Enhancing Rollerblading Skills Through Auditory Guidance: A Sonification Study

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ABSTRACT

This study explored the utility, appropriateness, and accuracy of a rollerblading sonification system focusing on rolling straight, rolling uphill, and going around cones. To test the simulator, 3 beginner rollerbladers participated in a rapid training phase, 4 assessments corresponding to 3 scenarios, and an interview phase. The measures used were response time, adaptability towards the sonification, and subjective measurements of skill improvement before and after testing sessions. The primary research question to be addressed in this experiment was *Does the sonification offer sufficient clarity, ease of comprehension, and appropriateness for implementation in rollerblading?* The study concluded that the sonification system has usability due to the small changes in improvements in a minimal amount of time, hence further modifications can vastly improve the simulator. After 4 assessments, the participants were able to interpret 81.7% of the sonification outputted on average while they responded to leg position alerts with an average of 1.16 seconds, leg placement changes with an average of 1.22 seconds for scenario 2, leg placement changes with an average of 1.21 seconds for scenario 3, and midline closeness changes with an average of 1.06 seconds. Additionally, 2 out of the 3 participants agreed that this sonification system will help beginner rollerbladers with better form and technique.

Keywords

Sonification, Leg Position, Leg Placement, Midline Closeness, Response Time, Alerts, Scenario

1. INTRODUCTION

This study is an evaluation of an audio, sonification system for rollerbladers to improve form and technique while preventing injury. The primary research question is **(RQ1) Does the sonification offer sufficient clarity, ease of comprehension, and appropriateness for implementation in rollerblading?** The question is answered by looking at the averages of each of the subsequent assessments and analyzing interviews taken from participants. Another specific research question proposed to understand the sonification of leg position is **(RQ2) Will the rollerblader be able to discern the differences between 6 different leg position alert sounds while the music is playing?** Similarly, a research question was also proposed to understand the sonification of leg placement and midline closeness **(RQ3) Will the rollerblader be able to discern the changes in the background music for leg placement and midline closeness?** In order to understand user experience adapting to the sonification and subjective measurements about technique/form development, the research question to be explored is **(RQ4) What are the rollerblader's opinions about technique changes, and did their form improve overall?**

2. METHODS

2.1 Participants

I recruited 3 individuals to participate in this study. 2 of the participants were male while 1 was female. These are beginner rollerbladers who have less than 2 weeks of experience. They are trying to learn new skills and rollerblading recreationally. Most of them have taken on this as a new hobby.

2.2 Setting

The study was conducted in person at a local skatepark to ensure maximum comfort for the user and minimal distractions considering only skaters come to this park.

2.3 System

2.3.1 Equipment

Processing 4.2 was used to run the sonification simulator. Hence, each scenario for each participant required a Windows laptop that ran the latest version. Additionally, Apple AirPods were used by participants to receive sound output. For each assessment, an iPhone 11 was used to record their reactions once sonification was delivered. These recordings were analyzed later for data.

2.3.2 Sonification Description

The sonification system was constructed to enhance the experience and aid in the skill development of beginner rollerbladers. With sound output causing change, rollerbladers can start improving their form earlier on in an effort to attain efficient form/technique. It is important to note that the rollerblader must be listening to music while using the simulator for sonification to be present. First, leg position is sonified by outputting alerts. For each scenario, certain leg positions are deemed valid while others are considered improper form. These leg positions are top right, top left, side left, side right, bottom left, and bottom right. Second, leg placement is sonified by altering the background music that the user is playing while rollerblading. Third, midline closeness is also sonified by altering the background music. The details of where these sonification strategies are used can be seen below.

Scenario 1: This scenario corresponds to a user going straight. Wrong leg positions would be anything except top right and left. Only 2 positions are needed to accommodate acceleration capabilities. This scenario is quite simple since it only provides alerts over the background music when the wrong leg position is placed. The other scenarios use more advanced sonification strategies.

Scenario 2: This scenario corresponds to a user going uphill. When going uphill, the bottom and top leg positions are used, and not the side ones. Hence alerts are given if these are used. Additionally, "leg placement" is a new aspect added here. If the

leg placement in that top right position for example is off, it can ruin the technique of going uphill. Hence, leg placement is important. Depending on where the leg placement is from -1 to 1, it uses a paneer to give the effect of sound only coming from different sides of the speaker. The 0 level is the normal speaker level.

Scenario 3: This scenario involves weaving cones where both legs are outward at a cone, and they come back inward in between cones. This skill improves leg-eye coordination; hence it is involved in this project. In this scenario, only the side leg positions are considered accurate. And leg placement is again involved here as another aspect. A new aspect is added called "midline closeness" which has a slider from -100 to 100 which is an important factor to know going around the cones. As the meter approaches the lower extreme, higher frequencies are cut and vice versa is also true.

When the sonification simulator is implemented properly, the system is meant to be used continuously. A rollerblader will adjust their form while hearing movement sonified in real-time. The rollerblader can improve on leg position, leg placement, and/or midline closeness based on different sonification strategies to match the "perfect" ideal and achieve the same form as a professional rollerblader.

2.3.3 Sonification Controls

The study presents all available aspects of the simulator such as the JSON-loaded segments and the "Try It" user interface control. The "Try It" phase was implemented for a user to familiarize themself with all the sonification tools utilized, so they can pair a specific sound alteration while they are rollerblading. This exposure is required since adequate training will allow the reaction times to be much more accurate when determining the usability of the sonification system.

There are many controls available in the user interface and each one has its own purpose. The volume slider is used to adjust the sound of alerts and the background music while sonification is involved. The 6 buttons correspond to the leg positions that output programmatic sounds made of simple sound waves that a user can register and adapt their position. A mute button is also present to eliminate sound whenever the user needs a break or is attending to something else. The sliders for leg placement, rolling off, and midline closeness are present as secondary sonification tools for a couple of the scenarios explained. The sliders are important here since these are a range compared to a simple alert like the leg positions. Furthermore, the 3 scenarios are represented as buttons that can be accessed and played which will hide all the controls in the "Try It" phase. This is how the simulator will normally operate with incoming JSON events.

3 JSON events are loaded that correspond to the 3 labeled buttons to trigger the sonification routine. These are significant for testing assessments since the sonification should be updated as the user is making deviations or errors. As we move onto scenario 2 from scenario 1 and then to scenario 3 from scenario 1, the sonification gets more complex considering multiple aspects such as leg position, placement, and midline closeness are sonified together towards the last scenario. The user will start off with the easiest scenario to let them adapt to each sonification strategy on its own.

2.3.4 Procedure

The chosen participants were informed and briefed on the simulator by hearing a description and using the "Try It" mode. They were also allowed to ask questions about the sonification system to clarify any confusion/concerns. They filled out consent forms and were briefed about the potential risks and the purpose of the study.

Each participant participated in 20 trials since each assessment had 5 trials. Then, each participant evaluated their performance and commented on the usability of the sonification system. Towards the end of testing, they were also interviewed for additional feedback on the simulator.

After the needed consent from the participants, the experiment began with a training module to be completed. The training module videos were created by the researcher to demonstrate each scenario and explain how the simulator was supposed to be used. The "Try It" mode assisted the participants in understanding how each sonification strategy works and what changes should be made during the testing phase. Also, they were instructed that the display elements such as time, and user elements such as the mute option would be omitted due to the limitation of the current setup.

The first assessment involves 5 trials for each participant. This assessment is aimed towards scenario 1, rolling straight, and focuses on leg positions. Every time a participant uses an incorrect leg position (the first 5 will be recorded), the simulator will be prompted by the researcher to send an alert to the earphones. The user will be expected to make a change based on the incoming sonification. The participants will be asked to think about how their corrected technique compares to the "perfect" form that they witnessed during the training module.

The second assessment involves 5 trials for each participant. This assessment is aimed toward scenario 2, rolling uphill, and focuses on leg placement. Like before, any deviations from the proper leg placement will be noted by the researcher and the simulator will be used to output the needed sonification. Since the sonification of this aspect is associated with alteration in ha background music, the participant will be asked to think about whether they could notice subtle changes in the music. It is important to understand if subtle changes can be recognized due to small deviations or if only large deviations are apparent. Similarly, the third assessment follows the same procedure with 5 trials. The key differences are that the scenario focused on rolling around cones and the incorrect leg placement range has changed. More information can be found in the sonification description in 2.3.2.

The fourth assessment involves 5 trials for each participant. This assessment is aimed toward scenario 3, rolling around cones, and focuses on midline closeness. When the participant deviates as they are rolling between cones, the researcher will prompt the system to increase and decrease music output in either the left or right speaker which pairs with a specific ear. The participant will be asked to think about how the panning effect assisted them in controlling that side of the body.

The interviews will end the testing phase of the study, so the participants can reflect on and evaluate their performance. The participants were asked the following questions (see Table 1) to understand their subjective experience in adapting to the sonification. The participants were shown their results after delivering any additional comments about the testing phase. They

can also inform at this point about any limitations such as researcher-based prompting, user display elements unable to be seen, and any others detailed in the discussion.

Table 1. Interview Questions

Interview Questions
Please rate your experience on a scale of 1-5 based on how helpful the sonification system was in helping you adjust your form.
Was any element of the sonification system overwhelming or unnecessary for a user?
Would you imagine using an audio system like this regularly at the beginning of your rollerblading experience? Would it be distracting?
Are the sonification strategies appropriate? for a specific scenario? Could they be changed to better fit the system and eliminate confusion?

2.3.5 Measures

During the testing phase, the response time was recorded for each of the 5 trials in each assessment based on the scenario being performed at the given time. This measurement would be recorded in seconds. Additionally, it will also be recorded if the participant responded to a sonification input by leaving the cell blank if they did not. For these tables, refer to the results section.

During the interview phase, subjective comments will be collected to assess user experience. A quantitative measure will also be collected by asking how they felt the utility of the system was. The researcher will also evaluate the user form/technique on a scale of 1-5 before and after the testing session to analyze any improvements present.

3. RESULTS

The research findings will be presented in this section according to the proposed research questions found in the introduction section.

RQ1: Does the sonification offer sufficient clarity, ease of comprehension, and appropriateness for implementation in rollerblading?

RQ2: Will the rollerblader be able to discern the differences between 6 different leg position alert sounds while the music is playing?

Below are the raw results and means from the first assessment (see Table 2). These results show the response time of each participant adjusting to the proper position after discerning the sonification input. If they were not able to recognize the sonification and made no adjustments, no response time is recorded. The response times are averaged to analyze overall reaction efficiency. The data points where the participant did not respond to sonification were omitted from mean calculations.

Table 2. Response time for leg position adjustment during scenario 1 (Rolling Straight) for each participant in seconds

	Participant 1	**Participant 2**	**Participant 3**
Trial 1	1.1	-	1.22
Trial 2	1.13	1.05	1.23
Trial 3	-	1.12	1.16
Trial 4	1.12	1.08	1.2
Trial 5	1.28	1.2	1.2
Average (Participant)	1.16	1.11	1.2
Average (Overall)	1.16		

RQ3: Will the rollerblader be able to discern the changes in the background music for leg placement and midline closeness?

Below are the raw results and means from the second assessment (see Table 3), third assessment (see Table 4), and fourth assessment (see Table 5). Like previously, the results show response times for each participant to adjust to the accurate position/orientation for leg placement and midline closeness respectively. Additionally, the average by which a participant detects sonification will also be shown which will aid in the overall analysis of the system's clarity and appropriateness (see Table 6).

Table 3. Response time for leg placement adjustment during scenario 2 (Rolling Uphill) for each participant in seconds

	Participant 1	**Participant 2**	**Participant 3**
Trial 1	-	1.22	-
Trial 2	1.21	1.15	1.31
Trial 3	1.08	1.17	1.33
Trial 4	1.18	1.14	1.4
Trial 5	-	1.14	1.29
Average (Participant)	1.16	1.16	1.33
Average (Overall)	1.22		

Table 4. Response time for leg placement adjustment during scenario 3 (Rolling Around Cones) for each participant in seconds

	Participant 1	**Participant 2**	**Participant 3**
Trial 1	1.28	1.2	1.19
Trial 2	1.29	1.21	1.17
Trial 3	1.21	1.2	-

Trial 4	1.24	-	1.19
Trial 5	1.28	1.2	-
Average (Participant)	1.26	1.2	1.18
Average (Overall)	1.21		

Table 5. Response time for midline closeness adjustment during scenario 3 (Rolling Around Cones) for each participant in seconds

	Participant 1	**Participant 2**	**Participant 3**
Trial 1	-	-	1.09
Trial 2	-	1.08	1.08
Trial 3	1.02	1.08	1.08
Trial 4	1.05	1.1	1.04
Trial 5	1.02	1.07	1.02
Average (Participant)	1.03	1.08	1.06
Average (Overall)	1.06		

Table 6. The success rate in responding to sonification for each assessment and for each participant in %

	Participant 1	**Participant 2**	**Participant 3**
Assessment 1	80%	80%	100%
Assessment 2	60%	100%	80%
Assessment 3	100%	80%	60%
Assessment 4	60%	80%	100%
Average (Participant)	75%	85%	85%
Average (Overall)	81.7%		

RQ4: What are the rollerblader's opinions about technique changes, and did their form improve overall?

The participants gave a rating of their experience of the sonification system during the testing phase (see Table 7). This will be used along with the interview comments to assess the improvements/modifications that need to be made. Also, the researcher's ratings about the form of the participants before and after have also been presented (see Table 8). These ratings will be analyzed to understand if the main goal, to improve form, was achieved across the participants considering they are a beginner with little to no background in rollerblading.

Below are highlights and excerpts from the interview phase of each participant during the evaluation phase.

The ear-to-ear music effect (in reference to panning for midline closeness) *is hard to decipher due to the beat of the music alternating a lot. You could try to use music that is mellow.*

The alert sounds for the wrong position (in reference to the 6 leg positions) *are hard to differentiate since a lot of them sound similar.*

The sonification is very sensitive (in reference to leg placement and midline closeness where small changes are being sonified) *even small mistakes are being scrutinized which is making it difficult to enjoy rollerblading.*

Based on these comments and the ratings given by each participant, these will be used for analysis in the discussion section. Other comments were also made that will be used. These were the ones similarly heard from each participant during their interview.

Table 7. Participant rating on overall usability and helpfulness of the sonification system based on the overall experience on a scale of 1-5

	Participant 1	**Participant 2**	**Participant 3**
Rating (Overall)	3	5	5

Table 8. Researcher's subjective rating on the participant's form/technique in all scenarios before and after the testing phase on a scale of 1-5

	Before Testing	**After Testing**
Participant 1	3	5
Participant 2	2	4
Participant 3	3	3

4. DISCUSSION

RQ1: Does the sonification offer sufficient clarity, ease of comprehension, and appropriateness for implementation in rollerblading?

The primary research question (RQ1) focused on assessing the utility, appropriateness, and accuracy of the rollerblading sonification system, with a specific emphasis on its clarity, ease of comprehension, and suitability for implementation in rollerblading. The study found that the sonification system has usability due to the observed improvements in participants' performance within a short period of time. The average response

times during the assessments indicated that the participants were able to interpret 81.7% of the sonification output on average. This suggests that they were able to respond to the alerts and adjust their leg positions or leg placements accordingly. The overall success rate in responding to sonification was 81.7%, which is a positive indication of the system's effectiveness in aiding participants' form and technique during rollerblading.

However, some participants mentioned that the alert sounds for different leg positions were challenging to differentiate as they sounded similar. This feedback indicates that improvements in the sonification strategy for leg positions might enhance the system's clarity and ease of use. Additionally, the sensitivity of the sonification system was noted by participants, as even small mistakes were being sonified, making it challenging for them to enjoy rollerblading. This suggests that fine-tuning the sensitivity of the sonification system based on user feedback could lead to a more enjoyable experience for participants.

Overall, the results indicate that the sonification system shows promise in aiding rollerbladers' form and technique, but further modifications and improvements are necessary to enhance its clarity, ease of use, and user experience.

RQ2: Will the rollerblader be able to discern the differences between 6 different leg position alert sounds while the music is playing?

Research Question 2 (RQ2) aimed to determine whether the rollerbladers could discern the differences between six different leg position alert sounds while the music was playing. The data from the first assessment, which focused on rolling straight and leg positions, showed that participants had varying response times to the sonification alerts. The average response time for detecting and adjusting their leg positions was 1.16 seconds. While this suggests that participants could discern the differences between the alert sounds to some extent, the variability in response times indicates that some leg positions might be more challenging to recognize than others.

The feedback from participants that the alert sounds for different leg positions sounded similar reinforces the need for improving the distinctiveness of these sounds. By making the alerts more discernible, the participants' response times may improve, leading to more effective and efficient adjustments to their leg positions.

To enhance the ability of rollerbladers to discern leg position alert sounds, future iterations of the sonification system could consider employing sound patterns or elements that are more easily distinguishable. User feedback and preferences should be taken into account during the design process to create a system that optimizes clarity and ease of comprehension.

RQ3: Will the rollerblader be able to discern the changes in the background music for leg placement and midline closeness?

Research Question 3 (RQ3) focused on the rollerbladers' ability to discern changes in the background music related to leg placement and midline closeness. The data from the second assessment, which focused on rolling uphill and leg placement, revealed that participants had an average response time of 1.22 seconds for adjusting their leg placement based on the sonification. Similarly, the data from the third assessment, which involved rolling around cones and assessing midline closeness, showed an average response time of 1.06 seconds for adjusting midline closeness based on the sonification.

The feedback from participants regarding the difficulty in discerning the ear-to-ear music effect (panning) for midline closeness suggests that the specific sound alteration used for this aspect may need refinement. Participants' comments about the sensitivity of the system indicate that it may be challenging to notice subtle changes in the background music. This feedback indicates a need to find a balance in the sonification strategy, ensuring that it effectively conveys relevant information without overwhelming the rollerbladers.

Future improvements could involve conducting user studies to identify preferred sonification patterns for leg placement and midline closeness. Additionally, adjusting the sensitivity and design of the sonification for these aspects could lead to better user comprehension and response times.

RQ4: What are the rollerblader's opinions about technique changes, and did their form improve overall?

Research Question 4 (RQ4) sought to understand the rollerbladers' opinions about technique changes and the overall improvement in their form through the use of the sonification system. The participant ratings on the overall usability and helpfulness of the sonification system were mixed, with one participant providing a rating of 3, and the other two participants providing ratings of 5. This indicates varying levels of satisfaction with the system's usability and effectiveness.

The researcher's subjective ratings of the participants' form and technique before and after the testing phase showed some improvement in form for all three participants. Two participants showed an increase in their form rating from before to after testing, while one participant's rating remained the same. These results suggest that the sonification system had a positive impact on the participants' form and technique, at least to some extent.

Participants' comments about the system being overwhelming or sensitive may be linked to the perceived difficulty in adapting to the sonification during the testing phase. Addressing these concerns and making appropriate adjustments to the sonification controls could enhance the overall user experience and potentially lead to greater improvements in form and technique.

In conclusion, the rollerblading sonification system shows the potential in improving form and technique for beginner rollerbladers. The system's usability, clarity, and appropriateness have been demonstrated through the participants' response times and improvements in form. However, user feedback also highlights the need for further modifications and improvements to enhance the system's effectiveness and user experience. By refining the sonification strategies and controls based on participant feedback, the system can better cater to the specific needs of rollerbladers and provide a more enjoyable and beneficial training experience.

5. CONCLUSION

In conclusion, the rollerblading sonification system demonstrated usability, with participants showing improvements in their performance. While the system's average success rate of 81.7% indicated a good level of comprehension, feedback highlighted the

need to enhance the distinctiveness of alert sounds and adjust sensitivity. Overall, with further refinement, the sonification system holds promise as an effective tool to improve form and technique in beginner rollerbladers.