Breathing Sonification Application Evaluation

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ABSTRACT

The evaluation will discuss the findings and results of the user experiments that were conducted on the breathing sonification program. This program was meant to help users improve their breathing form and exercise timings while doing exercise, through the use of sample breathing sonifications, and exercise timings. These tests were performed on three young-adult, athletic men who were specifically chosen for their participation in weight-lifting. This type of person is who the program is designed for, and these participants are a good representation of the intended audience. The goal of these tests was to discover whether hearing audio information could help improve an athlete's timing and form during intense exercise. More specifically, these experiments were meant to see whether this program could help improve a user's overall exercise fulfillment which was tracked through their breathing form and timings on transitioning exercises. While these are the goals of the program, it did not meet them, and seemed to have little to no effect on the user's exercise schedule, which means the program was not effective at achieving its intended purpose. However, this is most likely due to the implementation of the project and not the concept that it was originally based upon.

Keywords

Sonification; Audio; Schedule; Timing; Weight-Lifting; Waveform;

1. INTRODUCTION

This project is an audio-based program that is meant to help users improve their exercise routines. This was done by providing audio sonifications of the user's schedule and breathing quality, in order to provide users with information that would not interrupt the flow of their exercise routine. For the program that was implemented, it is best used for exercise routines that would warrant quick and frequent transitions. These sorts of routines are mainly present in training for weight-lifting and combat sports, where, not only are they physically intensive, they also require a large amount of concentration to perform them with proper form and effort. That would mean that the program would need to be catered towards athletes who participate in these specific areas, and the program would need to be unobtrusive as to not interrupt or distract the users who should be concentrating on the exercises.

With this being said, there are tools and even programs that deliver this information to athletes in a way that does not interrupt their exercises. For instance, a simple timer application could be enough to inform users of their schedule. Also, there exists equipment and health monitors that provide athletes with information on their breathing data and other performance information. While these programs and equipment do serve similar purposes as this program, the new program that was implemented helps users improve their routines by giving precise schedule readings at precise times, as well as providing them with real-time, continuous sonifications of their breathing form. This allows them to time their exercises more efficiently as well as allowing the athletes to correct their breathing in real-time with information provided by the program.

These were implemented to help these weight-lifting athletes improve their exercises routines, which would increase the muscle gains that are received from performing these exercises as well reducing any possible injury or strain. This program was meant to answer specific questions about what this program should accomplish and how it should do that. These research questions were what the application and testing were initially based on. These are shown below:

- Would a user like to use a product like this while they are doing strenuous exercise?

- Is there enough information being presented to the user to make a meaningful difference?

- Is there any useful or important information being presented that is unnecessary or is there any information that isn't in the program that might help improve the experience?

- Is the breathing sonification useful and if it isn't, is there any other metric that might warrant being sonified instead?

- Are the audio cues to change exercises audible enough, and if they are, is there any way they could be improved or changed to better convey information?

- Are users more fatigued before using the app or does the app actually help them with their fatigue?

- Do users see improved activity performance, as in, do they find that transitioning and timing their exercises are easier with the information that is provided with the program?

- If this was an actual product, what features might users want to see that are related to sonification?

- Are headphones or earbuds the best way of using the program while exercising?

- Does this program help perform better than simply freely exercising or using a clock?

These questions form the basis of the program, and the user experiments were conducted in order to discover whether the program fulfilled the expectations. Furthermore, these questions were based on the specific desire for these athletes to have information delivered to them that would help them adjust their performance of specific exercises. In conclusion, this program's main goal is to help weight-lifters improve gains and reduce

injury during their routines, by providing them with unobtrusive audio cues that convey important information regarding their exercise.

2. METHODS

2.1 Methodology Overview

The user tests were split into two sections, where the user did not directly interact the program until after the tests were completed. The two sections were used to serve as a control section and an experimental section.

Each user was first tested with six exercises where they were given a clock and they were told to perform each exercise for one minute and then switch to the next one. Each of these six exercises were chosen specifically to give a wide range of exercise types as well as to be rigorous enough to simulate the types of exercises that a weight-lifter would normally perform in a typical routine. This control section would have no influence from the program whatsoever, instead, it was used to get data on the participants to be used as control data to help determine whether the program helped improve an athlete's routine. After the participant performed the six specific exercises that they were instructed to do, they were given five minutes in order to rest. They were offered more if needed, but in all three tests, they only used five minutes.

Afterwards, they were tasked with performing the six specific exercises again on a one-minute interval. This time, however, the clock was removed and they were given a sanitized ear-bud that was playing the program's audio. Before this, they were informed on what the sonifications meant and how to interpret them. Additionally, while they were performing the six exercises, there was an observer controlling the program and manipulating it based on the participant's performance on each of the exercises. After the participant has completed the six exercises, they were allowed to interact with the visual user interface, and they were asked questions about their performance. In both the control and experimental sections, they were monitored and data was recorded on their timings, their form, their breathing rate, and their overall performance on each exercise.

2.2 Experiment Protocol

Before the experiment began, the observer informed the participant of the six exercises, and they were told they can take breaks or skip any specific exercises that they were not comfortable with. They were also told that they can leave the experiment at any time and that none of their identifying information would be used in the evaluation. Afterwards, they were informed that they would need to perform each of the specific exercises for one minute each and they were encouraged to stick to this specification as strictly as possible. This experiment was conducted in a local gym and they were provided with a clock and were allowed to check their phones at any time in order to simulate the typical environment where these experiments would naturally be performed. These six exercises and their specific conditions are listed below:

1. One-minute uninterrupted squats using a 45-pound bar without any weights
2. One-minute uninterrupted push-ups without any additional weights
3. One-minute high-knees
4. One-minute power cleans using a 45-pound bar without any weights
5. One-minute weightless chest-dips using the gym equipment

6. One-minute weighted lunges using a 20-pound kettle-bell

Before the control section of the experiment began, the clock was placed to the side so the participant would need to tilt their head to view the time. Once the exercise routine began, the observer did not interrupt or guide the participant in any way. Additionally, the observer collected data on the participant's performance, their timing, the number of times they referenced the clock or phone, and breathing form. These were all recorded while the participant was performing the exercises and the timings were recorded with the aid of a phone timer. Once all six exercises were completed and the data was recorded, the participant was given a five-minute rest and were offered more if they needed it.

After the user was sufficiently rested, they were informed that they would need to perform the six exercises, for one minute each, once again. However, this time they would be given a sanitized ear-bud that would output the audio from the program. They were told that at each exercise transition after one minute, there would be a text-to-speech voice that would inform them of what exercise they should be switching to. Also, they were informed they would be hearing a low-pitched humming sound, and that the louder it got the more intense their breathing is, and the higher the pitch was, their breathing form was worse. Since the data used in the program was simulation data and could not be applied to the current participant, the observer would need to control the output of sound to match the user's current performance. The user could also request to mute the humming sound, which the observer would do. Finally, the participant was informed they could start and the user would control the output of the sounds based on the user's performance. Everything was the same as the control section and the observer collected the same data metrics as the control.

After the participant was finished with all six exercises, they were allowed to rest and when they were willing, they were asked to test out the visual display of the program. Afterwards, they were asked to provide comments on the program and experience. They were also interviewed, and the questions used are listed below:

1. Do you think that the product was audible in this situation, and were there any moments where you missed a command?
2. Do you feel that your performance was improved overall by the product? Are there any specific exercises where the product helped you?
3. Would you use a product like this in the future, and was the mode of communication obtrusive during any of your exercises?
4. Did you feel an improvement in transitioning through exercises while using the program?
5. Were the breathing sonifications necessary in the program? If not, then is there any other sonification that could be more suitable for this program?
6. Were earbuds the best way of obtaining this information? Is there a better way to get information to you during exercise? Additionally, is audio the best way for you to get the sonification of your breathing and your schedule?
7. Was there any difference in your performance that you could feel when using the program, as in did you feel less fatigued or strained?
8. Finally, are there any comments you want to provide about the program or the experience?

After the interview, the experiment would be concluded.

2.3 Methodology Discussion

The overall experiment was conducted in a way to simulate the typical environment and tasks that would be performed for an average weight-lifting athlete. All of the participants fall in line with the intended audience for the program, however, there were limitations with the experiment. For one, the exercises performed, were not at the same level of rigor as what would normally be expected for a weight-lifters typical routine. Also, it was much shorter than a typical routine, which means this is not a completely accurate scenario of how the program would be used. Additionally, the user could be affected by the short time it would take between the control and experiment sections, and while rest time was provided, it potentially could not be enough for a complete recovery. These limitations were made to respect the time of the participants as well as ensure their safety throughout the experiment. While these are not the ideal conditions to test the program, they would be sufficient to mimic the overall experience of how and where it would be used.

3. RESULTS

3.1 Numerical Data Results

Below are the timing data recorded from the control exercises and the experiment exercises. For each participant, the time listed for each specific exercise is the exact time when they started doing the next exercise. For the final exercise on the list, the time recorded is the exact time they completely stopped doing the final exercise. The time starts at 0:00 when the participant began the first exercise. So, for the exercise squats, if the time was 1:20, then the participant stopped the current exercise and started the next exercise, push-ups, at exactly one minute and twenty seconds into the current routine.

Control Exercise Timings

	Participant 1	Participant 2	Participant 3
Squats	1:07	0:51	1:27
Push-Ups	2:13	2:12	2:44
High-Knees	2:49	3:23	4:11
Power Cleans	4:12	4:05	5:13
Chest-Dips	5:09	5:11	6:12
Lunges	6:33	6:12	6:52

Experiment Exercise Timings

	Participant 1	Participant 2	Participant 3
Squats	1:09	1:04	1:06
Push-Ups	2:09	2:11	2:03
High-Knees	3:12	3:06	3:13
Power Cleans	4:05	4:07	4:02
Chest-Dips	5:12	5:13	5:08
Lunges	6:23	6:08	6:02

For the following summary, statistic, it is based on a perfect mean of one-minute intervals. For instance, a perfect performance of this exercise routine would switch exercises on the minute every minute, and the deviation for the participants would be the amount of time they missed this marker by, in seconds

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The deviation, in seconds, away from one-minute intervals for control sections was 27.83 seconds.

The deviation, in seconds, away from one-minute intervals for experimental section was 8.5 seconds.

The difference between experiment deviation and control deviation is 19.33 seconds.

The following tables are based off of observations made by the observer. These include the number of times the user checked their phone, their overall performance of the exercise schedule, and the participant's breathing control. The last two metrics were scored on a scale of one to ten and are based on qualitative factors made by the observer as well as participant input after each section was completed.

Control Exercise Metrics

	Participant 1	Participant 2	Participant 3
Number of clock/phone checks	8	12	5
Breathing Form	7	7	5
Performance	8	7	6

Experiment Exercise Metrics

	Participant 1	Participant 2	Participant 3
Number of clock/phone checks	2	8	2
Breathing Form	7	8	6
Performance	8	7	6

3.2 Interview Summaries and Observer Notes

The following are summaries of the participant's responses during each interview and comments that were made by the observer.

Participant 1:

The participant had a negative view of the program. He described the routine text-to-speech as "a little helpful", but then described the wave sonification as, "hurting my ear after a while" and "too hard to concentrate on". Additionally, he said that he preferred to not use the program as it was too bothersome and annoying. As to if it would benefit him, he said that it had a slight benefit to him, since it allowed him to follow directions more easily, but overall, it was unnecessary. Finally, he stated that the program, and specifically, the waveform audio should be changed to sound better.

The participant did appear to do slightly better during the experimental section, although he did not seem to believe so. Also, he did not appear to show any discomfort or pain during the exercises, although he complained about the sonification in the interview. Finally, his breathing appeared to be similar in both

trials, but his performance did seem to improve, according to the observer. Also, the number of times he checked the phone and camera was significantly down from the control section.

Participant 2:

The participant stated, "I did not like the noise at all." and "I don't think it helped me.", when referencing the breathing sonification. His reaction to the program was negative, but he did say the schedule sonification made timing the exercises better. Also, he said he wanted to keep the sonification volume low as to not annoy him, but with the noise in the gym, it made it hard to concentrate on it. He said his performance and breathing in the experiment were slightly better, but he did not want to attribute it entirely to the program.

This participant seemed to do well in both sections, but he was prone to checking the clock a lot. He seemed fairly alert, but it was more present in the experiment section. He did at one-point remove the ear-bud in one ear and constantly switched them around from ear to ear. His timing seemed better, but his performance and breathing remained fairly stagnant from control to experiment.

Participant 3:

This participant asked for the breathing sonification to be muted at around 4:00, and when asked about this he responded, "It wasn't helping me and it was too high-pitched.". Also, the participant said he was sluggish due to being tired, and he said that the sonification did not help him at all. He said he enjoying using the program with just the schedule audio, and also stated he tried to control his breathing using the audio but gave up half way through the exercise routine.

The participant appeared to be sluggish, and tired throughout both exercises. He stated he was fine to keep going, and in no way did he appear to be injured or strained. The sonification did appear to cause him discomfort and he eventually decided to mute the audio of the breathing sonification. His performance did seem to improve slightly and his breathing was more controlled in the beginning of the experimental section. Also, he appeared to be more alert and vibrant during this phase of the experiment.

4. DISCUSSION

This program was not entirely successful in accomplishing the goals set by the research questions. To elaborate, the program concept did seem to provide, at least, a marginal benefit to the user's performance during exercise, however, the implementation of the project was not sufficient in helping the user. Most of the complaints were about the actual sound design of the program with all three participants complaining about listening to the sound for extended durations as well as it being too difficult to discern meaningful information from it. This means that instead of focusing on the exercises, the participants were being bothered by the program's audio or trying to discern the meaning from the sonification. In this area, it was a failure and did not meet the goals of the project. On top of that, the actual sonification structure did not seem to be particularly useful. This can be attributed to one of two things, with the first being the actual usefulness of the breathing sonification. From the interviews and research, it appears that the breathing form is relatively important to the weight-lifters since it helps preform each exercise better, and specifically improve their performance when lifting large

amounts of weight. With this regard, the breathing during exercise is important, but it might not be the most important thing to sonify. During the trials, the participants did not say it was particularly helpful. This could be due to the poor implementation, but it might not be practical to sonify the breathing due to the difficulty of reacting and altering breathing form using sound cues. It is either too sophisticated of a category to properly sonify, or it would be impractical for users to benefit from a sonification of this type. Without further testing, the current amount of data is not significant enough to determine the answer. However, with actual user breathing data and a better sonification approach, this seems entirely possible. This brings the second possible reason for the lack of impact of the breathing data; the limitations of the experiments. Without live breathing data from the participants, it was up to the observer to alter the program, in order to match the current situation. This brings in error that could alter and even invalidate the data obtained, but without leaving the scope of the project, this was a limitation that could not be avoided. In summary, the question on whether breathing sonification is useful in improving exercise remains unanswered due to the constraints and limitations of the project and experiment. With this being said, it can be definitively stated that the current sonification setup that was used in the experiments was not successful in helping users improve their exercise performance.

While the breathing sonification was not helpful in improving exercise routine quality, the other aspect of the program did seem to provide a noticeable impact on participants. The text-to-speech schedule reading appeared to have helped the participants improve their timings, and all of the participants appeared to be positive about this aspect of the program. The data shows it as well, since the number of times the users checked the clock was lower in each case and their timings were tighter and less deviant from the expected times. With such a small sample size, it can't be definitively stated that this schedule reading is entirely helpful improving the user's exercise performance, but the data shows trends that helped improve participants' timing. Also, the interviews suggest that participants did benefit from this sonification. Although it is a smaller aspect of the program, this schedule sonification has shown to improve a user's exercise routine by helping them keep a time that they have set for themselves.

The program failed in achieving the goal of helping users improve their exercises in a meaningful way. Although using the program did slightly help the user's time their exercises better, the overall sonification system is not sufficient for providing this meaningful data. Even with such a limited sample size and the limitations in the project scope, it is clear that the reason this program did not meet the research goals, is because the sonification was unpleasant and did not provide information in a way that was easily understandable and easy to act upon. Even if there were some aspects of the program that were positive, the main goal of helping weight-lifting athletes improve their exercise routines through the use of audio information, was not met. Even though, this program was a failure there are aspects of the tests that were limiting and while the implementation was the cause for many of the program's faults, the concept can be expanded and improved in order for athletes to truly benefit from audio-delivered health sonification.

5. CONCLUSION

Overall, this program was not successful, but the concept does show signs of potential. Most of the problems seemed to be with

the implementation of the project and its limited scope. In order to improve the program, the sonification should be redone in a way that is more pleasant and less distracting to the user. The schedule sonification seemed to be a positive, but the breathing sonification was clearly a detriment to the performance of the program. This would mean that the breathing sonification would need to have a new style or maybe even be replaced entirely. Also, while breathing form is important during weight-lifting training, there might be more important metrics to performance that may be more helpful to athletes. Also, while this was outside the scope of the current project, a continued implementation should also get real-time data from users and interpret it in order to provide actual information for users. While the current implementation is only a simulation, it does not completely mimic the data that could be received from users, and even with outside control from an observer, it did not seem to provide accurate information. This can only be achieved with direct lines of data from the user, and the program would seem to greatly benefit from that addition.

While there were faults with the program that prevented it from reaching the research goals, it can be improved and altered to eventually reach these goals. There does seem to be a need for easy and readily available health information, and the best was to provide users with this information during exercise is with audio. Specifically for weight-lifters, the desire for improvement and excellence can be greatly improved with this information, and while this program was not entirely helpful in this endeavor, with enough improvement, this concept can be fully actualized.