Short Report

**A replication of the inverted U-shaped relationship
between rhythmic complexity and the sensation of groove
with a small stimulus set**

Jan Stupacher¹, Markus Wrede², Peter Vuust¹

¹Center for Music in the Brain, Department of Clinical Medicine, Aarhus University &
The Royal Academy of Music Aarhus/Aalborg, Denmark

²Department of Clinical Medicine, Aarhus University, Denmark

Corresponding author:

Jan Stupacher
Center for Music in the Brain
Universitetsbyen 3, Building 1710
8000 Aarhus C, Denmark
ORCID: 0000-0002-2179-2508
Email: stupacher@clin.au.dk

The experience of groove is defined as a pleasurable state of wanting to move one's body in relation to the pulse of a musical rhythm (Janata et al., 2012; Madison, 2006; Senn et al., 2020; Stupacher et al., 2013). Most individuals feel a strong desire to move their body when listening to music with a moderate amount of *rhythmic complexity*, whereas low and high amounts of *rhythmic complexity* decrease the desire to move (Matthews et al., 2019; Witek et al., 2014). Consequently, the relationship between *rhythmic complexity* and the sensation of groove can be described by an inverted U-shape. Matthews and colleagues (2019) additionally investigated the influence of *harmonic complexity* on the sensation of groove and found that wanting to move ratings were similar for low and moderately complex harmonies, but dropped for a highly complex harmony. The present study tests whether these effects of *rhythmic* and *harmonic complexity* can be replicated with a subset of nine stimuli from the original set of 54 stimuli used by Matthews and colleagues (2019).

Method

Participants

Data were collected in an online questionnaire, which was completed by 174 participants. Five participants reported a history of motor-related neurological diseases and were excluded. The resulting 169 participants (116 female, 53 male) had a mean age of 25.1 years ($SD = 6.1$). Ninety percent of participants were Danish; the rest of the participants came from 13 different countries. Forty-eight participants had no musical expertise; the other 121 participants were singing or playing an instrument. The sample size was comparable to Matthews and colleagues' (2019) sample of 201 participants.

Stimuli

Nine audio clips were selected from a set of 54 stimuli used by Matthews and colleagues (2019). The audio clips were ten seconds long and consisted of rhythmic patterns played with one chord in a piano timbre. Every rhythmic pattern consisted of five onsets per bar, which were repeated for four bars in total. The *rhythmic* and *harmonic complexity* of the patterns had three levels. *Rhythmic complexity* varied between low, moderate and high levels of syncopation. The chords were in D major and varied between low *harmonic complexity* (D major triad and two inversions), moderate *harmonic complexity* (four note chords with extensions), and high *harmonic complexity* (flat ninth interval between chord note and extension). For more information about the stimuli, see Matthews et al. (2019). Pulse clarity and roughness were calculated with the MIR-toolbox (Lartillot & Toiviainen, 2007), to estimate

rhythmic and *harmonic complexity* of the selected stimuli, respectively. As expected, pulse clarity was highest for low *rhythmic complexity* (0.72), followed by moderate (0.31), and high (0.28) *rhythmic complexity*. Mean roughness was lowest for low *harmonic complexity* (188), followed by moderate (213), and high (266) *harmonic complexity*. The stimuli can be found online at <https://researchbox.org/487>.

Procedure

Each audio clip was presented once in randomized order. After each stimulus, participants rated the groove of the audio clip on a continuous slider ranging from “not groovy” on the left to “very groovy” on the right. The numerical values ranged from zero on the left side to 100 on the right side, but participants could not see these values. Groove was defined as “wanting to move in time with the music” (Janata et al., 2012; Madison, 2006; Stupacher et al., 2013). In contrast to Matthews et al. (2019) who asked, “How much does this musical pattern make you want to move?” the present study directly mentioned the term groove and connected it to the urge to move with a musical rhythm.

Results and Discussion

In line with previous research by Matthews et al. (2019) and Witek et al. (2014), groove ratings followed an inverted U-shape when plotted against *rhythmic complexity*, i.e. syncopation (Figure 1). The strongest sensation of groove was reported for patterns with a moderate amount of *rhythmic complexity* ($M = 61.2$, $SD = 23.7$), followed by low ($M = 41.3$, $SD = 24.4$) and high ($M = 20.1$, $SD = 20.5$) *rhythmic complexity*. The manipulation of *harmonic complexity* also led to similar results as in Matthews et al. (2019): Groove ratings were highest for low *harmonic complexity* ($M = 47.3$, $SD = 29.0$) followed by moderate ($M = 43.5$, $SD = 27.4$) and high ($M = 31.8$, $SD = 26.4$) *harmonic complexity*.

An ANOVA on groove ratings with the within-subject factors *rhythmic complexity* and *harmonic complexity* revealed main effects of *rhythmic complexity* ($F(2,1344) = 686.30$, $p < .001$, $\eta^2 = .46$) and *harmonic complexity* ($F(2,1344) = 105.43$, $p < .001$, $\eta^2 = .07$) as well as an interaction between the two factors ($F(4,1344) = 7.05$, $p < .001$, $\eta^2 = .01$). With the large effect size of $\eta^2 = .46$, the factor *rhythmic complexity* may be more important for the sensation of groove than *harmonic complexity*, with a much smaller effect size of $\eta^2 = .07$. This finding is in accordance with Matthews et al. (2019), who suggest that “rhythm plays a primary role in generating the sensation of groove, with harmony providing a modulatory role through its effect on pleasure”.

The interaction between the two factors was unpacked with Bonferroni-corrected paired t-tests (see Figure 1). Differences of groove ratings between low and moderate *harmonic complexity* were nonsignificant in stimuli with low and high *rhythmic complexity*, but significant in stimuli with moderate *rhythmic complexity*. All other pairwise comparisons between *harmonic complexity* levels within each *rhythmic complexity* level were significant ($p < .001$).

In conclusion, the inverted U-shaped relationship between *rhythmic complexity* and the sensation of groove can be shown efficiently with a set of nine stimuli that are only rated once. The effects of *harmonic complexity* on groove ratings measured with this small stimulus set are also similar to the effects of the original study with 54 stimuli (Matthews et al., 2019). This is especially important for future studies with time constraints.

Figure 1. Groove ratings as a function of rhythmic and harmonic complexity. Dots represent mean groove ratings. Boxplots: The centerline represents the median. The lower and upper ends of the boxes correspond to the first and third quartiles. Whiskers represent lowest and highest values within $1.5 \times$ interquartile range (IQR) from the lower and upper quartiles, respectively. Semi-transparent dots represent values outside $1.5 \times$ IQR. *ns* = nonsignificant, * $p < .001$.

References

- Janata, P., Tomic, S. T., & Haberman, J. M. (2012). Sensorimotor coupling in music and the psychology of the groove. *Journal of Experimental Psychology: General*, 141(1), 54–75. <https://doi.org/10.1037/a0024208>
- Lartillot, O., & Toiviainen, P. (2007). A Matlab Toolbox for Musical Feature Extraction from Audio. *Proceedings of the 10th International Conference on Digital Audio Effects (DAFx-07)*.
- Madison, G. (2006). Experiencing groove induced by music: Consistency and phenomenology. *Music Perception*, 24(2), 201–208. <https://doi.org/10.1525/mp.2006.24.2.201>
- Matthews, T. E., Witek, M. A. G., Heggli, O. A., Penhune, V. B., & Vuust, P. (2019). The sensation of groove is affected by the interaction of rhythmic and harmonic complexity. *Plos One*, 14(1), e0204539. <https://doi.org/10.1371/journal.pone.0204539>
- Senn, O., Bechtold, T., Rose, D., Câmara, G. S., Düvel, N., Jerjen, R., Kilchenmann, L., Hoesl, F., Baldassarre, A., & Alessandri, E. (2020). Experience of groove questionnaire. *Music Perception*, 38(1), 46–65. <https://doi.org/10.1525/mp.2020.38.1.46>
- Stupacher, J., Hove, M. J., Novembre, G., Schütz-Bosbach, S., & Keller, P. E. (2013). Musical groove modulates motor cortex excitability: A TMS investigation. *Brain and Cognition*, 82(2), 127–136. <https://doi.org/10.1016/j.bandc.2013.03.003>
- Witek, M. A. G., Clarke, E. F., Wallentin, M., Kringelbach, M. L., & Vuust, P. (2014). Syncopation, body-movement and pleasure in groove music. *Plos One*, 9(4), e94446. <https://doi.org/10.1371/journal.pone.0094446>

Acknowledgments

The Center for Music in the Brain is funded by the Danish National Research Foundation (DNRF 117). Jan Stupacher is supported by an Erwin Schrödinger fellowship from the Austrian Science Fund (FWF J4288).