Eating Disorders and Heart Health: Sonifying Heart Data for Comparisons to the Norm

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ABSTRACT

Eating disorders have one of the highest mortality rates for mental health diseases. One of the main contributors to this high mortality rate is issues related to the heart. Heart rate, blood pressure, and arrhythmias are three components of heart health that can be measured and compared to normal averages in order to help diagnose eating disorders or disordered eating behaviors in at-risk people. Because a lot of issues with the heart can be dismissed by those with eating disorders as normal or not worth discussing, it is important to find ways to relay the disordered person's heart health to them so that they are able to understand the damage being done to them by their disorder. In our study, we observed two adult females, both of which had previously struggled with anorexia nervosa and bulimia nervosa, as well as one adult male who previously struggled with OSFED. The two female participants disclosed that they had and currently still struggle with issues with their hearts due to their eating disorders, (primarily palpitations). For the study, we provided several scenarios followed by music samples that had been sonified based on random values for heart parameters that the user did not know in order to track the accuracy of the sonifications the participants were able to hear, the accuracy of the associations established between the sonifications and the parameters, and the participants' feelings based on the sonified sample and its relation to the particular scenario. We found that the participants were better able to understand how seemingly innocuous heart parameters related to disordered behaviors compounded to produce stark samples compared to the average. These findings were used to determine the effectiveness of the sonification simulator.

Keywords

Eating disorders; disordered eating; heart health; heart rate; blood pressure; heart palpitations; bradycardia; tachycardia; anorexia nervosa; bulimia nervosa; binge-eating disorder; OSFED; sonification

1. INTRODUCTION

Heart issues are one of the most prominent physiological changes that occur in people with eating disorders and disordered eating. The primary changes in heart health include changes in average heart rate, changes in blood pressure, and changes in heart rhythm. Changes in heart rate include tachycardia (high average heart rate) and bradycardia (low average heart rate). Changes in blood pressure include deviation from average by either being higher or lower than normal. Arrhythmias may also occur due to electrolyte imbalances from lack of nutrients due to periods of starvation or purging through vomiting or laxatives.

We have built a simulator that takes in the aforementioned parameters as well as the number of times the user has purged, and the number of times the user has experienced heart palpitations. The data from these parameters are sonified to produce a music sample for the user of the simulator to compare to an unmodified sample representing the average heart health of someone without an eating disorder. There is also a feature to allow the user to visually see their stats compared to the average in case they are unable to understand what exactly is being altered in the music sample.

In our study, we focused primarily on figuring out if there was too much mental load associated with listening to the sonified parameters. We provided random example data to the participants and tracked the accuracy of the sonifications the participants were able to identify and which specific heart parameters that the sonifications were mapped to. We also tracked the participants' feelings about the sonifications related to specific scenarios in order to determine the effectiveness of the simulator and sonifications at random times during a user's life.

Our primary research questions are ***(RQ1) Does the user hear a difference between the original sample and the modified sample based on their own heart parameters or example data?*** We answer this question by alternating between the modified and unmodified sample and asking the participant what sonifications they are able to hear in the modified sample. The accuracy of their answers helps us to determine whether more clarification or training is necessary in order to help a potential user make use of the samples produced by the simulator. Our second research question is ***(RQ2) Will the user be able to accurately map the modes of sonification used in the music samples to the representative heart parameters?*** Again, this question will be answered based on the accuracy of the participants' answers of sonifications identified in the sample and what these sonifications are respectively mapped to. The third research question is ***(RQ3) How would the user feel in a particular scenario after being provided their modified sample?*** This question will be answered by simply asking the participants after each scenario what their thoughts and feelings are if they were to hear a particular sample during some scenario. The last research question is related to the last and is ***(RQ4) Will there be any scenarios where the user will be inconvenienced by trying to review their music sample throughout the day?*** This question will be answered at the end of the study by asking the participants whether they can think of any situations or scenarios that would be an inconvenient time for a music sample to be produced.

In the remainder of this paper, we will describe the methods used to conduct the study, analyze the results of this study, discuss the research questions and how it relates to the effectiveness and potential shortcomings of the simulator, and conclude our findings.

2. METHODS

In this section, we will describe our setting, participants, and detail the system setup and procedure for potential replication of

the study. Some shortcomings of the study include the participants not being able to interact with the simulator themselves since they were not able to participate in person and the participants being a direct connection to us which could have created some bias in the data.

2.1 Setting

This study took place over a Discord call since we were unable to meet in person due to the COVID-19 pandemic. Both the researcher and the participants were in quiet, private spaces to complete the study.

2.2 Participants

We recruited adults with a prior history of eating disorders or disordered eating behaviors.

During the course of the study, 3 adults completed the procedure (66% female; *M = 21 years old*). All adults were asked about prior eating disorder behavior and physiological changes associated with their eating disorders. All of the adults confirmed struggling with diagnosed eating disorders, but only 2 adults mentioned issues related to their heart health from their disorder.

2.3 Procedures

The participants were solicited by the researcher on the basis of being a prior connection to the researcher and their history with eating disorders. All of the participants were explained the purpose of the simulator and the tasks to be completed before getting their consent to participate in the study.

After explaining the parameters collected by the simulator and how those parameters are sonified in the samples, we asked for the participant to provide some values to the parameters in order to see how the simulator sonifies them.

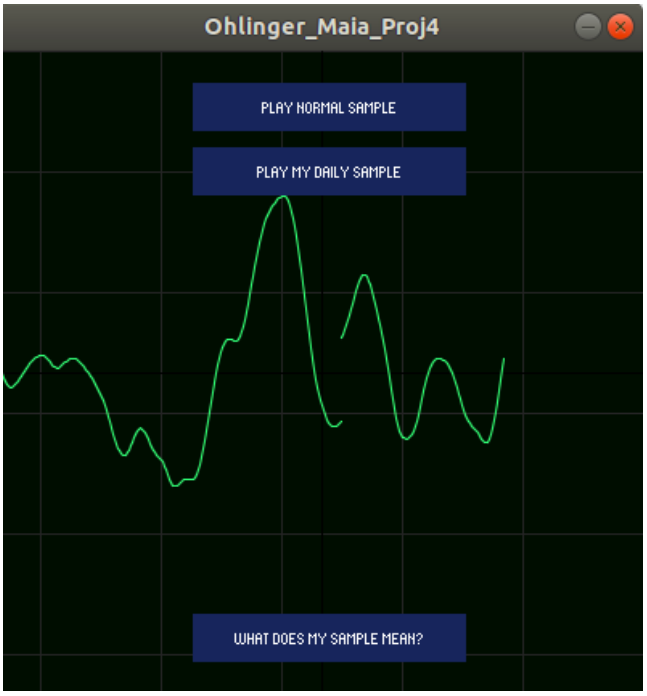

Figure 1. The user interface for the simulator. Contains a button to play the unaltered sample, a button to play the sample that sonifies heart parameters, and a button to visually see the differences in the user's averages versus a non-eating disordered person's averages.

After the explanation and demonstration, we presented three different scenarios representative of events that could occur in the participant's everyday life. We then played the unaltered music sample. After a few seconds, we switched to the altered music sample. This music sample was created using random values for the heart parameters that the participant did not know beforehand. Each scenario had a different sample for the user to listen to using different random values for the parameters. After the altered sample had finished playing, we asked the participant which modes of sonification they heard in the altered sample and what parameters these sonifications were mapped to. We then asked how hearing this sample during this scenario would make the participant feel.

After the completion of the three scenarios, the participants were asked about any concerns or questions that they had about the simulator. They were also asked about the usefulness of the simulator, as well as what situations would prove to be inconvenient to listen to a sample during.

3. RESULTS

In this section, we describe the analysis and discuss our findings to each of our four research questions.

3.1 RQ1: Does the user hear a difference between the original sample and the modified sample based on their own heart parameters or example data?

We reviewed the data collected from the participants regarding the accuracy of the modes of sonification heard in the samples. Two of the three participants noted that they had prior musical experience, but that did not seem to have an affect on whether the participants were able to distinguish sonifications in the modified sample.

Table 1. This table represents the number of correctly identified sonifications each participant was able to identify within the altered samples. Each scenario had a different sample, but all of the samples were constant among the participants.

Participants	1	2	3
# Correctly Identified in Scenario 1	5	3	5
# Correctly Identified in Scenario 2	4	5	5
# Correctly Identified in Scenario 3	2	2	4

For scenario 1, the parameters were as follows:

"currentHeartrate": 86,
"averageHeartrate": 55,
"currentBloodPressure": "150/100",
"heartRhythm": "ATRIAL FIBRILLATION",
"numberOfPurges": 5,
"numberOfPalpitations": 3

The sonifications that the participant should have heard were the slowing down of the music sample by half since the average heart rate was below average, a low-pass filter applied to the sample since the blood pressure was higher than average, the sample played backwards because of the arrhythmia, reverb added due to purging, and damping added due to palpitations. Since there are five different sonifications applied to the original sample, this means that participant 1 and participant 3 correctly identified 100% of the sonifications used in the sample, whereas participant 2 correctly identified 60% of the sonifications used to modify the sample. Participant 2 assumed that there was no reverb in the sample and assumed the sample was being played forward rather than backwards. If we were to average these percentages, we would get about 86.7% of the sonifications were correctly identified across the participants.

For scenario 2, the parameters were as follows:

"currentHeartrate": 99,
"averageHeartrate": 120,
"currentBloodPressure": "140/110",
"heartRhythm": "SINUS",
"numberOfPurges": 0,
"numberOfPalpitations": 0

The sonifications that the participant should have heard were the speeding up of the music sample by two times since the average heart rate was above average, a low-pass filter applied to the sample since the blood pressure was higher than average, the sample played forwards since there was no arrhythmia, no reverb added, and no damping added. Since there are two different sonifications being applied to the original sample and three sonifications not being added to the sample, if the participant noted either that there was only two sonifications being added or explicitly stated that there were two sonifications added and three not added, then they were noted to have correctly identified all of the sonification methods. Participant 2 and participant 3 correctly identified 100% of the sonifications used in the sample, whereas participant 1 correctly identified 80% of the sonifications used to modify the sample. Participant 1 assumed there was damping in the sample. If we were to average these percentages, we would get about 93.3% of the sonifications were correctly identified across the participants.

For scenario 3, the parameters were as follows:

"currentHeartrate": 56,
"averageHeartrate": 40,
"currentBloodPressure": "85/50",
"heartRhythm": "SINUS",
"numberOfPurges": 0,
"numberOfPalpitations": 0

The sonifications that the participant should have heard were the slowing down of the music sample by half since the average heart rate was below average, no filter applied to the sample since the blood pressure was within average, the sample played forwards since there was no arrhythmia, no reverb added, and no damping added. Since there is only one sonification being applied to the original sample and four sonifications not being applied to the sample, if the participant noted either that there was only one sonification being added or explicitly stated that there was one sonification added and four not added, then they were noted to have correctly identified all of the sonification methods. Participant 1 and participant 2 correctly identified 40% of the sonifications used in the sample, whereas participant 3 correctly identified 80% of the sonifications used to modify the sample. Participant 1 assumed that there was a low-pass filter added to the sample, that there was reverb added, and there was damping added to the sample. Participant 2 assumed that there was a low-pass filter added to the sample, the sample was being played backwards, and that the sample was dampened. Participant 3 assumed that there was damping added to the sample. If we were to average these percentages, we would get about 53.3% of the sonifications were correctly identified across the participants.

3.2 RQ2: Will the user be able to accurately map the modes of sonification used in the music samples to the representative heart parameters?

We reviewed the data collected from the participants regarding the accuracy of the parameters being mapped to particular modes of sonification that the participants heard in the music samples.

Table 2. This table represents the number of correctly identified parameters that each participant was able to identify based on the sonifications within the altered samples. Each scenario had a different sample, but all of the samples were constant among the participants.

Participants	1	2	3
# Correctly Matched in Scenario 1	4	1	5
# Correctly Matched in Scenario 2	4	2	5
# Correctly Matched in Scenario 3	3	3	5

For scenario 1, the parameters' values can be found in section 3.1. Participant 1 correctly identified 80% of the parameters related to the sonifications in the sample, participant 2 correctly identified 20% of the parameters related to the sonifications in the sample, and participant 3 correctly identified 100% of the parameters related to the sonifications in the sample. Participant 1 did not remember what parameter was related to damping. Participant 2 assumed that a low-pass filter meant low blood pressure, that damping added to the sample meant more purging, and did not identify the other two sonifications used and so did not provide an answer for those. If we were to average these percentages, we would get about 66.7% of the parameters were correctly identified based on the sonifications heard in the sample across all participants.

For scenario 2, the parameters' values can be found in section 3.1. Participant 1 correctly identified 80% of the parameters related to the sonifications in the sample, participant 2 correctly identified 40% of the parameters related to the sonifications in the sample, and participant 3 correctly identified 100% of the parameters related to the sonifications in the sample. Again, participant 1 did

not remember what parameter was related to damping. Participant 2 correctly identified the parameters of the sonification methods they named in the scenario, but did not provide an answer on what the other sonifications stood for. If we were to average these percentages, we would get about 73.3% of the parameters were correctly identified based on the sonifications heard in the sample across all participants.

For scenario 3, the parameters' values can be found in section 3.1. Participant 1 and participant 2 correctly identified 60% of the parameters related to the sonifications in the sample, whereas participant 3 correctly identified 100% of the parameters related to the sonification in the sample. Even though participant 1 only correctly identified one of the sonifications in this scenario, they correctly matched the parameters for reverb to purging, damping to heart palpitations, and the slowed down sample to low heart rate. They confused slowing down to being related to high blood pressure and did not mention anything about the arrhythmia parameter. Even though participant 2 only correctly identified one of the sonifications in this scenario, they correctly matched the parameters for a low-pass filter to high blood pressure, the sample playing backwards to an arrhythmia, and the slowed down sample being low heart rate. They did not remember the parameter for damping and did not mention the parameter for reverb. Even though participant 3 identified one of their sonifications incorrectly, they still associated damping with heart palpitations. If we were to average these percentages, we would get about 73.3% of the parameters were correctly identified based on the sonifications heard in the sample across all participants.

3.3 RQ3: How would the user feel in a particular scenario after being provided their modified sample?

We reviewed the data collected from the participants regarding their feelings for each scenario after listening to the modified sample and relating it to the scenario. Their thoughts and feelings will be snippets of quotes taken during the study.

For scenario 1, the participants were to imagine that they were grocery shopping while lightheaded from not eating and purging. The simulator then gives them their sample.

- Participant 1: "Sense of impending doom… Not uplifting… If you heard this you would wake up in a cold sweat."
- Participant 2: "Disorienting… Makes me nervous… Unsettling."
- Participant 3: "Disturbing… I'd be seriously concerned about the state of my heart."

For scenario 2, the participants were to imagine that they were talking to a friend before lecture when they get their sample despite feeling fine.

- Participant 1: "Feels like running away from a monster… Something needs to be checked out… Not as urgent as the last one."
- Participant 2: "Causes an adrenaline rush… Wouldn't think too much of it even given the scenario."
- Participant 3: "Would make me more nervous since I'm now hyper aware of my heart rate… Might cause an anxiety attack."

For scenario 3, the participants were to imagine that they were playing soccer with some friends on a hot day. The simulator then gives them their sample.

- Participant 1: "Suspenseful… Thinking that I need to stop playing now or I might die… Energy comes way down."
- Participant 2: "Probably feeling sick… Something about it felt unsettling, especially when compared to normal."
- Participant 3: "Honestly I've worked out to exhaustion and this sample sounds less severe than my heart probably did in a similar situation."

3.4 RQ4: Will there be any scenarios where the user will be inconvenienced by trying to review their music sample throughout the day?

We reviewed the data collected from the participants regarding their thoughts on scenarios where it would be inconvenient to review their music sample. Their thoughts will be snippets of quotes taken during the study.

- Participant 1: "Might be inconvenient when you need to use your ears for something else… Lecture, listening to someone talk, etc… Requires more mental load compared to an insulin pump… Simulator waits though, so taking 30 seconds to review the sample isn't really inconvenient."
- Participant 2: "Honestly I can see it working in all scenarios… It just seems disorienting for people not as accepting of their potential health problems."
- Participant 3: "I'm not really sure… Maybe during an exam or something… They do need to focus to hear the different sonifications, so maybe sometime where there is less focus."

4. DISCUSSION

In this section, we discuss the implications of our research on the limitations and benefits of our simulator.

Through our research, we found that the participants were able to correctly identify sonifications about 78% of the time and associate these sonifications with their correct heart parameters about 71% of the time. We found that our participants struggled most with identifying whether there was damping in a sample. This could be attributed to not being exposed to what damping is prior to the study. The fact that the participants had a more difficult time correctly associating parameters to sonifications was due to not remembering to list sonifications that were not used as well as only being exposed to these relationships for a short period of time. Though this percentage of correct identifications might seem low, we predict that more constant exposure to the simulator would help better build the associations between parameters and sonifications as well as allow the user to better identify which sonifications are present in a given sample.

One of the biggest strengths of the simulator is the very stark difference between the unmodified sample and the modified sample in relaying information about the user's heart health without the user visually evaluating numbers and comparing them to averages. This alertness to heart health could help those with eating disorders seek help for issues they may not have considered before. Though the noticeable differences between the two samples is useful, a large concern based on the comments

provided by the participants is that the samples can sometimes be disturbing or anxiety inducing depending on the values of the parameters. Because of this, this method could have the opposite effect on those looking to check out their heart health. It may scare people less willing to admit they have health issues into not wanting to recover because they are scared of what they are doing to their body.

Also based on the participants' comments, there does not seem to be a definitive answer on a particular time or scenario where providing a sample would be inconvenient to the user. Because there was no definitive answer, it is hard to say whether there is a scenario when the simulator would be ineffective.

5. CONCLUSION

One of the biggest indicators of an eating disorder or disordered eating are related to the physiological changes that occur with the heart. A lot of people struggling with these disorders either ignore or do not recognize there are issues until they are incredibly sick. Our simulator, though not a diagnostic tool, could be used to help users become aware of how their heart health deviates from the norm. Through our research, we found that the participants were able to correctly identify sonifications about 78% of the time and associate these sonifications with their correct heart parameters about 71% of the time. Overall, it seems as the participants enjoyed the concept and implementation of the simulator, as one of the participants in particular mentioned someone they knew would benefit greatly from this sort of technology in their life to monitor their heart health. Based on the data collected and the analysis of the data, going forward, we think it would be beneficial to study scenarios where a user would not be able to listen to their sample and fix the simulator so that it knows approximately better times to give a user their sample based on the user’s current environment. Looking into ways to effectively relay the values of the heart parameters without discouraging the user is another aspect of the simulator that could also be worked on.