# The musical influence on people's micromotion when standing still in groups

**Alexander Refsum Jensenius, Agata Zelechowska, Victor Gonzalez Sanchez**
University of Oslo, Department of Musicology, fourMs Lab
`[a.r.jensenius, agata.zelechowska, v.e.g.sanchez]@imv.uio.no`

## ABSTRACT

The paper presents results from an experiment in which 91 subjects stood still on the floor for 6 minutes, with the first 3 minutes in silence, followed by 3 minutes with music. The head motion of the subjects was captured using an infra-red optical system. The results show that the average quantity of motion of standstill is 6.5 mm/s, and that the subjects moved more when listening to music (6.6 mm/s) than when standing still in silence (6.3 mm/s). This result confirms the belief that music induces motion, even when people try to stand still.

## 1. INTRODUCTION

It is commonly assumed that listening to musical sound, and particularly dance music with a clear pulse, "makes" us move. This assumption is to some extent supported by the literature in embodied music cognition [1, 2], and there are also empirical studies of music-induced motion [3, 4] or motion enhanced by music [5, 6]. Many of these former studies have mainly focused on voluntary and fairly large-scale music-related body motion. As far as we know, there is little empirical evidence of music actually making people move when they try to remain at rest.

Our aim is to investigate the tiniest performable and perceivable human motion, what we refer to as *micromotion*. Such micromotion is primarily involuntary and performed at a scale that is barely observable to the human eye. Still we believe that such micromotion may be at the core of our cognition of music at large, being a natural manifestation of the *internal* motor engagement [7].

In our previous studies we have found that subjects exhibit a remarkably consistent level of micromotion when attempting to stand still in silence, even for extended periods of time (10 minutes) [8]. The measured standstill level of a person is also consistent with repeated measures over time [9]. These studies, however, were carried out on small groups of people (2–5), so we have been interested in testing whether these findings hold true also for larger groups.

In this paper we report on a study of *music-induced micromotion*, focusing on how music influences the motion of people trying to stand still. In order to answer that question, it is necessary to have baseline recordings of how much people move when standing still in silence. More specifically, this paper is aimed at answering the following questions:

Figure 1. The setup for the "Norwegian Championship of Standstill." Each subject wore a reflective marker on the head, and one static marker was recorded from a standing pole in the middle of the space as a reference.

- How (much) do people move when trying to stand still?
- How (much) does music influence the micromotion observed during human standstill?

To answer these questions, we have started carrying out a series of group experiments under the umbrella name of the "Norwegian Championship of Standstill." The theoretical background of the study and a preliminary analysis have been presented in [10]. This paper presents a quantitative analysis of the data from the 2012 edition of our experiment series.

## 2. THE EXPERIMENT

The experiment was carried out in the fourMs motion capture lab at the University of Oslo in March 2012 (Figure 1).

### 2.1 Participants

A little more than 100 participants were recruited to the study, and they took part in groups consisting of 5-17 participants at a time (see Figure 1 for a picture of the setup). Not every participant completed the task and there were some missing marker data, resulting in a final dataset of

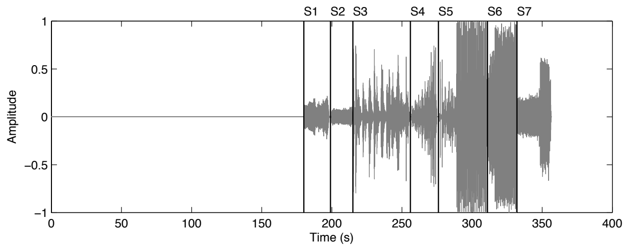

Figure 2. Waveform of the sound used throughout the experiment. Silence for the first 3 minutes, followed by 7 short music excerpts (S1–S7) ranging from non-rhythmic orchestral music to electronic dance music.

91 participants (48 male, 42 female, 1 unspecified).[1] The average age was 27 years (min = 16, max = 67). The participants reported quite diverse numbers for how many hours per week they spent listening to music (*M*=19, *SD*=15) and creating music (*M*=8, *SD*=8), reflecting that around half of the participants were music students.

### 2.2 Task

The task given to the participants was to attempt to stand as still as possible on the floor for 6 minutes in total, 3 minutes in silence and 3 minutes with music. They were aware that music would start after 3 minutes.

### 2.3 Sound stimulus

The sound file used as stimulus consisted of 3 minutes of silence, followed by 3 minutes of musical sound. There were 7 short musical excerpts, each with a duration of 20–40 seconds. The first musical excerpts were slow, non-rhythmic orchestral music, while the last ones were acoustical and electronic dance music.[2] As such, the rhythmic complexity and loudness increased throughout the experiment, as can be seen in Figure 2. The sound was played comfortably loud from a pair of Genelec 8020 loudspeakers and a Genelec 7050 subwoofer.

### 2.4 Motion capture

Each participant wore a reflective marker on his/her head, and its position was recorded using a Qualisys infrared motion capture system (Oqus 300) running at 100 Hz. We have previously shown that the spatial noise level of the system is considerably lower than that of human standstill [11].

Data was recorded and preprocessed in the Qualisys Track Manager, and the analysis was done in Matlab using the MoCap Toolbox [12].

To illustrate how the normalized position data looks like, Figure 3 shows plots of position on the three axes over time, as well as position spatial plots of the three planes.

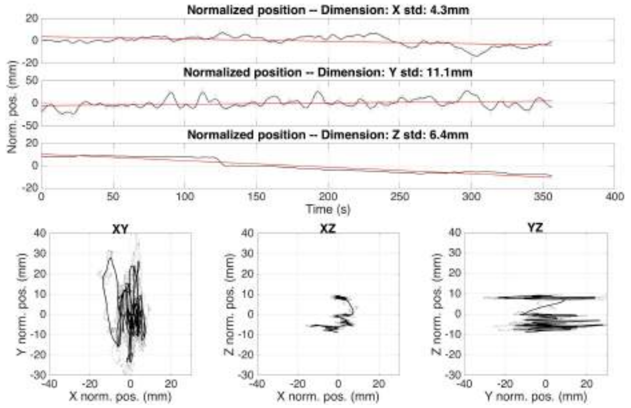

Figure 3. Example plots of the X (sideways), Y (front-back) and Z (updown) axes of the normalized position of a head marker. The light grey line is the raw data; the black line results from a ten-second smoothing; and the red line shows the linear regression (the trend) of the dataset.

## 3. RESULTS

### 3.1 Quantity of motion

To answer the question of *how much* people move, we calculated the *quantity of motion* (QoM) of each reflective marker by summing up all the differences of consecutive samples for the magnitude of the position vector, that is, the first derivative of the position:

$$QoM = \frac{1}{T}\sum_{n=2}^{N} \parallel p(n) - p(n-1) \parallel$$

where *p* is either the two-dimensional (XY axes—the horizontal plane) or three-dimensional (XYZ axes) position vector of a marker, *N* is the total number of samples and *T* is the total duration of the recording. The resultant QoM is measured in millimetres per second (mm/s).

In our previous studies [8, 9], we found QoM values in the range of 5–7 mm/s for a small group of people. Our new results confirm this range, with an average QoM of 6.5 mm/s (*SD* = 1.6 mm/s) over the complete recording, as summarised in Table 1. The lowest result was 3.9 mm/s (the winner!) and the highest was 13.7 mm/s. These values, however, included both the no-sound and sound conditions, so Table 1 also shows a breakdown of the values in these two conditions, as well as for the individual sound tracks. These differences will be further discussed in Section 3.5.

### 3.2 Motion over time

An interesting finding is that, for most participants, the quantity of motion did not change much over time, which can also be seen in the cumulative distance plots in Figure 4. There were a few extreme cases, but most participants had consistent linear motion distribution over time. Coefficient of determination (R-Squared) values were above 0.9 for most participants (mean $R^2$ = 0.94, s.d. $R^2$ = 0.0039 minimum $R^2$= 0.93).

---

[1] This paper is based on the complete dataset, while a subset was used for the qualitative analysis presented in [10].

[2] See `http://www.uio.no/english/research/groups/fourms/downloads/motion-capture/nm2012/` for detailed information about the music excerpts.

Table 1. Mean QoM values (in mm/s) for all sessions, in both no-sound and sound conditions, as well as for each of the individual music sections.

| | No sound (3 min) | Sound (3 min) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Part** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Mean QoM (mm/s) | 6.5 | | | | | | | |
| Mean QoM (mm/s) | 6.3 | 6.6 | | | | | | |
| Mean QoM (mm/s) | 6.3 | 6.2 | 6.5 | 6.7 | 6.5 | 6.6 | 6.9 | 6.7 |
| Standard deviation | 1.4 | 1.8 | 1.9 | 1.9 | 1.7 | 1.8 | 3.8 | 2.3 |

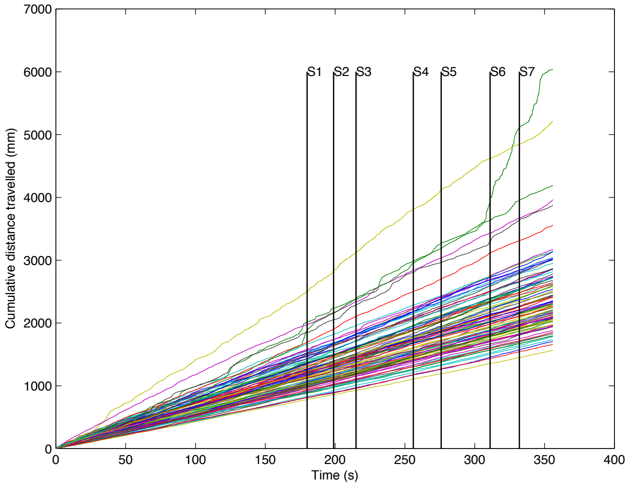

Figure 4. Cumulative distance travelled for all participants.

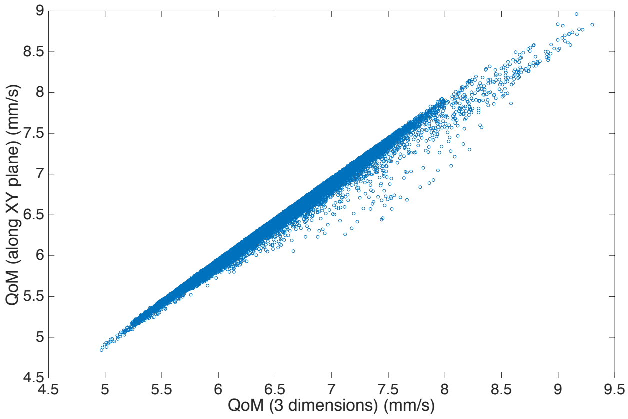

Figure 5. Scatter plot showing the linearity between QoM occurring in the horizontal (XY) plane and three-dimensional (XYZ) for the entire data set.

### 3.3 Horizontal Motion

To answer the question of *how* people move over time, we computed planar quantity of motion. The horizontal QoM (over the XY plane) was computed for all participants in order to further test the differences between conditions and stimuli. The mean horizontal QoM was found to be 6.4 mm/s for the entire 6-minute recording (*SD* = 1.5 mm/s). This value is only marginally smaller than the 6.5 mm/s found for the 3D QoM, suggesting that most motion, in fact, occurred in the XY plane. The relation between horizontal and 3D motion can also be seen in Figure 5.

### 3.4 Vertical Motion

To investigate the level of vertical motion, we also calculated QoM along the Z-axis. The mean vertical QoM across participants and conditions was 0.73 mm/s (*SD* = 0.52 mm/s), considerably smaller than the horizontal QoM reported above. This can also be seen in plots of the vertical motion (Figure 7) and in the frontal (YZ) plane (Figure 6), in which the bulk of motion in the Z axis is below 1 mm/s.

When looking at the differences between conditions, the mean vertical QoM during the no-sound segment of the trials was found to be 0.69 mm/s, while for the sound segment it was 0.77 mm/s.

### 3.5 Influence of sound on motion

For the 3-minute parts without sound we found an average QoM of 6.3 mm/s (*SD* = 1.4 mm/s), as opposed to 6.6 mm/s (*SD* = 2.2 mm/s) for the part with sound. This is not a dramatic difference, but shows that the musical stimuli did influence the level of standstill. A paired sample t-test was conducted to evaluate statistical significance of the observed differences between sound and no-sound conditions across the sample group. The results indicate the differences in means for three-dimensional QoM were significant for a 95% confidence interval ($t = 2.48$, $p = .015$).

Differences in the planar QoM between the sound (6.5 mm/s) and no-sound (6.2 mm/s) segments of the experiment were also statistically significant ($t = 2.5$, $p < .05$), although not considerably larger than those observed from 3D QoM.

These observed differences between sound and no-sound conditions were further explored by conducting a k-means cluster analysis of both 3D and 2D QoM for the entire data set. Using instantaneous QoM as a predictor, two clusters were identified by the implemented algorithm, although, as seen in the silhouette plot in Figure 8, most points in the clusters have silhouette values smaller than 0.3. This indicates that the clusters are not entirely separated, which could be due to the homogeneity of the sample group and the continuous nature of the musical stimuli.

The results are even clearer when looking at the individual stimuli in Table 1, with a QoM of 6.9 mm/s for the electronic dance music sample (#7) and 6.7 mm/s for the salsa excerpt (#8). As such, the results confirm our expectation that “music makes you move.” Even though the result may not be very surprising in itself, it is interesting to see that even in a competition during which the partici-

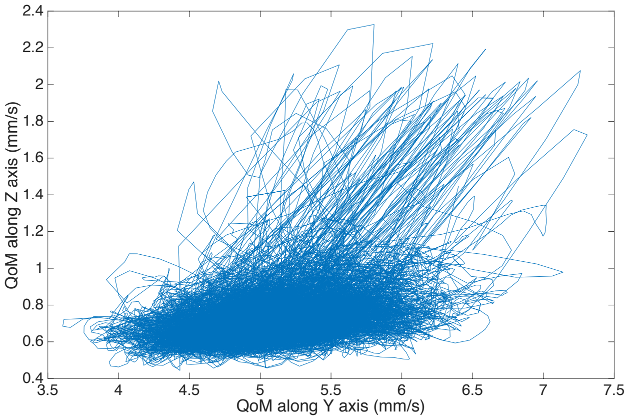

Figure 6. Plot showing QoM in the vertical plane (YZ) for the entire data set. The majority of the motion along this direction was below 1 mm/s.

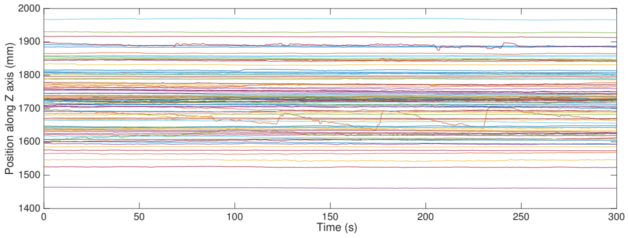

Figure 7. Instantaneous position of the marker along the Z axis (vertical direction).

pants actively try to stand absolutely still, the music has an influence on their motion in what can be termed "micro" level.

### 3.6 Age, Height and Gender

We found a significant negative correlation between the average QoM results and the participants' age. Generally, younger participants tended to move more ($r = -.278$, $p < .01$), both in the no-sound ($r = -.283$, $p < .01$) and sound conditions ($r = -.255$, $p < .05$). From the reported demographic information, we also found that the younger participants listened to music more frequently ($r$ = -,267, $p < .05$) and exercised more ($r = -.208$, $p < .05$). The younger participants also reported feeling less tired during the experiment ($r = -.35$, $p < .001$), subjectively experienced greater motion ($r = -.215$, $p < .05$), and also reported moving more when sound was being played ($r = -.22$, $p < .05$).

Unexpectedly, the QoM results did not correlate with the participants' height, which was estimated by calculating the average of each participant's Z-axis values. Due to a lower centre of mass, we would have expected to see shorter people with lower QoM results. However, the winner was 192 cm tall, while the runner-up was 165 cm.

Also, there were no significant differences in performance between male and female participants (no difference in average QoM, QoM in silence, QoM in music or QoM between both conditions).

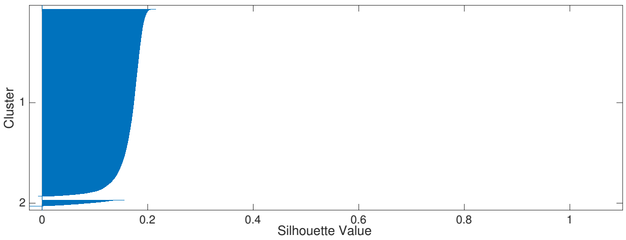

Figure 8. Silhouette plot from k means clustering analysis of QoM along the XY plane for the entire data set.

### 3.7 Effects of group, posture and physical activity

Aiming to evaluate the effects of standing strategies and postures, the participants were allowed to choose their standing posture during the experiment. In the post-experiment questionnaire they were asked to self-report on whether they were standing with their eyes open or closed, and whether they had their knees locked. The majority of the participants reported that they stood with open eyes ($N$ = 62 versus $N$ = 4 for closed eyes, and $N$ = 8 for those who switched between eyes opened and closed during the experiment). Furthermore, 33 of the participants reported standing with locked knees, 31 switched between open and locked knees and 10 reported standing with their knees open. A 1-way ANOVA was performed to test if any of these factors influenced the average QoM of the participants, but showed no statistically significant results.

Interestingly, the participants who reported greater amount of time spent doing physical exercise tended to move more during the experiment ($r = -.299$, $p < .01$). This tendency was particularly evident during the no-sound section ($r = -.337$, $p < .01$), but it was also observed during the sound section ($r = -.251$, $p = < .05$).

Additionally, we compared the average QoM results for all conditions (no-sound, sound, average no-sound and sound, and computed difference between sound and no-sound conditions) between groups of participants. Participants were split into 10 groups of varying age ($F(8, 82) = 3.43$, $p < .05$), experience with performing , composing or producing music ($F(8, 82) = 2.4$, $p < .05$), size (min = 5, max = 17) and the proportion of gender. We found no statistically significant differences between groups across these characteristics.

### 3.8 Subjective experience of motion

After taking part in the experiment the participants were asked to estimate how much they moved, to what extent the music influenced their movement, and how tiresome the experience felt. Overall, the self-reported tiredness showed some correlation with self-reported motion ($r = -.44$, $p < .001$) and with the self-reported experience of moving more to music ($r = -.289$, $p < .01$). The kinematic data confirmed this sensation: the more tired the participants felt, the more they moved to music ($r = -.228$, $p < .05$) and the greater was the difference in motion to sound compared to the no-sound conditions ($r = -.311$, $p < .01$). More importantly, although the subjective experience of motion did not correlate with the measured level of motion, the participants who reported moving more to music did move more during the sound condition when compared to the no-sound condition ($r$ = -.239, $p < .05$ for the difference in QoM between music and silence).

## 4. CONCLUSIONS

This study was aimed at further exploring the magnitude of micromotion and the influence of music on human standstill, based on the preliminary work presented in [10]. Quantity of motion (QoM) was shown to be a sensitive measure of micromotion for the conditions under analysis. The computation of both three-dimensional and planar QoM showed that micromotion occurred mainly on the horizontal plane. Additionally, statistically significant differences were found between no-sound and sound conditions across the dataset. Two clusters were identified in the data through k-means cluster analysis, although most points in the clusters had silhouette values below 0.4. This could be due to the continuous nature of the sound stimuli and the small (although statistically significant) differences between conditions.

The analysis revealed some relationships between QoM data and the self-reported characteristics of physical activity and demographic information. People who exercised regularly found it more difficult to stand still. Moreover, younger participants tended to move more during both no-sound and sound conditions. These results may suggest that people who tend to be more active struggle to reach and maintain a complete standstill posture, although they might be able to stand normally for longer periods of time and with greater balance. The correlation found between self-reported tiredness and both self-reported and measured motion can not be considered conclusive and further studies will focus on a more in depth assessment of the effects of tiredness in combination with sound stimuli during standstill.

The fact that there were no significant QoM differences between the groups of participants, indicates that testing varying number of participants at once is a viable way to test our hypotheses. Future work will focus on studying larger sample groups and use different stimuli, with a focus on investigating in more depth how different musical features influence the micromotion of people standing still.

### Acknowledgments

This research has been supported by the Norwegian Research Council (#250698) and Arts Council Norway.

## 5. REFERENCES

[1] M. Leman, *Embodied music cognition and mediation technology*. Cambridge, Mass.: MIT Press, 2008.

[2] R. I. Godoy and M. Leman, Eds., *Musical Gestures: Sound, Movement, and Meaning*. New York: Routledge, 2010.

[3] P. Toiviainen, G. Luck, and M. Thompson, “Embodied meter: Hierarchical eigenmodes in music-induced movement,” *Music Perception*, vol. 28, no. 1, pp. 59–70, 2010. [Online]. Available: http://mp.ucpress.edu/content/28/1/59

[4] B. Burger, M. R. Thompson, G. Luck, S. Saarikallio, and P. Toiviainen, “Influences of Rhythm- and Timbre-Related Musical Features on Characteristics of Music-Induced Movement,” *Frontiers in Psychology*, vol. 4, 2013. [Online]. Available: http://journal.frontiersin.org/article/10.3389/fpsyg.2013.00183/abstract

[5] M. Peckel, T. Pozzo, and E. Bigand, “The impact of the perception of rhythmic music on self-paced oscillatory movements,” *Frontiers in Psychology*, vol. 5, Sep. 2014. [Online]. Available: http://journal.frontiersin.org/journal/10.3389/fpsyg.2014.01037/full

[6] F. Styns, L. van Noorden, D. Moelants, and M. Leman, “Walking on music,” *Human Movement Science*, vol. 26, no. 5, pp. 769–785, 2007. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0167945707000589

[7] Y.-H. Su and E. Poppel, “Body movement enhances the extraction of temporal structures in auditory sequences,” *Psychological Research*, vol. 76, no. 3, pp. 373–382, May 2012. [Online]. Available: http://link.springer.com/10.1007/s00426-011-0346-3

[8] A. R. Jensenius and K. A. V. Bjerkestrand, “Exploring micromovements with motion capture and sonification,” in *Arts and Technology, Revised Selected Papers*, ser. LNICST, A. L. Brooks, Ed. Berlin: Springer, 2012, vol. 101, pp. 100–107. [Online]. Available: http://www.springerlink.com/content/j04650123p105646/

[9] A. R. Jensenius, K. A. V. Bjerkestrand, and V. Johnson, “How still is still? Exploring human standstill for artistic applications,” *International Journal of Arts and Technology*, vol. 7, no. 2/3, p. 207, 2014. [Online]. Available: http://www.inderscience.com/link.php?id=60943

[10] A. R. Jensenius, “Exploring music-related micromotion,” in *Body, Sound and Space in Music and Beyond: Multimodal Explorations*. Routledge, 2017, pp. 29–48, https://www.routledge.com/Body-Sound-and-Space-in-Music-and-Beyond-Multimodal-Explorations/Wollner/p/book/9781472485403.

[11] A. R. Jensenius, K. Nymoen, S. Skogstad, and A. Voldsund, “A Study of the Noise-Level in Two Infrared Marker-Based Motion Capture Systems,” in *Proceedings of the Sound and Music Computing Conference*, Copenhagen, 2012, pp. 258–263. [Online]. Available: http://urn.nb.no/URN:NBN:no-31295

[12] B. Burger and P. Toiviainen, “MoCap Toolbox - A Matlab toolbox for computational analysis of movement data,” in *Proceedings of the Sound and Music Computing Conference*, 2013, pp. 172–178. [Online]. Available: https://jyx.jyu.fi/dspace/handle/123456789/42837