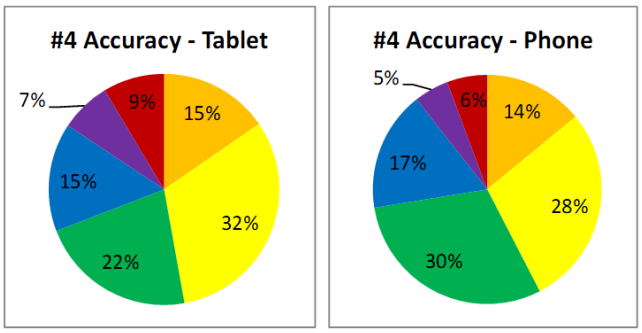

Figure 14: Mode #4 accuracy data.

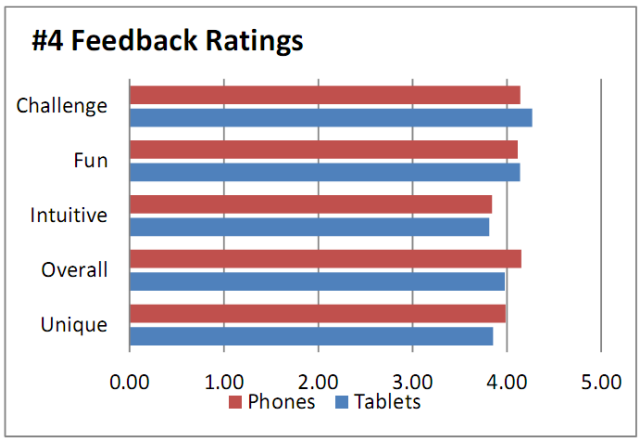

Figure 15: Mode #4 feedback data.

Mode #4's grid layout requires full focus on the entire screen, but at fixed points. The increased area of focus resulted in reduced focus per hitbox, leading to lower timing accuracy. The accuracy of this Mode was low at 47%.

Mode #4 received a high "Challenge" rating of 4.27, reflected in the low accuracy results. Despite this, the Mode was well received with ratings around 4.00 in the other four categories.

Mode #5: Sliding Hitbox

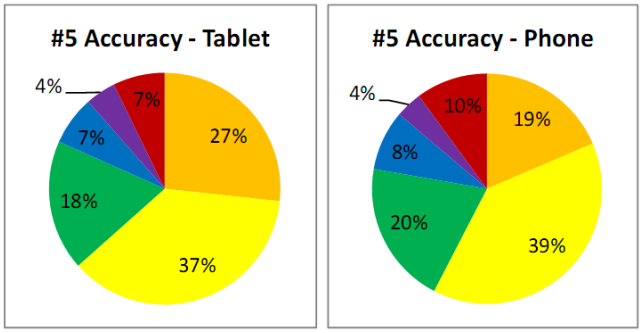

Figure 16: Mode #5 accuracy data.

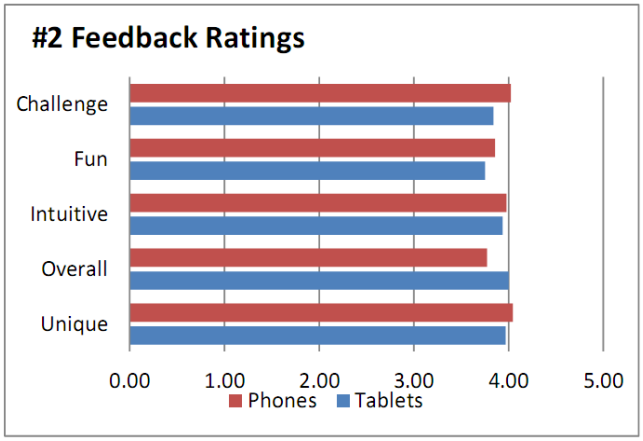

Figure 17: Mode #5 feedback data.

Mode #5 is the complement of Mode #1 and shares the same advantage of having a single-dimensional direction of motion. Unlike Mode #1, however, Mode #5 requires the user to continuously change focus to follow the moving hitbox, moving from the bottom immediately back to the top. The resulting accuracy is good at 64%.

Mode #5 received a low 3.50 for "Intuitive" rating, most likely due to the game mode being uncommon. Although the Mode had high accuracy results, the high "Challenge" rating is possibly attributed to users finding the interface new and unintuitive at first.

Mode #6: Expanding Hitbox

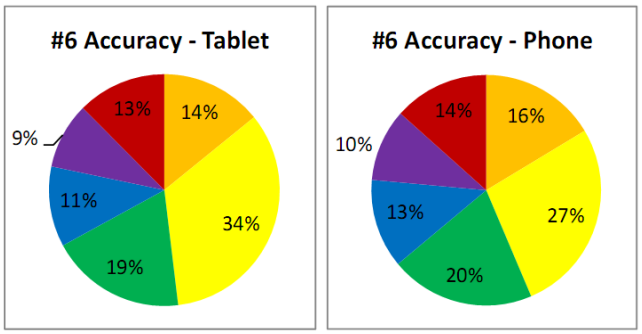

Figure 18: Mode #6 accuracy data.

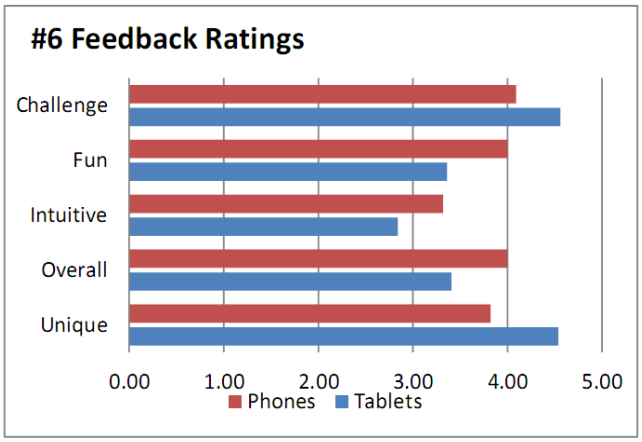

Figure 19: Mode #6 feedback data.

Mode #6 is the complement of Mode #2. Unlike Mode #2, however, the hitbox is not fixed, so the tapping fingers must continually move. Mode #6 suffers the same disadvantage as Mode #5 of a continously changing focus (from outside back to in). When tapping notes close to the centre, the same Mode #3 vision-obstructing issue from hands applies. These compounded disadvantages lead to a poor accuracy of 48%.

Mode #6 received an extremely high 4.56 "Challenge" rating and a correspondingly low 2.84 "Intuitive" rating. While it has a high 4.54 "Unique" rating, the low "Fun" and "Overall" ratings indicates poor reception of the Mode.

Mode #7: Collapsing Hitbox

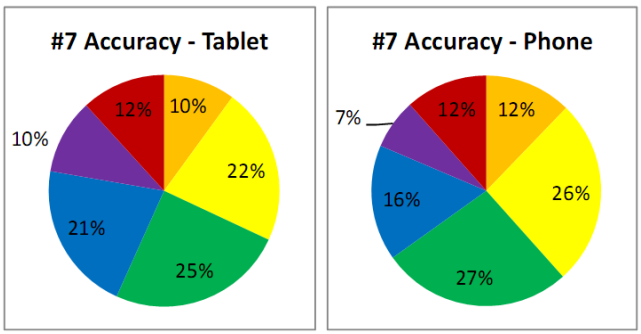

Figure 20: Mode #7 accuracy data.

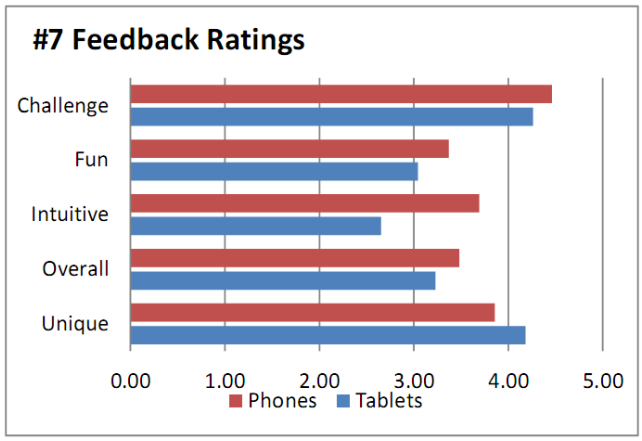

Figure 21: Mode #7 feedback data.

Mode #7 is the complement of Mode #3. It shares all the disadvantages of Mode #6 but with at a stronger level for vision-obstruction from hands. As a result, Mode #7 has the lowest accuracy of all the Modes, at 32% accuracy.

Mode #7 received similar poor ratings to #6, with the lowest "Fun" and "Intuitive" ratings of 3.04 and 2.65 respectively among all Modes.

Mode #8: Appearing

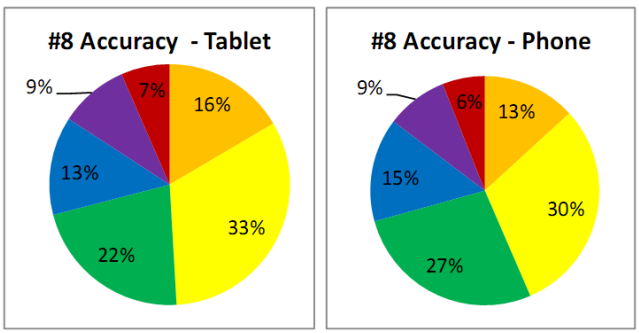

Figure 22: Mode #8 accuracy data.

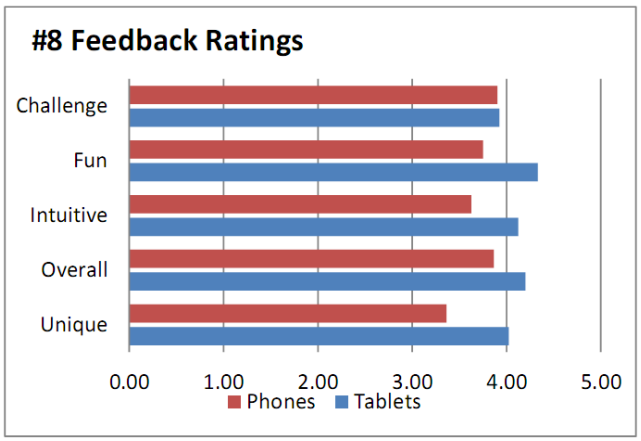

Figure 23: Mode #8 feedback data.

Mode #8 is the complement of Mode #4. Because the hitboxes only appear when the note appears, however, the interface is a lot less cluttered, allowing for greater focus on the notes that do appear. The accuracy is slightly improved from Mode #4 at 49%.

Mode #8 was very well received, with a ratings around 4.00 in all categories and the highest "Fun" rating of 4.33.

Overall

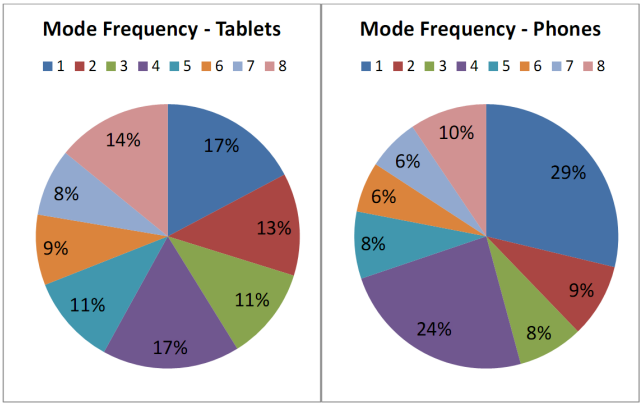

Figure 24: Overall mode selection frequency.

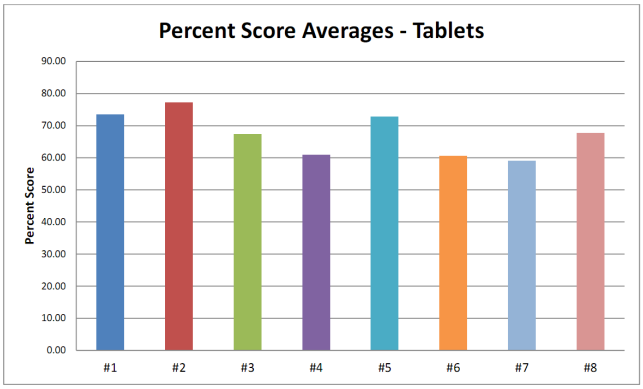

Figure 25: Overall percent score averages for each mode on Android tablets.

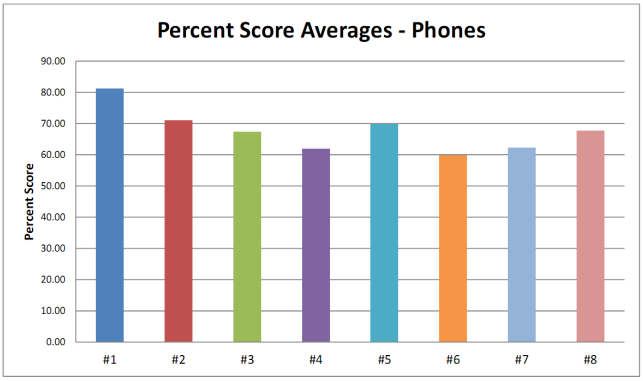

Figure 26: Overall percent score averages for each mode on Android phones.

Qualitatively, Modes #2 and #1 had the highest percent score averages, followed by #5 and #3 in that order. On the other hand, Modes #6 and #7 had extremely low percent scores and accuracy. This matches the relative accuracy percents determined from comparing each mode's accuracy value charts earlier.

Qualitatively, Modes #8 was the best rated, receiving the highest "Fun" rating of 4.33 and around 4.00 for the other ratings. Mode #2 was also very well received with almost 4.00 for all ratings. Mode #1 received the lowest "Unique" and "Overall" ratings of 2.43 and 2.33 respectively, most likely due to its "Falling Notes" style being very commonplace and uninteresting. Despite that, it was also the most commonly played mode, with the highest mode select frequency of 17

5. CONCLUSION

In this study, two aspects of rhythm game successfulness are studied: timing accuracy and game enjoyability. Swetser and Wyeth argues that enjoyment of games does not only depend on the final outcome but also factors such as concentration, mastery, and fun [13]. In this case, the final outcome is measured in timing accuracy via quantitative percent scores and accuracy charts, while the other factors are measured by game enjoyability via qualitative feedback ratings.

Because of the independence of these two aspects, two different concluding results can be made. When considering timing accuracy, Modes #1 and #2 are great choices, #3 and #5 are good choices, #4 and #8 are poor choices, and #6 and #7 are bad choices. When considering game enjoyability, Modes #2, #4 and #8 are great choices, #5 is a good choice, #1 and #3 are poor choices, and #6 and #7 are bad choices. These results are shown visually in Figure 27.

Mode	Timing Accuracy	Game Enjoyability
#1: Falling Notes	Great	Poor
#2: Spreading Notes	Great	Great
#3: Focusing Notes	Good	Poor
#4: Grid	Poor	Great
#5: Sliding Hitbox	Good	Good
#6: Expanding Hitbox	Bad	Bad
#7: Collapsing Hitbox	Bad	Bad
#8: Appearing	Poor	Great

Figure 27: Comparing timing accuracy and game enjoyability of the studied rhythm game Modes.

6. ETHICS

When using analytics services for mass data collection from users of software, privacy and unnecessary information collection is always a potential ethical concern. This study, unfortunately, is no exception.

For the *Evaluation* stage of this study, user data is collected through *Lumos*, an analytics service and associated software package written by Rebel Hippo Inc. (see the *Technical Resources* section). While *Lumos* is able to successfully

collect data users of the app willingly submit for the sake of this study, it also automatically collects additional data about the device itself. Unnecessary but possibly privacy-infringing information such as the device's hardware specifications, OS details, and even locale is collected by default. While they are not relevant to this study, they do pass through an unaffiliated third party (Rebel Hippo Inc.). One possible solution to this potential risk would be to implement an in-house data collection service to replace the *Lumos* setup.

7. FUTURE WORK

On the game development side, the results of the game enjoyability comparisons of this study can be used for designing of more complex touch-based game interfaces. In particular, Modes #2, #4 and #8 are strong candidates as starting points for interface designs of future rhythm games. The planned cross-platform "Beats2, Advanced Rhythm Game" will feature multiple game modes with designs based on those that proved popular in "Beats2 Prototypes" [10].

On the software development side, the results of the timing accuracy comparisons can be used in the designing of general user interfaces in other timing-sensitive applications. With touchscreens expected to become a prominent input method (a highly probably conclusion of current industry trends [1]), user interfaces for interacting with elements in time-critical scenarios will strongly benefit from designs targetting fast element recognition and reactivity. For example, research targetting military applications of touchscreens is still very active [14]. In many military-related endeavours, a few milliseconds delay in reaction time can lead to drastically different results (e.g. selecting enemy targets or dodging enemy projectiles in combat).

On the interface research side, similar studies can be conducted comparing how these same interface designs perform in other specialized input settings. For example, a worthwhile future project would be modifying the prototype app to support *Kinect* input and determining if the comparison results match. This can be accomplished through the *KinVi 3D* project, which allows users to control a computer through a *virtual* touchscreen powered by Microsoft *Kinect* depth sensors [15].

8. TECHNICAL RESOURCES

Test Platforms
The target touchscreen device for testing in this project was the Samsung Galaxy Tab 10.1. The Galaxy Tab is an Android tablet running on a 1GHz dual-core processor and has a 10.1-inch capacitive touchscreen [16]. A Samsung Captivate was also used to check phone compatibility. The Samsung Captivate is an Android phone running on a 1GHz single-core processor a 4-inch capacitive touchscreen [17].

Android SDK
`http://developer.android.com/sdk/`
The *Android SDK* is the set of development tools and core libraries required for developing Android applications.

Unity3
`http://unity3d.com/unity/publishing/android.html`
The *Unity 3* development tools consists of the *editor*, the series of tools for developing games, and the *game engine*, the software backend that allows the developed games to run on target platforms. *Unity 3* was chosen due to its cross-platform support of other touchscreen-supporting platforms and large community and professional support base. In this project, the prototype app runs on this game engine and was built for the Android target (as well as the PC target during development for debugging). The *Unity3* license obtained for this project was the regular *Unity3* package with the additional Android add-on to allow for development of Android apps.

Lumos
`http://www.uselumos.com/`
Lumos is a free online service for tracking usage of features and other metrics. It is provided as an easily integratable *Unity* package and was used in this study to collect user data for the *Evaluation* stage. Because it is still a new service in development, however, the tracking servers are not always stable, leading to occasional request timeouts and thus loss of data. This can be seen in the occasional missing data points in the charts in the *Appendix*. There currently is no other free, effective tracking service for *Unity3* apps, however, and the missing data is weighed out through averaging existing data.

ex2D
`http://www.ex-dev.com/ex2d/`
ex2D is a paid 2D framework for *Unity3* game development. This was chosen over other alternatives (e.g. the free *Othello 2D Framework* and the paid *2D Toolkit*) due to its optimizations for mobile platforms, particularly rendering dynamic text. All graphical elements of the prototype app were created as ex2D sprite objects.

9. APPENDIX

See figures on following pages.

10. REFERENCES

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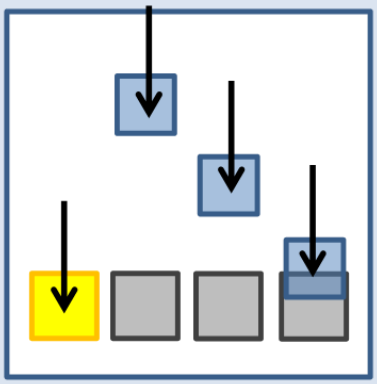
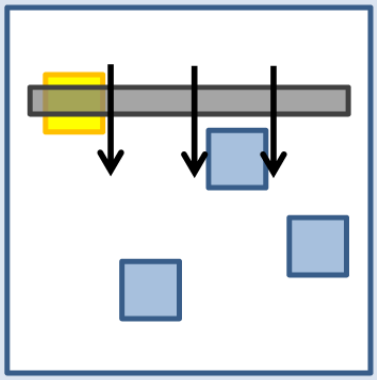
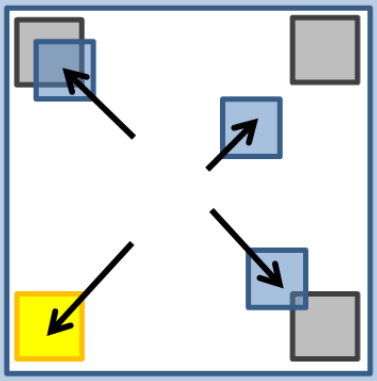
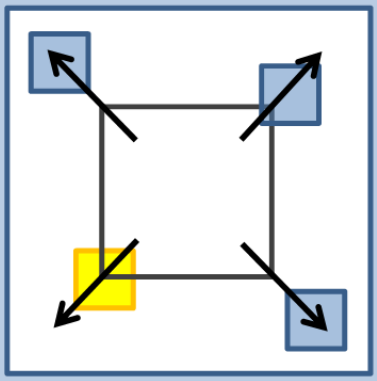
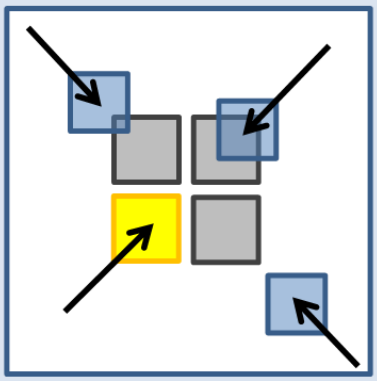
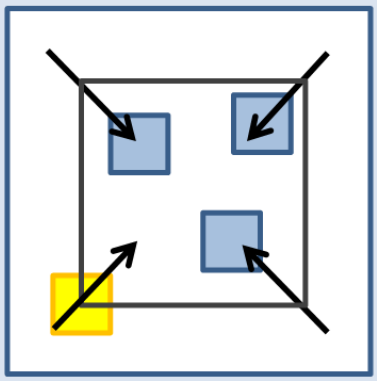
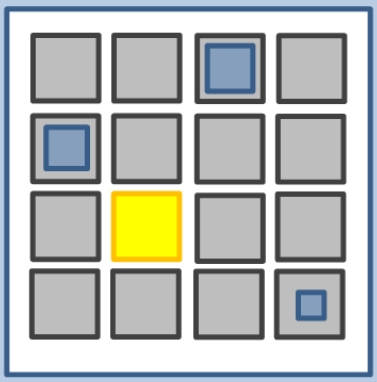
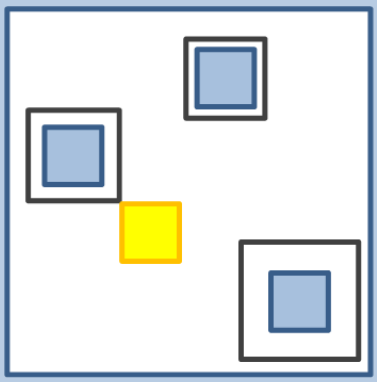
Moving Notes, Fixed Hitboxes		Moving Hitbox, Fixed Notes	
Diagram	**Description**	**Diagram**	**Description**
	**Mode #1: Falling Notes** **Moving notes** fall toward **fixed hitboxes** from **top to bottom**		**Mode #5: Sliding Hitbox** **Moving hitbox** fall toward **fixed notes** appearing from **top to bottom**
	**Mode #2: Spreading Notes** **Moving notes** slide toward **fixed hitboxes** from **centre to corners**		**Mode #6: Expanding Hitbox** **Expanding hitbox** grow toward **fixed notes** from **centre to corners**
	**Mode #3: Focusing Notes** **Moving notes** slide toward **fixed hitboxes** from **corners to centre**		**Mode #7: Collapsing Hitbox** **Collapsing hitbox** shink toward **fixed notes** from **corners to centre**
	**Mode #4: Grid** **Expanding notes** grow in **fixed hitboxes** at **grid points**		**Mode #8: Appearing** **Collapsing hitboxes** shrink around **fixed notes** appearing at **grid points**

Figure 28: Final interfaces designs (”Modes”) demoed in the final app.

Rhythm Game	Layout	Notes	Hitbox	Movement	Style
Dance Dance Revolution	4/6 columns	4/6 arrows	Box at top	Notes scroll up	Falling Notes
In The Groove	4 columns	4 arrows	Box at bottom	Notes scroll up	Falling Notes
Pump It Up NX	5 columns	4 arrows + middle stomp	Box at bottom	Notes scroll up	Falling Notes
Dance Maniax	4 columns	4 motion sensors	Bar at top	Notes scroll up	Falling Notes
Beatmania IIDX	6/8 columns	5/7 bars + 1 scratch	Bar at bottom	Notes fall down	Falling Notes
Pop 'N Music	9 columns	9 buttons	Bar at bottom	Notes fall down	Falling Notes
DJMax	4/5/6/8 columns	4/5/6/8 bars	Bar at bottom	Notes fall down	Falling Notes
GuitarFreaks	3 columns	3 tabs	Bar at bottom	Notes fall down	Falling Notes
Drummania	6 columns	5 drum + 1 foot pedal	Bar at bottom	Notes fall down	Falling Notes
Keyboardmania	24 columns	24 keys	Bar at bottom	Notes fall down	Falling Notes
Guitar Hero	5 columns	5 tabs	Bar at bottom	Notes approach from distance	Spreading Notes
DJ Hero	3 columns	3 buttons on scratch	Bar at bottom	Notes approach from distance	Spreading Notes
Rockband	5 columns	5 tabs or 4 drum + 1 foot pedal	Bar at bottom	Notes approach from distance	Spreading Notes
Taiko no Tatsujin	1 row	2 drum parts	Box on side	Notes stream to single point	Streaming Notes
The iDOLM@STER	1 row	6 buttons	Box on side	Notes stream to single point	Streaming Notes
Hatsune Miku: Project DIVA	Fullscreen	8 buttons	Sequence of hitboxes	Notes focus to corresponding hitbox	Focusing Notes
Gitaroo Man Lives!	Fullscreen	4 buttons	Box in centre	Notes focus to single point	Focusing Notes
DJMax Technika	3/4 rows	3/4 buttons	Moving bar	Hitbox slides across rows	Sliding Hitbox
Parappa The Rapper	1 row	4 buttons	Cursor	Cursor slides across row	Sliding Cursor
Audition Online	1 row	4 arrows	Cursor	Cursor slides across row	Sliding Cursor
Osu! Tatakae! Ouendan	Fullscreen	Anywhere buttons	Shrinking rings	Rings shrink around buttons	Appearing
jubeat	Grid	16 buttons	Collapsing box	Box solid fills grid	Grid

Figure 29: Analysis of the interfaces of various rhythm games.

Accuracy Category	Tablets Count	Sum	Average	Phones Count	Sum	Average	All Count	Sum	Average
#1: Falling Notes									
MARVELOUS	45	2043	45.40	140	9612	68.66	185	11655	63.00
PERFECT	45	4038	89.73	140	13735	98.11	185	17773	96.07
GREAT	45	1943	43.18	140	3526	25.19	185	5469	29.56
GOOD	45	448	9.96	144	571	3.97	189	1019	5.39
ALMOST	46	143	3.11	144	185	1.28	190	328	1.73
MISS	46	574	12.48	145	932	6.43	191	1506	7.88
#2: Spreading Notes									
MARVELOUS	33	2093	63.42	47	2989	63.60	80	5082	63.53
PERFECT	33	3093	93.73	46	3607	78.41	79	6700	84.81
GREAT	34	839	24.68	48	1209	25.19	82	2048	24.98
GOOD	34	211	6.21	48	304	6.33	82	515	6.28
ALMOST	34	133	3.91	48	141	2.94	82	274	3.34
MISS	34	364	10.71	48	1368	28.50	82	1732	21.12
#3: Focusing Notes									
MARVELOUS	29	969	33.41	42	1696	40.38	71	2665	37.54
PERFECT	29	2315	79.83	42	3176	75.62	71	5491	77.34
GREAT	29	1510	52.07	42	1983	47.21	71	3493	49.20
GOOD	29	556	19.17	42	751	17.88	71	1307	18.41
ALMOST	29	210	7.24	43	275	6.40	72	485	6.74
MISS	30	375	12.50	43	707	16.44	73	1082	14.82
#4: Grid									
MARVELOUS	45	1418	31.51	118	3397	28.79	163	4815	29.54
PERFECT	45	2925	65.00	118	6864	58.17	163	9789	60.06
GREAT	45	2025	45.00	120	7396	61.63	165	9421	57.10
GOOD	45	1399	31.09	124	4312	34.77	169	5711	33.79
ALMOST	45	652	14.49	124	1246	10.05	169	1898	11.23
MISS	50	877	17.54	124	1448	11.68	174	2325	13.36
#5: Sliding Hitbox									
MARVELOUS	28	1522	54.36	41	1560	38.05	69	3082	44.67
PERFECT	28	2093	74.75	40	3199	79.98	68	5292	77.82
GREAT	28	1037	37.04	40	1651	41.28	68	2688	39.53
GOOD	28	391	13.96	40	691	17.28	68	1082	15.91
ALMOST	28	242	8.64	41	313	7.63	69	555	8.04
MISS	29	427	14.72	41	847	20.66	70	1274	18.20
#6: Expanding Hitbox									
MARVELOUS	23	665	28.91	31	1026	33.10	54	1691	31.31
PERFECT	23	1591	69.17	32	1758	54.94	55	3349	60.89
GREAT	23	891	38.74	33	1357	41.12	56	2248	40.14
GOOD	23	526	22.87	33	832	25.21	56	1358	24.25
ALMOST	23	434	18.87	35	718	20.51	58	1152	19.86
MISS	23	585	25.43	34	921	27.09	57	1506	26.42
#7: Collapsing Hitbox									
MARVELOUS	21	423	20.14	30	749	24.97	51	1172	22.98
PERFECT	21	923	43.95	32	1707	53.34	53	2630	49.62
GREAT	21	1045	49.76	32	1749	54.66	53	2794	52.72
GOOD	22	925	42.05	32	1060	33.13	54	1985	36.76
ALMOST	22	463	21.05	33	475	14.39	55	938	17.05
MISS	22	521	23.68	34	803	23.62	56	1324	23.64
#8: Appearing									
MARVELOUS	37	1248	33.73	48	1304	27.17	85	2552	30.02
PERFECT	37	2457	66.41	48	2987	62.23	85	5444	64.05
GREAT	37	1650	44.59	50	2795	55.90	87	4445	51.09
GOOD	37	999	27.00	50	1504	30.08	87	2503	28.77
ALMOST	37	700	18.92	50	892	17.84	87	1592	18.30
MISS	37	494	13.35	51	629	12.33	88	1123	12.76

Figure 30: Collected data on note accuracy counts for each mode.

Rating Category	Tablets Count	Sum	Average	Phones Count	Sum	Average	All Count	Sum	Average
#1: Falling Notes									
Unique	47	114	2.43	113	427	3.78	160	541	3.38
Overall	49	114	2.33	112	448	4.00	161	562	3.49
Intuitive	45	188	4.18	112	457	4.08	157	645	4.11
Fun	51	192	3.76	117	486	4.15	168	678	4.04
Challenge	42	155	3.69	106	399	3.76	148	554	3.74
#2: Spreading Notes									
Unique	33	131	3.97	45	182	4.04	78	313	4.01
Overall	39	156	4.00	48	181	3.77	87	337	3.87
Intuitive	32	126	3.94	44	175	3.98	76	301	3.96
Fun	36	135	3.75	49	189	3.86	85	324	3.81
Challenge	31	119	3.84	43	173	4.02	74	292	3.95
#3: Focusing Notes									
Unique	34	129	3.79	35	129	3.69	69	258	3.74
Overall	37	131	3.54	38	129	3.39	75	260	3.47
Intuitive	33	124	3.76	35	122	3.49	68	246	3.62
Fun	36	123	3.42	37	129	3.49	73	252	3.45
Challenge	33	125	3.79	33	128	3.88	66	253	3.83
#4: Grid									
Unique	48	185	3.85	75	299	3.99	123	484	3.93
Overall	47	187	3.98	85	353	4.15	132	540	4.09
Intuitive	48	183	3.81	70	269	3.84	118	452	3.83
Fun	50	207	4.14	79	325	4.11	129	532	4.12
Challenge	45	192	4.27	70	290	4.14	115	482	4.19
#5: Sliding Hitbox									
Unique	29	119	4.10	31	128	4.13	60	247	4.12
Overall	30	114	3.80	33	136	4.12	63	250	3.97
Intuitive	28	98	3.50	32	115	3.59	60	213	3.55
Fun	29	118	4.07	33	131	3.97	62	249	4.02
Challenge	28	123	4.39	32	134	4.19	60	257	4.28
#6: Expanding Hitbox									
Unique	26	118	4.54	28	107	3.82	54	225	4.17
Overall	27	92	3.41	27	108	4.00	54	200	3.70
Intuitive	25	71	2.84	22	73	3.32	47	144	3.06
Fun	25	84	3.36	24	96	4.00	49	180	3.67
Challenge	25	114	4.56	22	90	4.09	47	204	4.34
#7: Collapsing Hitbox									
Unique	22	92	4.18	28	108	3.86	50	200	4.00
Overall	22	71	3.23	27	94	3.48	49	165	3.37
Intuitive	23	61	2.65	26	96	3.69	49	157	3.20
Fun	23	70	3.04	27	91	3.37	50	161	3.22
Challenge	23	98	4.26	26	116	4.46	49	214	4.37
#8: Appearing									
Unique	43	173	4.02	44	148	3.36	87	321	3.69
Overall	40	168	4.20	45	174	3.87	85	342	4.02
Intuitive	40	165	4.13	43	156	3.63	83	321	3.87
Fun	42	182	4.33	44	165	3.75	86	347	4.03
Challenge	40	157	3.93	41	160	3.90	81	317	3.91

Figure 31: Collected data on feedback ratings for each mode.

Percent Score	Tablets			Phones			All		
Design	Count	Sum	Average	Count	Sum	Average	Count	Sum	Average
#1: Falling Notes	44	3235	73.52	142	11511	81.06	186	14746	79.28
#2: Spreading Notes	32	2472	77.25	46	3263	70.93	78	5735	73.53
#3: Focusing Notes	29	1951	67.28	39	2625	67.31	68	4576	67.29
#4: Grid	44	2677	60.84	117	7249	61.96	161	9926	61.65
#5: Sliding Hitbox	28	2038	72.79	41	2861	69.78	69	4899	71.00
#6: Expanding Hitbox	22	1331	60.50	31	1853	59.77	53	3184	60.08
#7: Collapsing Hitbox	21	1238	58.95	31	1931	62.29	52	3169	60.94
#8: Appearing	36	2438	67.72	46	3113	67.67	82	5551	67.70

Figure 32: Collected data on overall percent scores for each mode.

Combo Max	Tablets			Phones			All		
Design	Count	Sum	Average	Count	Sum	Average	Count	Sum	Average
#1: Falling Notes	47	3981	84.70	153	17052	111.45	200	21033	105.17
#2: Spreading Notes	34	3127	91.97	48	2467	51.40	82	5594	68.22
#3: Focusing Notes	31	1516	48.90	43	2031	47.23	74	3547	47.93
#4: Grid	52	2075	39.90	131	4605	35.15	183	6680	36.50
#5: Sliding Hitbox	29	2189	75.48	42	1758	41.86	71	3947	55.59
#6: Expanding Hitbox	23	864	37.57	35	1060	30.29	58	1924	33.17
#7: Collapsing Hitbox	22	468	21.27	35	937	26.77	57	1405	24.65
#8: Appearing	37	1651	44.62	54	1965	36.39	91	3616	39.74

Figure 33: Collected data on ”COMBO MAX” counts for each mode.

Completion Rate	Tablets			Phones			All		
Design	Started	Completed	Percent	Started	Completed	Percent	Started	Completed	Percent
#1: Falling Notes	71	44	61.97	206	140	67.96	277	184	66.43
#2: Spreading Notes	44	32	72.73	84	44	52.38	128	76	59.38
#3: Focusing Notes	46	29	63.04	55	39	70.91	101	68	67.33
#4: Grid	57	43	75.44	150	117	78.00	207	160	77.29
#5: Sliding Hitbox	38	28	73.68	71	40	56.34	109	68	62.39
#6: Expanding Hitbox	34	22	64.71	48	30	62.50	82	52	63.41
#7: Collapsing Hitbox	31	21	67.74	54	31	57.41	85	52	61.18
#8: Appearing	43	36	83.72	76	46	60.53	119	82	68.91

Figure 34: Collected data on completion rate for each mode.

Feedback Rate	Tablets			Phones			All		
Design	Completed	Feedback	Percent	Completed	Feedback	Percent	Completed	Feedback	Percent
#1: Falling Notes	44	45	102.27	140	114	81.43	184	159	86.41
#2: Spreading Notes	32	30	93.75	44	43	97.73	76	73	96.05
#3: Focusing Notes	29	32	110.34	39	34	87.18	68	66	97.06
#4: Grid	43	45	104.65	117	71	60.68	160	116	72.50
#5: Sliding Hitbox	28	26	92.86	40	31	77.50	68	57	83.82
#6: Expanding Hitbox	22	24	109.09	30	23	76.67	52	47	90.38
#7: Collapsing Hitbox	21	21	100.00	31	27	87.10	52	48	92.31
#8: Appearing	36	38	105.56	46	42	91.30	82	80	97.56

Figure 35: Collected data on feedback rate for each mode. Note that some percentages are over 100% due to missing data from tracker-connectivity issues. See the note on *Lumos* in the *Technical Resources* section.