FINDING THE BEAT: CYCLES OF EXPERTISE IN RHYTHM GAMES

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Abstract

I have experienced an interesting puzzle when playing rhythm games: gameplay on a song usually proceeds from being so complex that I don't even know what I'm doing wrong, to being so fluent that I can play the song without conscious effort. Thus, I get better at the game without knowing how that improvement occurs or what it looks like. To better understand the development of my own rhythm game literacy, I downloaded four songs on the popular rhythm game *Jukebeat*, and recorded all of my gameplay on those four songs over a period of nine months. From this recording I observed how quantifiable measures of my performance and improvement in the positioning of my fingers and compared with my self-perceived gameplay skill. It was found that I regularly underwent unconscious experimentation and improvement that showed disjointed but gradual progress over time, and was generally misaligned to my self-percieved efficacy. Along with observations and reflection of my gameplay recordings, I also present a theoretical framework for understanding the development of rhythm game literacy.

Introduction

Literacy is a fundamental aspect to learning. Literacy takes many forms, but generally involves interpreting meaning from sensory inputs. The process of interpreting meaning can be quite complex: it often involves more than just knowing definitions, but rather having a situational or systemic knowledge (Gee 2007). Literacy thus involves "embodied intelligence," or having a well developed understanding of the contextual nature of symbols developed through actions, or embodied experiences. Embodied intelligence is built up from multiple sessions of practicing and reflecting on that practice, or what can be referred to as cycles of expertise (Gee 2007). Squire goes so far as to describe game literacy as particularly embodied in the interactivity of a game, and thus is most directly represented as performance expertise (Squire 2008).

Rhythm games are often considered to involve practice with musical literacy. Musical literacy generally involves understanding the timing of notes in meter and beats as described in Lerdahl and Jackendoff's Generative Theory of Tonal Music (Lerdahl and Jackendoff's 1996). Professionally trained musicians are known to perform better than non-musicians in understanding and interpreting the timing of both visual and auditory signals (Ramsayer et al. 2012). Of additional interest, coupling physical movements to beats have been found to increase musical literacy (Manning & Shutz 2013), indicating that movement is useful in developing musical expertise and there is a potential use for rhythm games to develop genuine musical literacy. On the other hand, rhythm games do not offer an exact parallel to the way music is performed (Miller 2009, Arsenault 2008) and evidence that skills transfer from rhythm games to general musical literacy has not been found (Gaydos 2010). Emergent timing and event timing are recognized as two distinct skills, the former involving the coordination of fluid and continuous movements and belonging to the realm of the

athlete, and the latter involving discrete and regular events and belonging to the realm of the musician (Janzen et al. 2014). In this light, games are more similar to sports than music performances, potentially explaining why attempts to show increases in event-timing musical literacy from gameplay have been unsuccessful. This paper will mostly avoid this tricky issue by recognizing that game-based musical literacy is increasing (i.e. a player's scores in rhythm games increases over time with practice), and concern itself with understanding how this game-specific literacy develops– whether or not a more generic and transferable music literacy is also developing. In this way, rhythm games are simply treated as a convenient case study for understanding the development of a specific, context-dependant expertise.

For that purpose, rhythm games are a particularly useful case study for several reasons. First, rhythm games have clearly defined cycles of practice, namely replaying songs. Second, the game offers a clear mode of performance to express the mastery gained, thus providing an embedded assessment of mastery (Shute 2013). Third, a player's score in a rhythm game can be considered a close analogy to a quantifiable measure of literacy.

This well-played example plans to investigate a simple issue-how does literacy expertise develop over repeated cycles of gameplay? To answer this general question, I focus specifically on rhythm games. I have noticed from my gameplay that the development of such literacy seems to be far from a regular, linear process. It involved the development of several, functionally separate literacies, which each seem to develop in jumps and spurts. The end result is that gameplay on a song usually proceeds from being so complex that I don't even know what I'm doing wrong (i.e. lack of literacy) to being so fluent that I can play the song without conscious effort (full literacy through embodied intelligence). The transition between these two states happens so subtly that I am not quite sure when and how the transition occurs, nor am I able describe what exactly

changed in my gameplay to cause this increase in performance. This well-played session is a conscious investigation into how exactly this unconscious transition from low to high literacy occurs in rhythm games. This is achieved through analysis of video recordings and journaling throughout several months of my mastery of four new songs.

Methods

Author background

I am relatively experienced in several forms of the rhythm games genre, including *Dance Dance Revolution*, *Elite Beat Agents*, *Guitar Hero*, *Rock Band*, *Osu Stream*, and *Jukebeat*. In all of these games, I progressed from a beginner to some moderate to high level of expertise. This study focuses on *Jukebeat* which proved one of the easier games to record and analyze, but I believe that the patterns described for *Jukebeat* likely also hold true for other rhythm games. I can currently pass most songs on *Jukebeat* at a level 9 difficulty, but have yet to pass any songs on level 10 difficulty. Thus I am at an advanced level of literacy in *Jukebeat*, but still have room to grow in expertise.

Description of Jukebeat

Jukebeat (Konami 2011) is a freemium game available on the iPad and iPhone. It comes preloaded with three playable songs, but has many "4 song packs" available for purchase through the in game store. Each song has three levels of difficulty, and each level has a further rating from 1-10 allowing for a more absolute metric of difficulty that can compare various songs to each other.

Songs are played on a 4×4 grid of square buttons. Players press one or more of the buttons in sequences as a song plays. A visual cue appears about one second before a player is suppose to strike the button, cueing them into the intended timing (Figure 1). One of three feedback animations occurs after a player hits a

button, to indicate whether the player hit the note in perfect, near perfect, or far from perfect timing (Figure 1). Players are not penalized for taps on empty buttons. Notes can occur individually or in groups that must be pressed together. A typical Jukebeat song on a high level of difficulty involves coordinating the movement between 3-4 fingers on each hand.

Like most rhythm games, the point system awards more points for the closer you are to the beat, but also weights the score for each note by your "combo," or the number of consecutive prior beats hit in perfect or near perfect timing. Thus the score accounts for both individual accuracy on a note, and repeated accuracy across notes. Individual notes are worth different points on different songs, such that the more notes a song has, the less points each note is worth to ensure the maximum possible score on any song is 1,000,000. Thus the system is weighted in such a way that scores between different songs feel comparable. The game also awards a letter grade for various final scores: less than 700,000 is an F, above 700,000 is a C, 800,000 is a B, 850,000 is an A, 900,000 is an S, 950,000 is SS, and 1,000,000 is SSS. Typically the only way to score an SS or higher is to get a full combo on a song. This scoring system also seems as though a fair way to quantify skill in a song in the game, and so I adopted end-song score as a quantifiable measure of my expertise with the song.

I rarely get scores above an A on any particular song- at the point where I can regularly achieve A's on a song, the song tends to lose my interest. I am most engaged and interested in a song when trying to move my score from an F to a B.

Setup and analysis

In June 2014, I downloaded four new songs from *Jukebeat*'s store. These were songs I had never heard nor played before. The songs also captured the range of my current skill levels: three were ranked at level 9, and one was ranked at level 10. Based on my

current expertise level, I would expect to master three of the songs and struggle with the final one.

I built a device to record my hands and the screen as I played *Jukebeat* (Figure 1). I did not use screencapture because I was interested in the motion of my hands and fingers in particular, and if they might show any subtle changes over the cycles of practice. I recorded every playthrough of the four downloaded songs, over a period of nine months. I did play more than just those four songs, but only recorded playthroughs of those songs. I continued my natural play cycles with the game, which usually involved playing the game intensely for a few days to weeks, then putting it down in favor of other games for a few weeks to months, then returning again.

I also wrote down thoughts in a journal as I played the songs, to capture my current understanding of my gameplay. In the journal, I would pay special attention to noting which portions of the song I felt as though I was struggling with most, what in particular was causing me to struggle, and when I felt that I had overcome the difficulty. This would allow me to correlate my self-perceived progress with my actual progress as measured in my gameplay videos.

I analyzed several features of my play in the recorded videos. These include easily quantifiable things like total song score and scores during particularly challenging sequences of notes. Each song also had a progress bar at the top of each song (Figure 1). This progress bar was shown as a series of grey boxes initially, with each set of boxes corresponding to one meter in the song and the number of stacked boxes corresponding to the number of notes needing to be tapped in that meter. If all notes were hit with perfect timing, the stack of boxes would turn yellow. If all the notes were hit with perfect or almost perfect timing (as measured by the game), the stack of boxes would turn blue. If at least one note was hit with less than almost-perfect timing, the stack of boxes would turn black (or transparent against the background). At the end of a song, the image of this progress bar

could then be used to measure how well I was playing at different moments in the song, providing a nice quantifiable measure of detailed performance.

My analysis also includes more qualitative information about which fingers were predominantly used both during the song as a whole and during particularly challenging sequences (Figure 1). I developed a coding scheme that recorded which fingers were used to hit certain groups of beats in the song. I observed what caused me to miss sequences of beats, whether I was moving my fingers in the wrong positions, or moving them at the wrong timing. The coding scheme and analysis emerged naturally as I identified parts of the song that seemed difficult, and in which I noticed changes in my gameplay over time.

Theory

Categorizing literacies

In thinking about my gameplay over the years, I believe that there are three primary skills involved in doing well at any rhythm game. The first is literacy, or making sense of stimuli acquired through senses. Second is coordination, which involves translating inputs into outputs. It still involves a sense-making activity, but involves coding inputs from one or more sources into a suitable output, usually muscle movement. "Muscle memory" is another word for this. Third is physical finesse, and involves the physical action required to complete the desired output. Conceptualizing the motion that you would like to take is not the same as actually achieving that motion and the desired end result, which describes the difference between coordination and finesse.

Although these three skills were described based on reflections of my own gameplay, there are clear parallels with the conceptions of musical literacy described in the introduction, particularly in the conception of emergent timing skills of professional athletes (Janzen et al. 2014). Also, Squire's concept

of game literacy as being a performance expertise (Squire 2008) encompasses all three of these skills as part of a single game literacy, as all are required to exhibit performance in the game.

In rhythm games, I believe that for practical purposes, we are not being stretched to the limits of finesse. Besides *Dance Dance Revolution*, most rhythm games do not require a vast amount of physical exertion, and do not require movements that the average person is incapable of performing. What we lack is the coordination, or the muscle memory, to execute these movements fast enough, or the literacy required to accurately read visual and audio cues.

Literacies in Jukebeat

I will now refer to *Jukebeat* in particular, though these same literacies would likely apply to most rhythm games. In *Jukebeat*, there are three primary skills that must be perfected to advance one's performance: Visual literacy (VL), Tactile Coordination (TC), and Audio Literacy (AL).

1. *Visual literacy* is about being able to make sense of note patterns as they come up. It's the earliest skill learned in the game- you need to be able to understand notes before being able to respond to them. This literacy has different levels of competency- the notes become harder to read at more difficult levels both because there are more notes and because they move faster, requiring you to improve your VL. Once VL is attained at a particular level of difficulty though, it is easily transferred to other songs at that same difficulty level.
2. *Tactile coordination* is the reflexes and finger agility required to respond to particular note patterns. It involves making sense of visual and audio clues to produce muscle movements. TC can actually be viewed as a series of different minute skills, rather than one big skill. Being able to hit different types of sequential patterns requires

different motor actions, and therefore each sequence requires it's own TC. This is akin to being able to read the letter "A", but not yet understanding the letter "B." Additionally, being able to string multiple sequences together is an additional skill, just as being able to recognize the letter "A" is different from being able to read the word "ant". Understanding where one finger leaves off in one sequence and how to connect it to the first note of the next sequence is an additional level of TC. Based on my experience, TC's seem to be highly transferable- a discrete TC gained for one sequence in one song readily applies when that same sequence is played in other songs.

3. *Audio literacy* is about being able to read the metrical structure of a song. This is actually one of the last skills needed to play the game well, despite being the one most commonly associated with the game genre. At higher level songs, VL informs *where* you should move and AL informs *when* you should move (with your ability to actually move in the desired sequences determined by TC). AL is on the one hand extremely song specific. AL gained for lower levels on one song often travels up to and improves performance on higher levels of that same song. In general though, AL is its own higher-order skills that develops over time across many songs, and can allow you to grok the beats of new songs faster. But, a part of it is always song specific, and your song-specific AL will typically improve the more that you practice a particular song, no matter how much of an expert you are.

Cycles of Expertise

Rhythm games offer multiple opportunities for repeated cycles of practice. First, any given song repeats certain sequences of notes throughout the song, which gives you a chance within a song to practice that sequence multiple times. Second, the songs themselves are clearly meant to be replayed, giving the

opportunity repeat that song multiple times. Third, songs at equal difficulty offer opportunity to practice playing at that difficulty in multiple ways, with equally challenging but different note sequences.

From my experience, I would suggest that there are four distinct levels of expertise that a player progresses through the more that they play a rhythm game. This progression is summarized visually in Figure 2.

Level 1: When you first start playing rhythm games, you really are just practicing VL. You play the songs better when you use your VL to learn both when and where to hit a beat. TC skills are pretty minimal, there aren't really even sequences yet, the notes are played so far apart that each motion to hit a beat feels separate from the next motion. TC at this point just involves getting the timing of single notes right. The AL skills are pretty nonexistent and aren't really even being practiced. Although notes are being played on a beat, they are being played so slowly that you induce their timing visually more than auditorily.

Level 2: Once your VL becomes somewhat advanced, you can progress to the next level of songs, where the idea of sequences, or series of notes played on the half or quarter beat, becomes prominent. This challenges both your VL and TC, as you now need to think about several motions happening in close repetition. Muscle memory of sequences starts to be built, and TC is undergoing the most improvement at this stage (though VL is still becoming more advanced too). At this point, AL is still irrelevant, as the sequences happen in enough isolation from each other that VL still informs the timing of the sequence more than AL, and the sequences are short enough that AL is not needed to keep you on beat.

Level 3: Once your TC has mastered basic 3-note sequences, you can progress to songs where sequences become faster and longer. Smaller sequences previously learned must be chained together, in sequences that can be 5-15 notes long. The VL task becomes more challenging, and less about reading individual

notes as much as seeing patterns of sequences and letting your muscle memory move from one sequence to the next. You no longer see the notes as individual beats, but you read them visually as sequences. TC is constantly strained, and fingers will actually begin to tire over the course of several songs, building up finesse to some degree. These long repetitions of notes, and the increased speed of the songs and the speed at which the notes pan across the screen, means that it becomes increasingly difficult to infer timing visually. Visual pattern recognition still informs *what* sequences of muscle movements should be enacted, but audio cues start to inform *when* those movements should be enacted, and how to remain on beat over a 10-15 note sequence. In my opinion, it's at this level that the game becomes fun, and this is when you begin to really flex your AL.

Level 4: In the highest level songs, it is primarily about AL. VL is still continuing to be strained by some especially difficult songs, but for the most part this skill is fully formed and most songs are completely readable. The player has also built an extensive muscle memory library of TC's, which continues to be added to and challenged by each new level of song. But songs at this level are simply impossible to be played correctly if audio cues are not used to infer beat timing. At this level, it is fully incorporating TC with AL that most determines performance.

From this hypothesized progression of skills, one can see that the main literacy that most influences one's performance changes as one's skill level changes, starting with VL, then moving to TC, then to AL. This also means that AL is only practiced in rhythm games in a highly complex way that must be fully integrated with other visual and tactile skills. This is an interesting comparison to most of the musical literacy tests described in the introduction, which test that literacy in a highly simplified, abstract manner (e.g. Ramsayer et al. 2012).

Hypothesizing from theory

Based on this theoretical framework, I have several hypotheses

about how my performance would progress, depending on which skill is being strained the most in a new song.

H1: If Audio Literacy is most constraining performance, timing should be off for beats, but fingers should be moving in the correct sequences. This timing should get fixed with time, and be the primary factor behind performance improvement. This improvement is only seen over the number of repeated playthroughs of that song.

H2: If Tactile Coordination is most constraining performance, then one would hit the beats at the right time, but in the wrong positions, or to happen in the right position but always with a delay due to higher processing time to execute the maneuver. Over time, the positioning and timing should rectify itself as the appropriate muscle memory is built up.

H3: If Visual Literacy is most constraining performance, then there should be trouble inferring both position and timing due to general cognitive overload. Improvement should proceed from random to more purposeful motion. That random motion may or may not be on beat.

Gameplay Observations and Reflections

In looking at my gameplay records, several patterns are apparent. First, my performance, measured as end-song score, has increased over time, and the increase has been somewhat linear, though with a lot of variability (Figure 3). The quantifiable increase in whole-song ability is certainly more regular that I expected it to be. Comparing this with my journaling notes, my self-perceived feeling of mastery occurs over 1-3 playthoughs of a song, which was much more sudden than the measurable score of mastery, which occurred gradually over all 10-20 of my playthroughs. I gained mastery in two of the songs (i.e. achieved at least a B level rating), and despite my focused attention on the issue, still found my feeling of mastery to appear subtly and thoroughly, without exactly knowing when and how it occurred.

Even more interesting conclusions can be found by looking at

my individual playthroughs of each song. In Figure S1, you can watch two playthroughs of each of the four songs, the left being one of my first two initial attempts, and the right being one of my last three attempts. Thus you can see visually how my playing performance changed over time.

The most challenging song is shown first, Red Zone (Figure S1, song 1). This song clearly exceeded my abilities, and I showed little improvement over time. The progress bar for the most part shows few blue or yellow sections, and little consistency over time (Figure 4). There were few meters or sections of the song that I definitively mastered in any significant way.

The second and third songs, Historia of Ruined Kingdom and Flip Flap (Figure S1, song 2 and song 3), were the two easier songs in the set and were both mastered by the end of the recording period (Figure 3). In the progress bar, Historia of Ruined Kingdom showed a lot of consistency over time- there were certain sections of the song, particularly in the "main1" section of the song, that consistently received yellow bars, while the neighboring meters received blue bars (Figure 5). There was also a noticeable increase in performance from grey to blue across the entire song over the first 3-4 playthroughs, which corresponded with a sharp increase in total score over that period (Figure 3). Flip Flap showed a little less consistency over time, with yellow bars appearing over different portions of the song in successive playthroughs (Figure 6). The "transition" section was consistently played fairly well on the fourth playthrough onwards, but most other sections of the song showed slight and inconsistent increases in performance with time. Although the score for this song does increase over time (Figure 3), it's unclear that one particular section might have been the cause of that increase.

Both songs included a particularly challenging note sequence. In Historia of Ruined Kingdom, there were two double notes that occurred in the upper left corner of the screen that were particularly challenging (Figure S2). The first double occurred

on the second row from the top, with two horizontally aligned, adjacent notes. The second double occurred on the second column from the left, with two vertically aligned, but separated notes. This sequence of double notes caused some trouble, as they required a sudden rotation and separation of two fingers to hit both sets of notes. This particular sequence of notes had not appeared in previous songs, and I had no muscle memory for it. This resulted in misplaying the notes on my earlier playthroughs. I noticed five distinct ways in which I misplayed the pattern (Figure S2), and I generally proceeded through the patterns in the following order, named by the codes I had given them:

1. "bottom" (I attempted the second sequence as two sequential rather than simultaneous notes, hitting the bottom one first)
2. "top" (same as before, but hitting the top one first)
3. "right invades" (my left hand takes the top note, and my right hand "invades" to simultaneously hit the bottom note)
4. "almost" (I seem to realize that both notes are simultaneous rather than sequential, and attempt to hit them together with the index and middle finger of my left hand, but don't quite get it right)
5. "hit" (index and middle finger of left hand hit the second two notes simultaneously)

What is most interesting about this sequence is how regular it seems: I am clearly experimenting with different forms of sequential notes, then I realize it's not sequential, then I experiment with different forms of simultaneous notes until I master the pattern. What is most shocking is that this experimentation went completely unrecognized in my journaling and memory. I did recognize that I was improving over time, but I had no recognition that there was a particular sequence in the song that was causing me difficulty, and that I was attempting multiple techniques to master the obstacle over time. All the experimentation occurred on a subconscious level,

and in fact my perception of mastery tended to occur at the same point in time with my resolution of this difficult pattern.

A similar story holds true for Flip Flap. In this song, there was a three-note sequence that caused much difficulty (Figure S3). These three notes were simultaneous and occurred as a middle beat in a long and challenging sequence of beats. The notes also needed a large repositioning of both hands and coordinated effort to be hit in sequence with the other notes (meaning, they had high tactile coordination difficulty). Look for the two notes in the middle-top that are diagonally connected, and the third note in the bottom right corner of Figure S3. Note that this pattern had a corresponding left-facing orientation, and that the right and left facing orientation occurred 4 times each in the song (Figure S1). I found 4 unique ways in which I hit this pattern (Figure S3):

- "0" (the pattern caught me off guard and I hit 0 of the notes)
- "2" (I hit the two notes at the top, but missed the third one)
- "x-off" (I was slightly off, but almost hit all three notes)
- "x" (x marked the spot- I hit all three notes)

Figure 7 shows how the codes played out over time. There was a distinct effect of handedness in my ability to master this sequence. The very first playthrough was interesting- I hit all of the left facing notes, and missed all of the right facing ones. From then on, I started experimenting with both of the right and left facing sequencing. My performance on the left facing ones back-tracked- I got a lot of 2's mixed with x's, which gave way to x-offs and x's, before finally settling back into x's. The right-facing sequences were a different story, remaining a mix of 0's and 2's for many playthroughs. Once the left-facing sequences had settled back into x's, the right facing ones were still mostly x-offs, and it's only with the last playthrough or two that the right-facing sequences seemed to be close to mastery. Similar to Historia of Ruined Kingdom, there is no mention in my notes

about this troublesome sequence nor do I recall struggling with it- I seemed to have no conscious awareness that there was a sequence that was causing me difficulty, nor that I was experimenting in my attempt to solve it.

The final song caused me a lot of difficulties (Figure S1 song 4) that were known to me, and much reflected upon in my journaling. Sakura Sunrise had a tricky sequence that I called the "star pattern"; it involved a nine note sequence, a simultaneous 4 note sequences followed by a simultaneous 5 note sequence that together mapped out a kind of 8-sided star (Figure S4). I had seen this sequence before, but it had only appeared once in other songs, and as a separate sequence from any other notes. In Sakura Sunrise, the sequence appeared many times and at the end of a long and complicated note sequence. In the progression feedback (Figure 8), this sequence occurred in the "main1" and "main2" sections of the song, which were sections in which I achieved little consistent mastery over time. In contrast, the "intro" and "piano" sections had no star patterns and showed consistent mastery from the first few playthroughs onward.

I was quite aware that this sequence was causing me difficulty, and that I was experimenting with different ways of hitting the pattern. From my journaling notes, I identified at least 2 different techniques I had been testing out. Here's my notes directly from the journal on 11/28, after my 8th playthrough:

"On the last run of Sakura, I noticed there were two different hand motions I was using to hit the star- one seemed to work, and one didn't. I either tried to use my index and middle finger on both hands, or my middle finger and thumb. I suppose a few more songs will get me into the right routine and I'll start nailing it."

Of course, I did not "start nailing it" anytime soon. But also unaware to me, I had been experimenting with not two, but eight different variations of finger patterns (Figure S4). Here were the codes:

1. 3+4 (three fingers on first quartet, four fingers on second quartet, only using index and middle fingers)
2. 4+4 (four fingers on first quartet, four fingers on second quartet, only using index and middle fingers)
3. 3+4t (three fingers on first quartet using index and middle fingers, four fingers on second quartet, using thumb and middle fingers)
4. 4+4t (four fingers on first quartet using index and middle fingers, four fingers on second quartet, using thumb and middle fingers)
5. 3t+4t (three fingers on first quartet, four fingers on second quartet, only using thumb and middle fingers)
6. 4t+4t (four fingers on first quartet, four fingers on second quartet, only using thumb and middle fingers)
7. 3+5 (as you might guess, it was like 3+4, but I used a quick succession to hit the final middle note right before the other four notes, treating them as sequential rather than simultaneous)
8. chaos (no discernible pattern)

The initial patterns were primarily 3+4, with some of 4+4, in my first 6 playthroughs. But 4+4 was an awkward positioning of my fingers, and offered no opportunity for a 4+5 to occur without pulling in my ring finger is an even more awkward fashion. The star pattern also occurred in different corners of the screen, and in certain corners 4+4 was more difficult than others to pull off. This generally gave way to 3+4t, 3t+4t, and 4t+4t in playthroughs 7-14, but every other potential sequence was still prevalent in this period to some degree. Score was generally low but highly variable during this period (Figure 3). The use of the thumb allowed for more consistent performance despite the changing position of the star pattern on the scree. In playthroughs 15-23, 3+4t and 4t+4t were the most dominant two patterns, and over time 3+4t became less prominent and 4t+4t became more prominent. Score showed a general increase over time during

this period (Figure 3). It was almost if I knew what I had to do, but still had difficulty executing it with consistency.

What is clear is that in this song, even when the obstacle was very conscious to me and I knew what part of the song to be paying attention to, there was still a massive period of unconscious experimentation that occurred during that sequence, and that the conscious knowledge of the problem didn't help at all in solving the problem faster. There was a fair amount of experimentation and even retrogression to previous patterns in the process of learning.

Conclusion

In general, my progress in *Jukebeat* was primarily an unconscious and highly irregular process that showed little correspondence with my self-perceived feeling of sudden efficacy. This on the one hand is reassuring- gradual progress towards mastery over many cycles of expertise is expected. On the other hand, this is a bit unsettling- even when I was devoting explicit, conscious effort towards being aware of my progress, I was unaware of how my mind was struggling, experimenting, and learning to be better.

To bring the results back to the different literacies involved in rhythm games, my general sense is that my TC was most constrained by the songs, and I saw a lot of confirmation for H2 in how I progressed through troublesome sequences, and the sequences themselves had clear signs of being challenging from a TC standpoint. There was in some sense a sharp and binary transition through discrete finger configurations, a clear indication of TC issues. But the transitions occurred in a disjointed and gradual progression that involved significant retrogression. I wouldn't suddenly move from configuration 2 to configuration 3, but would in contrast still be employing configuration 2 and 3 in a song while simultaneously perfecting configuration 5.

I did also observe a general song-wide increase in proficiency

over my first few playthroughs, as well as a high initial proficiency in a song (Figures 5,6,8). The initial proficiency indicates that there was a high degree of transfer of all three literacies from other songs. And the initial increase over the first 3-4 playthroughs, which primarily occurred in sections of the song that had no TC issues, is likely due to increasing AL with the song and offers some support for H1.

I found that my learning was filled with discrete steps that transitioned gradually over time. My learning and progress also seemed generally misaligned with my self-perceived efficacy. But perhaps this cycle between success and failure, progress and retrogression, is how game literacy expertise does and should develop during repeated cycles of play.

Figures and Tables

Figure 1: An example of my fingers in the midst of gameplay on a song. Beats appear as the colored green and white shades, and must be tapped when the shades fully cover the square. The rainbow circle is the feedback response indicating that a note was recently tapped with perfect timing. The shaded bars between the info at the top and the play region is the progress indicator.

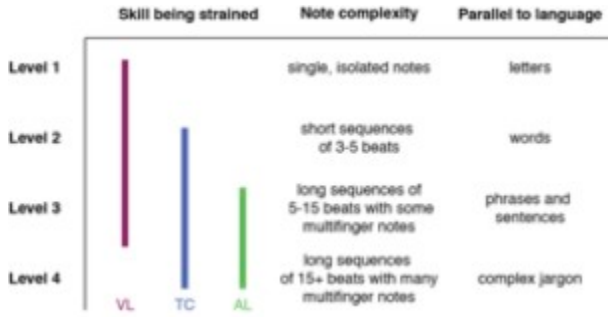

Figure 2: A visual diagram of how difficulty increases with the level of the songs.

Figure 3: A graph of the author's gameplay performance over time. In this graph, the x axis shows the number of repeated playthroughs of the song, which occurred over a period of 9 months at unequal time intervals.

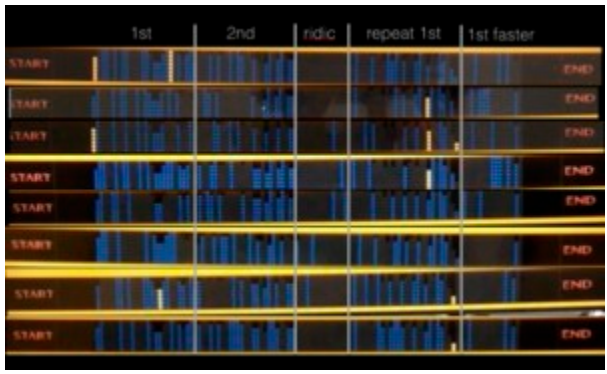

Figure 4: The end-game recap of Red Zone, shown across all of my playthroughs.

Figure 5: The end-game recap of Historia of Ruined Kingdom, shown across all of my playthroughs.

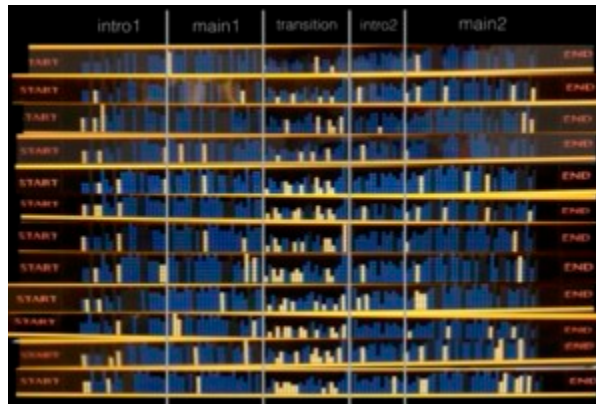

Figure 6: The end-game recap of Flip Flap, shown across all of my playthroughs.

Left 1	x		2	2	2	x	x	x	2	x	x	x	x
Left 2	x	x	2	x	x	x-off	x	x-off	x	x-off	x	x	x
Left 3	x	2	2	2	x-off	x	x	2	x	x	x	x	x
Left 4	x	2	2	x	x-off	x	2	x	x	x	x	x	x
Right 1				2			2		2		x-off	x-off	
Right 2				2	2				2		x	x	x-off
Right 3			2					2		x-off		x	x
Right 4							2		x	x-off	x-off	x	x

Figure 7: Progression over time in Flip Flap's difficult sequence.

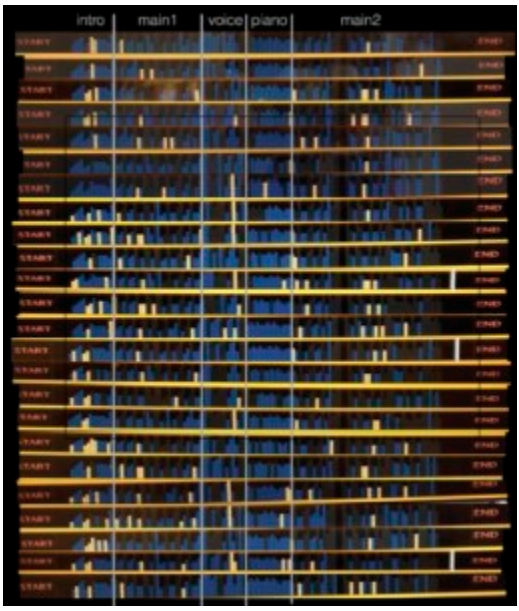

Figure 8: The end-game recap of Sakura Sunrise, shown across all of my playthroughs.

Figure S1- https://www.youtube.com/watch?v=_oaVUqjRSDk
Figure S2- https://www.youtube.com/watch?v=CpJ3x_SiNfE
Figure S3- https://www.youtube.com/watch?v=UAQgh9AEcn8
Figure S4- https://www.youtube.com/watch?v=TFT8246QiXM

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