

MUSICAL EXPECTANCY IN SQUAT SONIFICATION FOR PEOPLE WHO STRUGGLE WITH PHYSICAL ACTIVITY

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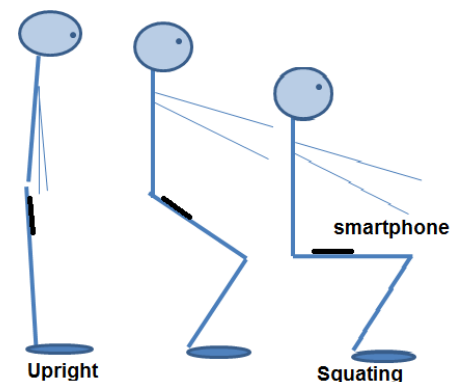
ABSTRACT

Physical activity is important for a healthy lifestyle. However, it can be hard to stay engaged with exercise and this can often lead to avoidance. Sonification has been used to support physical activity through the optimisation/correction of movement. Though previous work has shown how sonification can improve movement execution and motivation, the specific mechanisms of motivation have yet to be investigated in the context of challenging exercises. We investigate the role of music expectancy as a way to leverage people's implicit and embodied understanding of music within movement sonification to provide information on technique while also motivating continuation of movement and rewarding its completion. The paper presents two studies showing how this musically-informed sonification can be used to support the squat movement. The results show how musical expectancy impacted people's perception of their own movement, in terms of reward, motivation and movement behaviour and the way in which they moved.

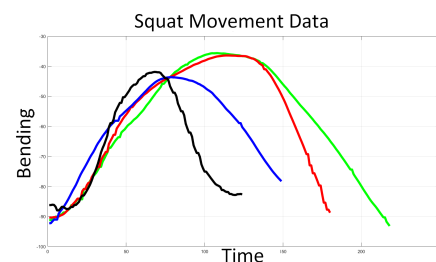
1. INTRODUCTION

Despite the majority of adults having a positive attitude toward physical activity, most do not meet the minimum UK government recommendation for physical activity [1] and adherence to physical activity is poor [2]. Prior work has shown how in-the-moment feedback can be used to optimise and improve the quality of movement [3, 4, 5, 6, 7]. People who struggle with physical activity often not only struggle with the form and technique of a specific movement but also with psychological barriers related to the perceived capability to perform such activity [8]. In this paper, we investigate how real-time movement sonification enriched with musical expectancy affects people's motivation during a challenging physical exercise.

The current use of sonification in physical activity primarily only informs users of their movement and does not focus on the specific mechanism within sound that can support people overcoming psychological barriers to physical activity [3, 4, 5]. Conversely, literature on behavioural changes has shown the importance of addressing psychological barriers to motivate an increased general activity level [9, 10, 11, 12]. However, such studies have focused only on long-term changes in the amount of activ-



(a) Set up for measuring the squat movement



(b) The movement data for one participant's first squat in Study one

Figure 1: a) The phone on the the upper leg measures the angle between the leg and the floor. b) The movement data measured by the phone: Green-musically stable, Red-musically unstable, blue-non-stability and black-no sound

ity by typically using goal-setting, quantify-self and post-activity rewards and reflection type of approaches. They fail to address the psychological barriers to performing a challenging movement.

In this paper, we aim to combine these two ideas: a real-time sonification during the performance of a challenging exercise which provides in-the-moment motivation and reward. To achieve this, we combine the use of auditory display (which has been shown to aid motor learning and improvement [3, 4, 5]) and principles from music theory and cognition which have an impact on not only people's emotional state [13] but also on the embodied perception of one's movement [14, 15]. We focus on the principle of musical expectancy (the way we expect a piece of music to con-



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tinue) to affect the way people endure in reaching the ending point of a movement.

We build on the work by Newbold et.al that showed how different harmonic stability at the target point of a movement can be used to motivate progress and reward the completion of movement [16]. However, that work focused on the stretch forward movement, a movement which has no defined ending to the movement and with a population that did not struggle with the performance of that movement. It has yet to be seen how this kind of sonification may differ from a more challenging exercise and one that has stronger perceptual (proprioceptive) cues at the target point. We focus on the squat down movement because 1) it is a fundamental movement in exercise [17] but where people often struggle with; and 2) it is one in which it is difficult to assess one's own form visually and is often performed incorrectly [17, 18]. Specifically, we focus on the depth of the squat movement, which is often misjudged by people who struggle with squats [17]. This study, therefore, aims to examine how this kind of movement may be impacted by different types of expectation at the ending of the movement sonification. We report here two studies that extend Newbold et al.'s work to investigate further the mechanisms surround musical expectancy within sonification. The first study aims to understand the effect of expectancy over motivation and movement within the squat movement by comparing it with a sonification that does not carry any expectancy information at the termination of the movement. The second study investigates more closely how different kinds of expectancy affect the reaching of target points in the squat. In addition, these studies focus on people that struggle with performing such movement.

2. BACKGROUND

Previous work on how technology can be used within physical activity has taken one of two approaches to tackle the problem. The first uses real-time sound feedback to help people correct and optimise their technique during a specific exercise [3, 4, 5, 19, 18, 20]. The aim of these kinds of feedback generally focus on informing people on their deviations from a particular movement path and focus more on the biomechanics of a movement over providing limited motivation or emotional support. The second utilises the promotion of activity through motivational prompts or goal-setting within activity tracking as a way to motivate and increase in one's overall activity levels [9, 10, 11, 12]. While this has shown to be effective in the past, there is also evidence that interventions like this have high rates of abandon and do not provide any information on the quality of a movement but only the amount. In this section, we review the benefits of these two approaches and suggest to extend these two threads of work by investigating how motivational mechanisms can be brought into sonification to enhance motivation on the moment of performing a challenging movement rather than just motivating increasing amount of activity.

2.1. Sonification for Physical Activity

Within sonification, there have been many works in general physical activity in which sonification have been used to inform people of their movement, e.g. [3, 4, 5]. In these works, various sound mappings have been used to inform the individual of their movement. Cesarani et.al used stereo balance in the headphones to represent asymmetry in a swimmers movement, allow them to correct their trajectory [5]. Yang and Hunt used the transforma-

tion of sound to provide feedback during the bicep curls on both movement and muscle activation [20]. Hale et.al demonstrate how sound feedback could be used to improve squatting form [18]. Using concurrent feedback on both flexion of the leg and pressure distribution on the foot, they found that participants with the feedback showed more improvement than those without. The prior work demonstrates how movement feedback can be used to improve people's performance of given movements and aid in motor learning. Still, studies have shown that, beyond working as information, sonification of movement milestones may work as a motivational mechanism. For example, in physical rehabilitation, sonification has been used to represent a change in the movement range, for example, the adding layers of music to inform that the range of movement has passed a set threshold [7]. Singh et al [6] went a step further by investigating how the combination of changes in sonification to mark movement milestone and self-calibration of those changes help to increase self-efficacy and sense of safety in people with motor difficulties. Tajadura et al. showed how the altering the feedback heard from one's footsteps can make a person perceive to be lighter led the person to walk faster and perceived the raising of the leg easier [21]. However, there is limited work investigating the motivational mechanisms found within the way sound can be structured as music and how this might be leveraged to motivate and reward people who struggle with physical activity.

2.2. Tracking and Motivational Tools

Biddle's work has shown that it is difficult to understand why it is that people do not adhere to an exercise routine as often only "surface reasons" are given, masking the deeper barriers affecting adherence [8, Ch. 2]. Sonstroem and Morgan highlight the link between exercise and self-esteem [22] in their proposed model for measuring the effect of physical activity interventions on self-esteem. Their model associates the self-perception of physical self-efficacy, competence and acceptance as the contributors to one's self-esteem with regards to physical activity. Additionally, as Shieh et.al show self-efficacy has a direct association with adherence to exercise [23]. Building on the importance of psychological barriers to physical activity, many researchers have proposed technological interventions focus on behaviour change theories to increase the amount of activity people do in their day-to-day lives. As outlined by Sullivan and Lachman, goal setting and rewards are often used in conjunction with activity tracking to motivate increased activity [9]. Goal setting is often used within fitness trackers as a way to motivate people to engage in physical activity [24] and, as shown by Munson and Consolvo [10], can be beneficial within self-monitoring of physical activity. Goal-setting and tracking provide people with a clear target to achieve and measures of their achievement. Additionally, motivation prompts to be more active through text messages or through an automated activity programme have been shown to effectively increase people's activity levels [25, 26]. Furthermore, physical rewards, e.g. a refreshing drink/monetary compensation [11, 12] have shown to impact people's motivation to do physical activity, however, virtual rewards may not have as substantial an impact [10].

While these previous works may demonstrate some efficacy for increasing people's general levels of activity, the focus is on the quantity of activity over the quality. These kinds of intervention, while motivational, do not give any support to facilitate engagement with challenging movements in real-time, which is important not only for optimising technique but for engaging in physical

activity that is beneficial to people well-being and health. Based on the previous success of sonification for real-time feedback to enhance confidence in movement as it is executed and on the importance to understand how motivational mechanisms works, we investigate how musical expectancy added to sonification facilitates the engagement with challenging movement by working not only as a goal-setting and reward mechanisms but also by providing a bottom up embodied desire to move.

3. MUSICAL EXPECTANCY AND MOVEMENT

Music and physical activity have some fundamental connections. Even the way in which music is described in terms of movements and scales moving up and down betrays the embodied way in which we experience music [27, 28]. Moreover, it can be seen how listening to different kinds of music during exercise can have an effect on both affective states and motor performance in physical activity [14, 15]. People have shown an implicit ability to synchronise their movements with music [29] and that certain music can even motivate more exercise/limit the effects of exertion [14, 15]. From this work, it can be seen how powerful a tool musical sound can be in promoting physical activity. People's relationship with music is not inherently linked to formal musical education. Simply through the general everyday exposure, people are able to understand and recognise many aspects of music [30]. Specifically, we look at musical expectancy, which can be described as the way we expect a piece of music to evolve. Whether this expectancy is met or defied creates the relaxations and tensions we feel within music. The work of Bigand demonstrates how harmonic stability, whether the harmony of piece music is complete, and rhythmic stability, whether the piece completes rhythmically, were correctly recognised by both musicians and non-musicians [31]. More recent work by Sears et.al. also shows how the traditional cadences used in classical music can be interpreted by non-musicians [32]. This musical expectancy has been demonstrated to impact people's movement. The work by Komeilipoor et.al [29] showed how musical dissonance impacts people ability to synchronise their movement with an external musical stimulus. It was found that participants were able to better synchronise with a consonant sound (one that fits expectation) than a dissonant sound (one which defies such expectations). Additionally, it was found that the consonant sound improved both form and accuracy. Newbold et.al. demonstrate how aspects of harmonic stability may be built into a movement sonification [16]. Using the stretch forward movement (moving from a neutral standing position and stretching forward to a comfortable target point); it was found that a harmonically stable cadence at the target point promoted the conclusion of the movement and a harmonically unstable sound encouraged additional movement. In addition, it was found that the stable cadences provided a greater sense of reward. However, that work focuses on executing a movement without a clear ending point executed by people that did not have difficulty with it. It is not clear if such mechanism would still work with movements that are supported by clearer interoceptive and exteroceptive feedback mechanism (i.e., proprioceptive and visual perceptual feedback). For example, in the stretch forward exercise (exercise used in Newbold et al.) the movement space has no boundaries and has an open stretching target point, one simply stretches forward into space and could theoretically continue indefinitely. However, the squat down movement offers a closed target that is a 90-degree bending of the knees. Such target position could be said to be signalled by clearer

perceptual cues (the flexion of the legs together with the visual feedback with respect to body height rather than depth) and has a definite ending to the movement squat (when the person reaches the squatting position). It is hence to be asked if the expectancy information carried by the sound would still contribute to changes in movement. In addition, Newbold et al. did not investigate the overall effect of expectancy versus sound with no expectancy information on motivation and movement. These are the two questions we address in the following two studies.

In the following, we report two experiments in which we measured both the effect that the sonifications have on the perception of people's own movement and on the quality of the movement itself. Our musical informed sonification leverages people's implicit knowledge of musical endings, i.e. how we expect a piece of music to end. We aim to understand the effect of people's embodied perception of the expectancy of when a music is supposed to end on their movement [27, 16, 29].

4. STUDY 1: MUSICAL EXPECTANCY IN SQUAT SONIFICATION

Our first study investigates if sonification carrying musical expectation, i.e., if or not a piece of music should end, has an impact on motivation to either reach or continue beyond a target position. More specifically, we investigate the use of stable and unstable cadences for defining the target point of the squat movement and compare them to how the squats are performed with either no feedback at all or with feedback that provides no musical expectation, i.e. is purely informative. Based on the previous works showing the effect of musically-informed sonification on physical activity, We hypothesised that:

H1: Sonification will be more motivating than no sound given their pleasurable effect, with the musical sonifications being favoured over white noise.

H2: Unstable cadence will encourage the most additional movement, while the sonification carrying no expectation will have the quickest start of return time from the squat position to standing position;



Figure 2: The two chord sequences used to create our two musical conditions, unstable shown top, ending on an imperfect cadence, dominant 7th and stable below, ending on a perfect cadence.

4.1. Materials

The squat movement is tracked using a smartphone strapped to the upper leg, as shown in 1. The on-board gyroscope, 50 FPS,

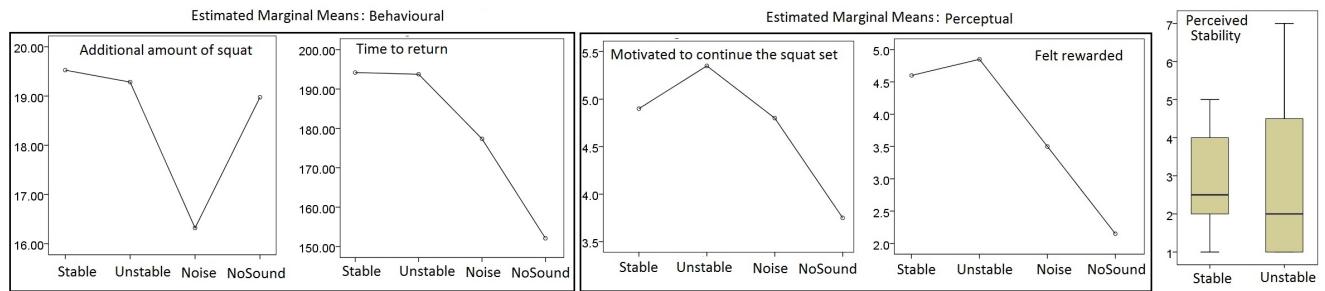


Figure 3: Overview of the finding of study one, both behavioural and perceptual

measured the angle of the leg during the squat. The phone is calibrated between the participant's starting position (i.e., standing in the squat case) and their target squatting position. The calibration consists in dividing the range of movement between the standing position and the target point into 6 movement segments with each segment triggering the next chord, thus playing the full chord sequence as the movement progresses towards the target point and which point the sonification ends (see Figure 2).

Four sonification conditions are defined: two creating expectations of musical endings (Stable, Unstable) and two that create no musical ending expectation (noise as sound and no-sound condition). These are described below:

- **Stable (ST) and Unstable (UN) sonifications:** As the participant moves through the calibrated space, each chord is played in equidistant intervals with the final either ending in a stable or unstable cadence (perfect or imperfect dominant 7th respectively) as seen in Figure 2.

- **Noise or also defined hereafter as non-musical sonification (NM):** white-noise was used so as to convey no musical expectation. The white noise sounded during the movement and reaching the target point was signified by the noise stopping. This sonification was used to compare these musical sonifications to one that is purely informative; as such participants would still know when the target point was reached, but there would be no prior expectation of its ending.

- **No-sound condition (NS):** this condition was considered to compare these sounds to how a squat would be performed unaided.

4.2. Participants

A total of 20 paid participants were recruited for the study (age=20-62 (mean = 26.5), 15 female and 5 male). All participants reported that they did not currently engage in regular physical activity.

4.3. Experimental Design & procedure

The study followed a randomised within-subject design using the four conditions described above. The study measured two behavioural data, the average amount of movement beyond the target point (**Additional Squat**) and the average time taken between the target point and the maximum amount of movement (**Time of Return**) before returning were measured using the smartphone device placed on the upper leg of the participants. For self-reported measures: For all conditions, perceived motivation to continue squatting after the target point (1 for not motivated to 7 for very moti-

vated), motivation to do more squats in the set (1 for not motivated to 7 for very motivated), and perceived reward at the target point (1 for not rewarding to 7 for very rewarding), were taken with 7-point Likert-type response items. Perceived angle of the final squat was reported in degrees, 0 degrees being standing and 90 degrees being the upper leg is parallel to the ground. For the three sound conditions participants were asked how informative the sound was and for the two musical conditions, perceived stability was measured (1 for completely stable 7 completely unstable). The participants were first introduced to the experiment and given a demonstration of the smart-phone application. For each condition participants were asked to set a goal of how many squats they would aim to do. This was done so as to give each participant a practical and safe goal to aim for; however, they were informed that they could stop the set before reaching the goal if they wished and to use the goal as a ballpark number to aim toward. They were instructed to squat down at a steady pace allowing each sound to play and to use the music/sound produced to inform them when they had reached the target point (i.e., the end of the feedback), in the no sound condition they were told to go until they felt they had reached the target point. After each set of squats, a questionnaire was used to collect the self-report measures.

5. RESULTS

Results are summarised in Figure 3 and further details of the descriptive statistics can be found in Figure 4. The behavioural measures were submitted to repeated measures analyses of variance (ANOVA) followed by Bonferroni-corrected pairwise comparisons; 17 observations for each condition were analysed, three participants were removed due to data loss. Self-reported data was analysed with Friedman tests, followed by Bonferroni-corrected Wilcoxon signed rank tests.

Additional Squat: Significant effects were found for the amount of squat past the target point ($F(3, 48) = 5.36, p = .003, \chi^2 = .251$). Participants moved significantly more in both musical conditions than in the non-musical conditions:

- ST > NM and NS ($p = .022$ & $p = .047$).
- UN > NM and NS conditions ($p = .014$ & $p = .029$).

However, no differences were found between the two expectancy conditions (i.e., ST vs UN) and between the two non-expectancy conditions (NM vs NS).

Time of return: Significant effects were found across conditions ($F(3, 48) = 10.23, p < .001, \chi^2 = .390$). Significant differences were found:

- ST (stability) > NS ($p = .004$)

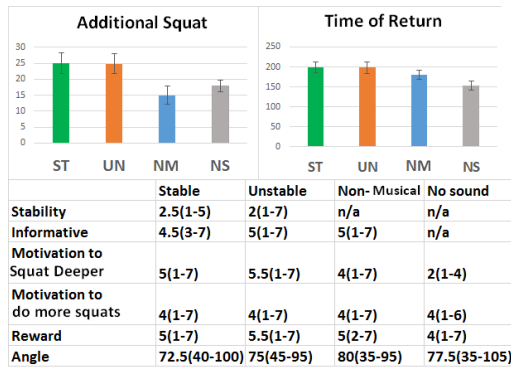


Figure 4: Overview of results from study one, showing the mean additional squat and time of return (SE) for stable, unstable, non-stability and no sound. Bottom shows the median (IQR) of the self-report measures.

- UN (unstable) > both NM ($p=.005$) and NS ($p < .001$)

This means that people took longer to start the return to a standing position with the cadence sonifications. However, while the stable condition had an effect only on the no-sound condition, the unstable ending did have an effect with respect to noise. At the same time

- NM > NS ($p=.018$) with people taking longer to start the return in the NM condition.

This suggests that the musicality of the sonification encourage movement in itself beyond the target point in comparison to no-sound or noise. Still, it appears that even with simple noise feedback people show a slower time of return.

Self-reported measures: A series of Friedman tests found significant differences for: perceived motivation to continue ($\chi^2(3) = 11.354, p = .010$) and perceived reward ($\chi^2(3) = 22.288, p < .001$). Subsequent Wilcoxon tests (the adjusted significance level was at $p = 0.008$) showed that:

- motivated to continue the set: UN > NS condition ($Z = -2.815, p = .005$)

- perceived reward both ST > NS ($Z = -3.35, p = .001$) UN > NS ($Z = -3.42, p = .001$)

It should be noted that the two musical conditions (ST and UN) were not found to be significantly different in terms of perceived stability, ($Z = -.144, p = .886$). These latter results differ from Newbold et al. where participants did perceive differences in stability between these two musical endings [16].

6. DISCUSSION

The results presented above support in part the set hypotheses. The results show some effects in movement behaviour when comparing musical cadences with non-musical feedback/no sound at all. In fact, less movement past the target point and a faster return were found for both the NM and NS conditions. However, no differences were found between the two levels of stability in terms of behaviour, only partially supporting **H1**.

For the self-reported measures, there was also a limited impact of the different stabilities, however, the unstable (UN) cadence was found to motivate participants to do more squats than the no sound condition (NS). In addition, both musical sonification (UN and ST) were found more rewarding than the no-sound condition NS. The

shorter movement and quicker return time found in the NM and NS conditions suggest that upon reaching the target point participants began standing back up from the squat. This may suggest that the stopping point (either because of abrupt stopping of the sound or because of proprioceptive feedback) is much clearer in these conditions, leading to an immediate and almost jerky turn around. Conversely, in the musical conditions this ending is perhaps less clear cut, meaning the return takes longer to come about and while this does lead to more movement, it also gives a smoother turning point. The stability for both ST and UN condition was quite low. It is possible that this has invited to continue to move as the sonification built the expectation of sound continuation despite the sound ended. Indeed, people reported being more motivated to continue the movement beyond the target point in the musical condition rather than in the non-expectation.

What is not so clear is why people did not perceive differences in stability levels between the ST and UN conditions. One possibility is that the lack of expectation of sound continuation in the noise condition has led to perceive both musical conditions having a more movement engaging perception. It may also be possible that the fact that the people executed a sequence of squats rather than just one, the music melody was perceived as continuing from one squat to the other leading to a smoother inversion between two consecutive squats. This is supported by the fact that the unstable was perceived as most motivating to continue the set; participants being motivated by the perceived continuation of the music.

In addition, while no differences were identified between conditions in terms of information carried (see figure 4), both musical conditions had a greater impact on the motivation and reward, as hypothesised in **H2**. These results show how these musical sonifications can motivate people during physical activity and how musical sonification can be seen as a reward for completed music. This verifies previous works in sonification findings [16, 6] on the impact of music on motivation during exercise. In the following study, we better investigate the if there is an effect of stability level on movement by exposing participants to only ST and UN conditions, this time for a single squat.

7. STUDY 2: SINGLE SQUAT SONIFICATION

The above study found that while musically informed sonification did impact people's perception of their movement, no differences were found between the two levels of stability. These results are somehow in contradiction with Newbold et al [16] the squat repetitions (versus a single instance of the movement as in Newbold et al) had on the perceived stability or due to the much greater perceived difference between the musical and non-musical sonifications. Therefore, in this study, we explore the effect by exposing participants to only the ST and UN condition and to a single squat scenario. We hypothesised that:

H1: stable cadences will feel more rewarding and increase the sense of achievement, while unstable cadences will trigger more motivation to continue the movement.

H2: Unstable target points will encourage the continuation of the downward movement;

7.1. Materials

The squat movement was tracked in the same way as the above study, see Figure 1. This time only the two musical sonifications were compared. The sonification used a combination of the two

cadence types (stable and unstable) and three lengths (8 chords, 7 chords and 6 chords), used to avoid participants learning the location of the final cadence during the experiment.

7.2. Participants

A total of 20 paid participants were recruited for the study (age=19-48 (mean = 28.4), 10 female and 10 male). All participants reported that they did not currently engage in regular physical activity.

7.3. Experimental Design & procedure

The study followed a randomised within-subject design using the six total conditions described above (two cadences (ST and UN) x three lengths). The study measured two behavioural and four self-reported measures. In terms of behavioural data, the additional squat past the target point and the time take to return were measured using the smartphone device. For self-reported measures: Measures of perceived stability (1 for completely stable to 7 completely unstable), perceived motivation to continue the movement (1 for very unmotivated to 7 very motivated) and perceived reward (1 for not rewarding to 7 for very rewarding) at the target point were taken with 7-point Likert-type response items. The perceived angle of the squat was reported in degrees, 0 degrees being standing and 90 degrees being the upper leg is parallel to the ground. The participants were first introduced to the experiment and given a demonstration of the smart-phone application. They were instructed to squat down at a steady pace allowing each chord to sound and to use the music produced to inform them when they had reached the target point (i.e., the end of the feedback). After each squat a questionnaire was used to collect the self-report measures.

8. RESULTS

Descriptive statistics for all measures are summarised in Figure 5. The behavioural measures were submitted to repeated measures analyses of variance (ANOVA) followed by Bonferroni-corrected pairwise comparisons;. Self-reported data were averaged across lengths and analysed with Wilcoxon signed rank tests.

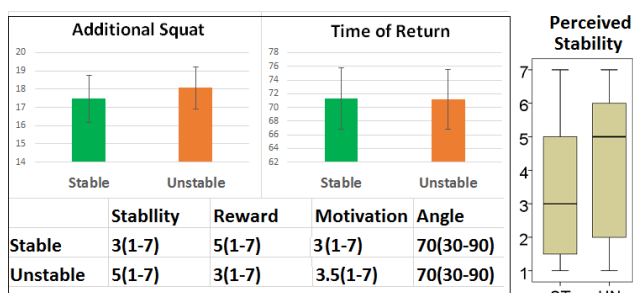


Figure 5: Overview of results from study two, showing the mean additional squat and time of return (SE), top and the median (IQR) of the self-report measures.

Additional Squat: No significant effects were found for the amount of squat past the target point across the two stability's. However the length condition did have a significant impact of the

amount of additional squat ($F(2, 38) = 8.14, p = .001, \chi^2 = .300$). With the pairwise comparisons showing a significant difference between the long and short length ($Z = .842, p < .001$) and the middle and short length ($Z = .723, p = .001$).

Time of return: No significant effects were found for the amount of squat past the target point across the two stability levels. However the length condition did have a significant impact of the time of return ($F(2, 38) = 4.74, p = .015, \chi^2 = .200$). With the pairwise comparisons showing a significant difference between the long and short length ($Z = 21.33, p < .034$) and the middle and short length ($Z = .723, p = .001$).

Self-reported measures: Wilcoxon tests showed that:

- Perceived Stability ST > UN ($Z = -2.65, p = .014$).
- Perceived motivation to squat further UN > ST endings ($Z = -2.45, p = .014$).
- Perceived depth of the Squat ST > UN ($Z = -2.36, p = .018$).

9. DISCUSSION

These two studies demonstrate how musically informed sonifications may be used to support general physical activity and specifically their effect on the squat movement. While previous works have shown the efficacy of sonification in improving the squat movement [18], these musical sonifications aim to concurrently announce progress and provide motivation. The results of our second study did not demonstrate how musical completion at the end of the movement can create a sense of reward, as utilised previously in work focused on physical rehabilitation [33, 16]. However, it was found that participants perceived that they had squatted deeper in stable conditions, even though no such difference was found in the actual movement. This may be due to the sense of completion leaving participants feeling they have moved further may come from the expectancy they feel in the cadences, the unstable being incomplete making people feel like they had completed less movement.

Additionally, it demonstrates how unstable endings provide a motivation to continue which we can link to previous works that show how the response time to unexpected endings is longer than complete ones [34]. These results, support **H1** and suggest that the use of this kind of feedback could improve self-efficacy in people engaging in physical activity; as well as acting as a motivational tool during the movement. While in the first experiment, this effect was lessened, likely due to the lack of perceived difference in the stability, both the musical sonifications were still perceived as more rewarding than both the control of no sound and to the non-musical feedback. The unstable ending then also motivated people to continue the set of squats more, perhaps as the incomplete ending of the sonification made the future repetitions more natural.

However, whereas Newbold et al [16] found that stable cadences promoted the conclusion of a movement, while unstable cadences encouraged additional movement in the stretch forward exercise, we do not find evidence to support **H2** as the same was not true in squat down exercise in this or the previous study. This could be related to the use of additional perceptual cues used by participants. The may also explain why significant differences were found for different length stimulus, as participants would move to the same point regardless. As the stretch forward is a more open-ended movement, the cadences stability has a bigger impact on movement.

As noted above, there was a difference in the way participants perceived the sonifications when doing a single squat versus the full set. Most notably it seems the difference in the two stabilities was not perceived by participants during the sets of squats. This finding disagrees with previous research both on how people perceive harmonic stability [31, 32] and how it is perceived during exercise [16]. However, in the single squat study, the difference in stability was perceived. While may come from the impact of the non-musical stimulus in study one affecting participants perception of the musical sonifications, it could be that the repetition of the movement impacted how the stability of the music was heard; musically this is understandable as the phrase would no longer be heard in isolation, as shown in Figure 2, but would be heard as a single longer piece of music comprises the phrases in sequence. This may also what cause the unstable conditions in study one to have the greatest impact on motivation to continue the set, due to the feeling of musical continuation. This may also account for the changes in perception between the two studies, as in the first experiment the unstable ending was heard as a continuous piece of music but the stable endings meant that where one would expect the sound to be driven forward, there was an unnatural stopping point.

These results of these studies also point toward new questions about how these sonifications may be applied to certain kinds of movements and how the repetition of movements may impact how they are perceived. Future work will include investigating how this kind of sonification can be designed for repetition based exercise. For example, rather than using static sonifications as presented here, sonifications could be designed to evolve and develop throughout a set of repetitions to fully take advantage of people's embodied interaction with these sonifications. Further investigation of categories of movement targets (i.e. open/closed) may enable greater exploitation of musical strategies to support physical activity. Additionally, the impact of musically informed sonifications on people's exercise patterns over the long-term would be interesting to study, particularly in terms of increasing people's self-efficacy over time and their ability to maintain a routine.

10. CONCLUSION

This paper presents a musically-informed sonification that uses musical expectancy to support people who struggle with physical activity. We present two experiments that investigate how musical expectancy impacts people who struggle with physical activity during the squat down exercise. This work demonstrates how musically-informed sonification can support motivational needs of people struggling with physical activity. In addition we show that by using musical expectation people feel they have achieved more movement (in the stable case). While in the unstable case people are motivated to move more and motivated to do more repetitions. However, changes in movement behaviour are less pronounced in the squat down exercise than exercises where perceptual cues at the target are weaker, as found by Newbold et.al [16].

In conclusion, this paper presented a musically-informed sonification of movement in the context of general exercise and the results of studies that investigate how it can be applied to the squat down exercise. This work shows both how the use of musical expectancy can be used to provide in-the-moment motivation and how the impact of perceptual cues within a movement and repetitions should be considered when designing this kind of sonification. The use of musical expectancy within sonification demon-

strates that we can combine the power of sound as a feedback mechanism with motivational aspects of music to support people who struggle with physical activity.

11. ACKNOWLEDGMENT

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