Temporal Hierarchies in Music and Neural Timing:

An Exploratory Review

Abstract

Predictive, hierarchical relationships in temporal experience are fundamental aspects of both music and language, serving as ubiquitous vehicles of communication, and greatly facilitating human social bonding and survival. This exploratory review considers music as a lens through which to explore neural timing, examining fourteen works across four decades of research in music cognition. Through these works, this review describes and synthesizes findings on how humans track, predict, and actively respond to hierarchical temporal structures in music and considers what these layered, multisensory mechanisms can reveal, more broadly, about human cognition and communication. A limitation identified in this exploration is the recurring use of "groove" as an overarching construct, of which it is suggested to adopt more precise terminology to accurately capture phenomena of interest. Additionally, it is proposed that future music cognition investigations prioritize (1) ecologically valid designs supporting naturalistic social interactions, (2) whole-body movement as central to temporal perception, and (3) multisensory integration. These considerations will situate music cognition research in a meaningful position for translatable, interdisciplinary and cross-cultural application, contributing to greater understandings of the multimodal, temporal underpinnings that support human communication.

Keywords: Music cognition, temporal processing, neural timing, hierarchical framework communication

Introduction

Predictive, hierarchical relationships in temporal experience are fundamental aspects of music and language, serving as ubiquitous vehicles of communication, and greatly facilitating social bonding and survival. Through these neural processes, complex information is integrated across multimodal systems (e.g., auditory, visual, vestibular, kinesthetic, and motor), contributing to the perception and production of temporally bound stimuli. Successful perception, expression, and information exchange hinges on the ability to process, produce, and synchronize multiple streams of information that are, at their core, rhythmic. Utilizing music as a lens through which to explore neural timing and temporal processing provides a useful perspective that can contribute to the understanding of these hierarchical frameworks, advancing research on human communication and cognition.

The *time* aspect of music—involving beat, meter, rhythm, attending, and entrainment—may be described as event-based phenomena eliciting predictive oscillatory processes in the listener. This review conducts an exploration of time- and event-based investigations of music cognition across fourteen works and several decades of research. Studies were selected based on their focus on temporal processing in music cognition, identified through literature searches and designated readings during an independent study course at Middle Tennessee State University (MTSU) in Summer 2025 (with one additional study added in Winter 2026). Selection prioritized empirical studies of rhythm, meter, beat perception, and temporal attention, alongside foundational theoretical works in music cognition. The intention of this review is to synthesize investigations of temporal processing in music cognition, identify limitations in current music science approaches (particularly, the repeated use of "groove" as a catch-all construct), and consider a framework for future directions in music science that is translatable across interdisciplinary domains of language and communication research.

Table 1: Comparison of published works explored in this literature review

Author	Year	Design	N =	Form
Desain and Honing	1989	Theoretical Model	N/A	Article
Duman et al.	2024	Experimental Design	88	Article
Henry et al.	2025	Registered Replication	60	Article
Hickock et al.	2015	Experimental Design (2)	5; 3	Article
Huron	2006	Meta Analyses, Theoretical Exploration	N/A	Book
Kalender et al.	2012	Experimental Design	56	Article
London	2004	Meta Analyses, Theoretical Exploration	N/A	Book
Palmer	1996	Case Study	1	Article
Povel and Essens	1985	Experimental Design, Theoretical Model	N/A	Article
Jones et al.	2002	Experimental Design (3)	21; 21; 11	Article
Spiech et al.	2024	Experimental Design	30	Article
Stupacher et al.	2025	Experimental Design	35	Article
Witek et al.	2014	Experimental Design	66	Article
Wu et al.	2025	Experimental Design (4)	30; 30; 31; 32	Article

Within the fourteen works reviewed, all of which were directed towards audiences within areas of music theory, music psychology, or cognitive neuroscience of music, a variety of experimental designs were used. As shown in Table 1, three of the included works were theoretical or written as meta-analyses, eleven of the works were experimental studies (including one registered replication study and one case study) with stated hypotheses, methodology, procedures, and reported findings. The experimental studies ranged from a single case study to an online study with 88 participants in total. These publications spanned many topics involving investigation of music theory and expressive choice (Palmer, 1996), psychology of musical expectation (Huron, 2006), a study of rhythmic entrainment and perceptual oscillations with a follow-up registered replication study reporting countering results (Hickok et al., 2015; Henry et al., 2025), perception of musical meter (Kalender et al., 2012; London, 2004; Povel & Essens, 1985), dynamic attending (Jones et al., 2002), computational modeling methods representative of musical time (Desain & Honing, 1989), eye blinks synchronizing to the beat as a biobehavioral marker of temporal attending while listening to music (Wu et al., 2025), and experimental studies investigating concepts related to movement, groove, and syncopation (Duman et al., 2024; Spiech et al., 2024; Stupacher et al., 2025; Witek et al., 2014).

The scientific literature within this review exploring groove, defined as "the pleasurable urge to move to music," (Janata et al., 2012), investigates different facets of the described phenomenon through the lens of cognitive neuroscience, clinical application in substance abuse disorders, and a redefining of the concept (Janata et al., 2012; Duman et al., 2024; Spiech et al., 2024; Stupacher et al., 2025). As psychological investigations of this concept are synthesized, "groove" as it is typically defined serves to be a useful paradigm for music science investigations. However, there is ambiguity in the term's meaning, complicating its use in scientific studies (Duman et al., 2024). Nuanced meanings of the term "groove" may be particularly unique to different generations, cultural groups, or professions (e.g., professional musicians). These inconsistencies complicate data collection, interpretation of results, and communication of findings, further narrowing the potential investigations of the multilayered, complex rhythmic and oscillatory phenomena of interest. As this review explores various facets of rhythm, meter, and temporal perception in music, I critically examine the concept of "groove" and propose a more precise and integrated terminology.

Investigating Musical Notation and Expressive Choice

As a starting framework, consider how humans superimpose expressive choices and patterns on music as they perform, as is the case in Palmer's 1996 case study. This study utilizes statistical analyses to disentangle expressive performance choices made by an expert performer that are not explicitly indicated in the musical score of a Mozart piano sonata. This research is relevant because it provides background information on the landscape of music cognition work in the 1990s, making it clear that the study of interactions between music and humans should involve the study of physical or recorded performances rather than using a score to quantify the stimuli and its effects. While the study lacks generalizability and has an extremely small sample (N = 1), the hypotheses investigated and analyzed expressive performance choices not indicated in a musical score and were able to extract evidence of an expert musical performance delineating from the score through interpretation of notational information (e.g., dynamic choices between notes of different pitches), performance-specific sources of expression (e.g., instrument-related timing tendencies), general characteristics of performance expression (e.g., microtiming of note onset choices in dissonant vs. consonant chords), performer-specific expression (e.g., choices of timbre/resonance), and cultural/cognitive norms (e.g., prediction of tension-relaxation and melodic expectancy influencing dynamic and timing choices).

This case study posed novel hypotheses related to human musical expressive choice and opened many questions for further investigation into expressive choices made by performers and perceived (whether consciously or unconsciously) by listeners. Through the lens of cognitive neuroscience, it seems apt to ask what might be learned through investigating how humans process and transmit musical (or communicative) expression and how it differs from its source, often a written score or audio transmission. The ways a performance differs from a musical score could uncover more about social and cultural expectations in emotionally expressive timing, communicative patterns in timbre, and microtiming choice. Since music and language are both vehicles of expressive communication, it would also be helpful to study how these unwritten expressive choices also occur in written and spoken language, considering prosodic inflection choice in a reader, and how these map onto musical expressive choice. While the differences between reading music and written words involve distinctive neural processes and cross-cultural considerations, this context can be leveraged to identify individual expressive choice (or the lack thereof) to be conceptualized as a form of cultural transmission, neurotype, or phenotype associated with different neurological conditions or health considerations. Generally, findings from music-language comparisons such as this can shed light on different neural mechanisms underlying communicative expression and point to (re)habilitative strategies for those facing communication-related developmental challenges.

A Theoretical Framework for Musical Expectation

Mental representations of expectation, predictability, and the creation of surprise in musical experience are thoroughly investigated by Huron (2006), whose elegantly simple framework is proposed to identify different types of expectation and surprise in the musical context. His proposed concepts name four categories relating to musical expectation and surprise, which can be fluid and may shift in interpretation depending on the listener's exposure and experience with a musical work. Huron's four categories of expectation are: 1) Schematic, involving expectations emerging from an existing schema that a listener brings to their experience of a musical work; 2) Dynamic, involving expectations that are created within the context of the musical work; 3) Veridical, involving the use of musical forms or sounds that are unexpected and found in other domains; and 4) Conscious, involving verbalizable knowledge—like knowing the song order of a favorite album.

Huron's recapitulative point that "the biological purpose of memory is not *recall,* but *preparation*" (Huron, 2006, p. 219) is an important reminder for scientific investigators to consider memory skills and memory processing differences when exploring concepts of event-attending, oscillatory rhythmic and meter entrainment, and patterns of social timing. Individual and clinical differences in attentional focus theoretically will lead to individual differences in memory. Populations with divergent attentional and/or memory experiences (e.g., post-traumatic stress disorder, attention-deficit hyperactivity disorder, autism spectrum disorder, Alzheimer's disease) may show identifiable behavioral or neural signatures of event preparation and surprise, perhaps further benefitting from tools leveraging musical expectation and surprise as metrics for identification and therapeutic use. While Huron's work is theoretically rich and poses several open-ended questions in the realm of memory, attending, expectation, and surprise, this current review is limited in that it does not include follow-up works that dive deeper into modern neuroscientific explorations of these phenomena.

Initial Study and Replication Study: Exploring Rhythms in Perception

A study exploring human entrainment to acoustic rhythms reported that perceptual oscillation was effectively induced in listening participants for at least two cycles after the cessation of the rhythmic stimulus, where $N = 5$ and, in a follow-up experiment extending up to four cycles, $N = 3$ (Hickok et al., 2015). The findings from this study indicated positive results of perceptual sensitivity oscillating after rhythmic auditory stimulation, though the analyses were limited by low statistical power. A multi-lab registered replication study published 10 years later with $N = 60$ did not find the same results and concluded that while neural entrainment remains a valuable concept, the behavioral signature reported in the original study might be weaker or less reliable than initially suggested (Henry et al., 2025). This pair of studies exemplifies the complexities of studying neural entrainment and the importance of transparency, replication, and clearly identifying and reporting study limitations along with results. While the replication study has significantly higher statistical power, a limitation of both studies is the lack of neural measurements in the experimental procedure. Future investigations exploring these hypotheses would benefit from implementing neural measurements alongside a replication of the original behavioral measures, perhaps illuminating the nuanced differences between the original and replication study's findings.

Movement, Groove, and Syncopation Studies

When viewed through the lens of cognitive neuroscience, research on groove, which has been defined in the psychological sciences as the pleasurable urge to move to music, can utilize investigations of oscillatory attention (Spiech et al., 2024) and attempt to disentangle the degrees of rhythmic syncopation most highly related to body movement and pleasure in study participants (Witek et al., 2014). In a clinical application, one study explored hypotheses related to the experience of groove in complex musical stimuli for populations with substance use disorders (Stupacher et al., 2025). Limitations of these studies include the use of simple drum stimuli, which is not as ecologically relevant in movement or dance-based musical activities, as well as terminological generalizations of rhythmic stimuli and reporting (e.g., using "syncopation" to describe rhythms that could be described more accurately using more precise language), hindering comprehension and translation of the work across different domains of academic research.

Future directions for studies in this realm include exploring tonal and melodic characteristics of music that might mediate or modulate a desire to move to music. Previously mentioned scholarly work exploring anticipation and surprisal in musical experience provide ample hypotheses that could be applied to tonal expectation (Huron, 2006). As mentioned in Witek's work, moving to music inherently changes the experience of the music, and further exploring this phenomenon is a promising area of investigation that could have implications for applied work in brain-based processing and movement disorders.

Finally, the study by Duman et al. (2024) investigates the currently accepted, working definition of "groove," pointing out gaps in how participants interpret the term and how the term is applied to use in the psychological and brain sciences. Duman et al.'s (2024) work concluded that groove might be better identified as a "multidimensional participatory experience" (p. 93), not only marked by a pleasurable urge to physically move but to mentally participate as well. This group of studies provides evidence that the experience of groove is a valid concept in the psychological sciences, though it would benefit from a more inclusive overall definition with tighter sub-terminologies, allowing for a more comprehensive definition of how such multidimensional experiential phenomena is described, experienced, and therefore studied.

Perception of Musical Meter

Three papers within this review focus on the topic of perception of musical meter. London (2004) provides a comprehensive theoretical background of the foundational psychological research supporting current explorations of time perception, dynamic attending, and entrainment. In this work, London proposes that meter and accent are entraining and attending processes for listening individuals, consisting of the development of a temporal schema based on past auditory events and prediction of future ones. Similarly, Povel and Essens (1985) characterize meter as hierarchical. It has been found that metrical accents, while not present in stimuli, can be imposed by a listener (Brochard et al., 2003). These foundational works and concepts are interwoven throughout the more current research explored in this review, demonstrating the ubiquitous nature of meter in the perception in music and temporal expectation.

Kalender et al. (2012) reports the results of an experimental study examining the influence of unfamiliar musical meter on a listener's ability to perceive a deviation from an established, repeated, metrical meter. The participants in this study were stratified into groups described as "mono-musical" (familiarity with one musical tradition and meter, e.g., Western, Turkish, or Indian) and "bi-musical" (familiarity with two or more musical traditions and meters). The experimenters accounted for bilingualism and musical training in their analyses. Grouping the participants in this way introduces several lines of inquiry related to temporal experiences in mono-musicality, bi-musicality and the perceptual narrowing of novel musical meter throughout an individual's developmental trajectory. The study reported that adults who listened exclusively to Western music detected changes in simple meter of Turkish music but not complex meter. Simultaneously, adults who listened occasionally to Indian music detected metrical changes in *both* simple and complex meter in Turkish music. Overall, this study is well-situated in the cognitive neuroscience and music cognition literature, providing a cross-cultural perspective and indicating that prior cultural music experiences significantly impact the metrical processing of meter. However, a limitation of the work involves the need to further illuminate the concept of bi-musicality. While the term implies a conceptual parallel to bilingualism, music and language exposure and absorption involve distinctly different processes. Further investigations devoted to the nature of bi-musicality and how it differs from bilingualism could yield highly beneficial avenues for future work.

Povel and Essens' 1985 work investigates the ways that humans perceive and structure temporal patterns in rhythmic sequences. The cognitive framework proposed involves a listener's imposition of a mental clock that organizes time intervals into predictable patterns. Through three experiments, the authors explore how experiences of regularity, accents, and timing deviations affect rhythm perception and synchronization. This publication has left an evident legacy on subsequent studies of temporal and metric patterns and is the oldest one included in this review, highlighting how internalized time structures guide perception and reproduction of complex temporal patterns.

Dynamic Attending to Auditory Rhythms

Jones et al., (2002) explores how rhythmic timing in auditory sequences influence attention and pitch perception. Across three experimental designs, the authors test whether listeners' accuracy in judging pitch was affected by the timing of tones in a sequence. The results of this study support a model of dynamic attending, where attention aligns with predictable temporal structures. This source provides a robust illustration of the landscape of psychological literature in the realm of music cognition and psychological mechanisms of prediction and expectation at the time of publication. While this paper was published in 2002, scientific explorations continue to further expand on theories related to dynamic attending theory in the realm of auditory and cognitive neuroscience.

Wu et al. (2025) explores auditory-motor synchronization during musical experience, reporting a novel finding that unconscious eye blinks in EEG experiments are found to synchronize with the musical beat, controlling for tonal differences and tempo changes. Across multiple experiments, the strength of synchronization was found to be modulated by auditory attention, with stronger neural beat tracking resulting in more blink synchrony. These findings underscore the importance of developing experimental designs with the intention of identifying the multimodal underpinnings of temporal tracking and auditory attention. New avenues for further refinement and exploration emerge, including the examination of unconscious blinks as a biomarker for temporal attending in non-isochronous stimuli, such as naturalistic speech and speech-in-noise conditions.

Computational Representation of Musical Time

Desain and Honing (1989) is a unique work in this review, centered around providing a novel, theoretical computational framework to represent the quantization of musical time. While this paper is primarily addressed to audiences working in computational analyses, it is of additional interest to cognitive scientists working to disentangle musical time in perceptual experience related to application in user experience, psychological and cognitive science, and artificial intelligence research. The study proposed a framework of musical time operating on two separate time scales: beat-based (smaller) and expressive-based (larger), applying a connectionist approach consisting of interconnected elements within a complex network. At the time of publication, this method outperformed other approaches and represented a cutting-edge contribution to the field.

The Problem of "Groove" in Music Science

Within the music cognition literature explored in this review and beyond, the term "groove" appears often. Duman et al. (2024) reports the results of an online study analyzing participants' understandings of the word "groove" throughout musical experience and what the experience of "groove" evokes for listeners. The study yielded results overlapping with the currently used definition of groove in the psychological sciences and further expanded into less definitive territories related to participation in solely mental experiences. This information should steer researchers towards considering Duman et al.'s proposed definition of a "multidimensional participatory experience" (p. 93) involving mental and/or physical engagement by the listener. New pathways for investigations of attending, pleasure, and participatory engagement in musical experience are apparent. While the desire to move and participate in music is an intriguing concept to explore in music cognition and cognitive neuroscience research, I propose that solely using the term "groove" to describe this phenomenon remains problematic and overly generalized.

Terminological Precision in Music Science Research

The limitations of language-based categorizations on human perception and experience are meticulously documented in seminal works throughout the field of psycholinguistics (e.g., Lakoff and Johnson, 1980). Since early uses of the concept of musical "groove," the term has been loosely defined, subjectively experienced, and globally popularized. While more research is needed, it is a valid concern that music cognition investigations attempting to contribute to an understanding of "groove" will face interpretive and translational challenges by relying on ambiguous terminology.

A large, multi-lab study deconstructing multiple aspects of "groove" into distinct, underlying constructs, such as rhythmic entrainment, motor affordance, affective engagement, and temporal attending, could more accurately describe the varied multidimensional experiences underlying the "pleasurable urge to move to music." Drawing on movement science frameworks like "affectively-charged motion states" (ACMS) and "psycho-physiological drive" (Stults-Kolehmainen et al., 2022; Stults-Kolehmainen, 2023) could inform components of this deconstruction and bridge terminology across relevant fields.

Toward Multidimensional, Predictive Temporal Hierarchies

Considering the lens of an experienced musical performer accustomed to isochronous time and micro-timing of familiar meters, a worthwhile investigation for additional theoretical framing would be to explore the emergence of nonlinear, cross-hierarchical temporal expectations and tensions that occur simultaneously during music performance. Exploring these phenomena could further reveal more nuanced and complex hierarchical experiences of schematic, dynamic, and veridical expectation, and surprisal experienced in those with primed memory and motor systems for such an experience. This phenomenon could be further applied across variables such as cultural context, lifetime musical exposure, language experiences, motor affordance, and affective states. Studying psychological musical phenomena while considering the impacts of individual differences and utilizing physiological neural measurements can yield more direct terms applicable to the experiences of these populations, perhaps guiding the rearrangement of “groove” into new subcategories and conceptual domains, revealing the different overarching, dynamic processes occurring in human musical experience and enjoyment.

Future Directions: Temporality, Neural Timing, and Human Communication

While this review has focused on temporal experience in music, the importance of temporality and neural timing in human language and communication is evident. While *musical* timing is often beat-based (isochronous) and hierarchically categorized using simple frequency ratios, *speech* timing contains hierarchical and non-isochronous rhythm and stress patterns, known as prosody. In both speech and music, the precisely timed coordination of sensorimotor gestures, facial expressions, head movements, and eye contact are crucial to conveying highly specific and meaningful messages. This poses the question: how do hierarchical rhythmic structures in music and language support multimodal communication and entrainment in social interactions? Further, what can this tell us about the neurobiological mechanisms underlying these processes?

The complex neurobiological processes underlying communicative timing enable elaborate and successful interpersonal information exchange–a vital skill for social cohesion and survival in all living species. While rhythmic processing in both music and language is suggested to be partially distinct, these processes are also known to share neural mechanisms and genetic architecture (Barchet et al., 2024; Alagöz et al., 2025). Recent studies exploring the multimodal underpinnings of language and music emphasize the need for ecologically valid study designs incorporating whole-body movement (e.g., co-speech gesture, beat gesture, posturing, and dance) and dyadic or group interactions (e.g., caregiver and child interactions, synchronization, speech-in-noise recognition) in temporal analyses. These investigations could contribute to a more comprehensive understanding of how afferent and efferent neural pathways support prediction and temporal attention, calling on multiple sensory systems to track, interpret, and express communicative messages (Hartmann et al., 2023; Momsen, 2024; Wu et al., 2025).

Prioritizing an investigation of temporally driven, hierarchical frameworks across both music and language will be instrumental to disentangling the distinct and shared neural timing mechanisms across both modalities. This approach calls for (1) ecologically valid study design within naturalistic dyadic and group interactions, (2) whole-body movement as central to temporal perception, and (3) multisensory integration.

Differences in temporal processing are implicated in a range of neurological conditions involving altered predictive coding, reduced multisensory integration, atypical memory functioning, and impaired motor abilities, which can cause difficulties during interpersonal communication. Across the lifespan, a range of genetic and environmental experiences can negatively affect the capacity for naturalistic communication and rhythmic processing, with downstream impacts at the level of the individual, family, community, and greater society. Contributing to a greater understanding of these temporal mechanisms across domains of language and music can inform future investigations and aid in the development of interventions for conditions involving impaired rhythm and communication skills.

Conclusion

This exploratory review, spanning fourteen works across forty years of music cognition research has examined musical rhythm, meter, and temporal perception across a wide range of musical contexts and stimuli. While additional research is needed to cultivate understandings of cross-cultural and developmental musical phenomena, establish greater terminological precision, and explore neurophysiological measures that may support or refute aspects of currently adopted theoretical frameworks, the field of music cognition has made great strides in the last four decades. Pioneering studies have contributed to understandings that are deeply relevant to our collective conception of human perception and cognition, psychology, neuroscience, movement science, and development.

To situate future music science research in an effective position for translatable, interdisciplinary application and cross-cultural collaboration, deconstructing ambiguous concepts and using precise language, (e.g., the concept of "groove") to develop future hypotheses will be paramount. Additionally, music cognition investigations should consider adopting: (1) ecologically valid designs incorporating naturalistic dyadic and group interactions, (2) frameworks positioning whole-body movement as central to temporal perception, and (3) active inclusion of multisensory integration. These considerations can position new hypotheses and investigations towards exploring a greater understanding of the multimodal, temporal underpinnings that support human connection, communication, and expression, as well as uncovering the distinct and shared neural mechanisms involved in both music and language processing, informing therapeutic and clinical applications.

Working to understand temporal hierarchies across music and language domains has great promise to contribute to understandings that support clinical populations facing communication challenges, memory differences, movement disorders, and differences in multisensory integration. By leveraging the clear similarities and differences in music and language, researchers can move towards multidimensional frameworks supporting multimodal perception and action through hierarchical temporal relationships. This will advance a greater understanding of human communication and connection–skills that are essential for social cohesion, communicative agency, and survival.

References

Alagöz, G., Eising, E., Mekki, Y., Bignardi, G., Fontanillas, P., Nivard, M. G., Luciano, M., Cox, N. J., Fisher, S. E., & Gordon, R. L. (2025). The shared genetic architecture and evolution of human language and musical rhythm. *Nature Human Behaviour*, *9*(2), 376–390. https://doi.org/10.1038/s41562-024-02051-y

Barchet, A. V., Henry, M. J., Pelofi, C., & Rimmele, J. M. (2024). Auditory-motor synchronization and perception suggest partially distinct time scales in speech and music. *Communications Psychology*, *2*(1), 2. https://doi.org/10.1038/s44271-023-00053-6

Brochard, R., Abecasis, D., Potter, D., Ragot, R., & Drake, C. (2003). The "Ticktock" of Our Internal Clock: Direct Brain Evidence of Subjective Accents in Isochronous Sequences. *Psychological Science*, *14*(4), 362–366. https://doi.org/10.1111/1467-9280.24441

Desain, P., & Honing, H. (1989). The Quantization of Musical Time: A Connectionist Approach. *Computer Music Journal*, *13*(3), 56. https://doi.org/10.2307/3680012

Duman, D., Snape, N., Danso, A., Toiviainen, P., & Luck, G. (2024). Groove as a multidimensional participatory experience. *Psychology of Music*, *52*(1), 93–116. https://doi.org/10.1177/03057356231165327

Hartmann, M., Carlson, E., Mavrolampados, A., Burger, B., & Toiviainen, P. (2023). Postural and Gestural Synchronization, Sequential Imitation, and Mirroring Predict Perceived Coupling of Dancing Dyads. *Cognitive Science*, *47*(4), e13281. https://doi.org/10.1111/cogs.13281

Henry, M. J., Obleser, J., Crusey, M. R., Fuller, E. R., Lee, Y. S., Meyer, M., Acosta, E. A. M., Van Hedger, S. C., Inbar, M., Oderbolz, C., Dunham, S. A., Anankul, Y., Sabo, L. E., Keitel, C., Maddox, R. K., Mehl, K., Aslan, G., Martens, P. A., Sauppe, S., … Peelle, J. E.

(2025). How strong is the rhythm of perception? A registered replication of Hickok et al. (2015). *Royal Society Open Science*, *12*(6), 220497. https://doi.org/10.1098/rsos.220497

Hickok, G., Farahbod, H., & Saberi, K. (2015). The Rhythm of Perception: Entrainment to Acoustic Rhythms Induces Subsequent Perceptual Oscillation. *Psychological Science*, *26*(7), 1006–1013. https://doi.org/10.1177/0956797615576533

Huron, D. B. (2006). *Sweet anticipation: Music and the psychology of expectation*. MIT Press.

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

Jones, M. R., Moynihan, H., MacKenzie, N., & Puente, J. (2002). Temporal aspects of stimulus-driven attending in dynamic arrays. *Psychological Science*, *13*(4), 313–319. https://doi.org/10.1111/1467-9280.00458

Kalender, B., Trehub, S. E., & Schellenberg, E. G. (2012). Cross-cultural differences in meter perception. *Psychological Research*, *77*(2), 196–203. https://doi.org/10.1007/s00426-012-0427-y

Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. University of Chicago Press.

London, J. (2004). *Hearing in Time: Psychological Aspects of Musical Meter*. Oxford University Press, Incorporated.

Momsen, J. (2024). *The Conversational Dance: Assessing the Sensorimotor Account of Multimodal Prosody* [UC San Diego]. https://escholarship.org/uc/item/237833z4

Palmer, C. (1996). Anatomy of a Performance: Sources of Musical Expression. *Music Perception*, *13*(3), 433–453. https://doi.org/10.2307/40286178

Povel, D.-J., & Essens, P. (1985). Perception of Temporal Patterns. *Music Perception*, *2*(4), 411–440. https://doi.org/10.2307/40285311

Spiech, C., Danielsen, A., Laeng, B., & Endestad, T. (2024). Oscillatory attention in groove. *Cortex*, *174*, 137–148. https://doi.org/10.1016/j.cortex.2024.02.013

Stults-Kolehmainen, M. A. (2023). Humans have a basic physical and psychological need to move the body: Physical activity as a primary drive. *Frontiers in Psychology*, *14*, 1134049. https://doi.org/10.3389/fpsyg.2023.1134049

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Boullosa, D., Janata, P., Koo, B. B., McKee, P. C., Casper, R., Budnick, C. J., Gilson, T. A., Blakemore, R. L., Filgueiras, A., Williamson, S. L., SantaBarbara, N., Barker, J. L., Bueno, F. A., Heldring, J., & Ash, G. I. (2022). Urges to Move and Other Motivation States for Physical Activity in Clinical and Healthy Populations: A Scoping Review Protocol. *Frontiers in Psychology*, *13*, 901272. https://doi.org/10.3389/fpsyg.2022.901272

Stupacher, J., Matarrelli, B., Cozzoli, D., Ventura, M., Montinaro, F., De Gennaro, L., Vuust, P., & Brattico, E. (2025). Individuals with substance use disorders experience an increased urge to move to complex music. *Proceedings of the National Academy of Sciences*, *122*(20), e2502656122. https://doi.org/10.1073/pnas.2502656122

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

Wu, Y., Teng, X., & Du, Y. (2025). Eye blinks synchronize with musical beats during music listening. *PLOS Biology*, *23*(11), e3003456. https://doi.org/10.1371/journal.pbio.3003456