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Short Papers

Individual Differences in Musical Tempo Perception Are Predicted by Body Height, Age, Music and Dance Sophistication in an Online Paradigm

Individuelle Unterschiede in musikalischer Tempowahrnehmung werden durch Körpergröße, Alter, Musik- und Tanzexpertise in einer Onlinestudie vorhergesagt

Luca Matsukawa [1], Hauke Egermann [1]

[1] *Institute of Musicology, University of Cologne, Cologne, Germany.*

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Corresponding Author: Luca Matsukawa, Institute of Musicology, University of Cologne, Albertus-Magnus-Platz, 50923 Cologne, Germany. E-mail: luca.matsukawa@uni-koeln.de

Supplementary Materials: Code, Data, Materials [see Index of Supplementary Materials]

Abstract

The perception of musical tempo and/or beat has been studied extensively. However, the reasons for the subjective perception of a piece of music as fast or slow remain unclear. We propose that individuals form a long-term preferred motor tempo (LTPT), which is less susceptible to short-term influences (e.g. arousal) than the spontaneous motor tempo commonly used in studies. LTPT creates a framework in which musical tempo is evaluated: individuals with slower LTPT perceive music as faster compared to individuals with faster LTPT. Participants listened to 20 musical stimuli with different tempi (40–135 BPM, 5-BPM intervals) presented in randomized order. Immediately after listening, participants rated each stimulus on a 5-point slow-to-fast tempo scale. Using a linear mixed model, we found that stimulus tempo predicts perceived musical tempo and this effect is moderated by factors assumed to influence LTPT (height, age, music/dance sophistication). The moderation is dependent on the tempo range in which it occurs, mainly appearing at the higher and lower ends of the tempo scale used. Another tested factor, body weight, did not yield significant results and was removed in a backwards elimination procedure. Our data indicate that taller and younger participants perceive music as faster, that musically sophisticated participants tended to use the ends of the slow-to-fast scale (1 = very slow, 5 = very fast) less, and that more sophisticated dancers use these ends more.

Keywords

embodied cognition, spontaneous motor tempo, music, tempo perception, body height, age, musical sophistication, dance sophistication

Zusammenfassung

Die Wahrnehmung musikalischen Tempos wurde bereits ausgiebig erforscht. Es ist jedoch unklar, was zu der subjektiven Wahrnehmung eines Stücks als langsam oder schnell führt. Wir postulieren, dass Individuen ein über größere Zeiträume geformtes präferiertes Tempo (*long-term preferred tempo*, LTPT) entwickeln, das weniger beeinflussbar durch kurzfristige Einflüsse ist (z. B. Arousal) als das häufig in Studien verwendete spontane motorische Tempo. LTPT erschafft einen Referenzrahmen für die individuelle Wahrnehmung musikalischen Tempos: Individuen mit langsamerem LTPT nehmen Musik als schneller wahr als Individuen mit schnellerem LTPT. Teilnehmende hörten in randomisierter Präsentationsreihenfolge 20 Stimuli in unterschiedlichen Tempi (40–135 BPM, 5-BPM-Intervalle). Nach jeder Präsentation bewerteten die Teilnehmenden auf einer 5-Punkt-Skala (sehr langsam bis sehr schnell) das Tempo des Stimulus. In einem linearen gemischten Modell sagte das Stimulustempo das wahrgenommene musikalische Tempo voraus und dieser Effekt wurde durch Faktoren moderiert, die wir als LTPT-beeinflussend postulieren (Körpergröße, Alter, Musikalische Erfahrenheit, Tanzerfahrenheit). Körpergewicht war als Moderator nicht signifikant und wurde per Rückwärtselimination aus dem Modell gelöscht. Der Moderationseffekt findet sich nur in den Randbereichen der verwendeten Temposkala. Unsere Daten suggerieren, dass körperlich größere sowie jüngere Menschen Musik als schneller wahrnehmen, musikalisch erfahrenere Menschen die Enden der subjektiven Tempowahrnehmungsskala weniger verwenden und im Tanz erfahrenere Menschen diese Enden häufiger verwenden.

Schlüsselwörter

Embodiment, Kognition, Spontanes Motorisches Tempo, Musik, Tempowahrnehmung, Körpergröße, Alter, Musikalische Erfahrenheit, Tanzerfahrenheit

The way listeners perceive tempo is a key aspect of the cognitive processing of music and important for many aspects of musical experience, for example, the expression of emotions (van der Zwaag et al., 2011). While it seems to be common to refer to music as fast or slow, the framework to which we apply these terms remains unclear. Our goal was to explore individual differences in musical tempo perception within the framework of embodied cognition.

Movement and Music Perception

The idea that body movement plays a role in the perception of music in general and in tempo and rhythm specifically is not a new one (Clarke, 1999; Fraisse, 1982; Gabrielsson, 1982; Honing, 2013) and has inspired many empirical studies. In an experimental study, Maes and Leman (2013) found that the perceived expressive character of music is affected by prior movement, while Sedlmeier et al. (2011) provide evidence that body movement influences music preference ratings. Similarly, Phillips-Silver and Trainor (2005, 2007) demonstrated that rhythm perception of metrically ambiguous stimuli can be influenced by prior movement in both 6-month-old infants and adults. This has been attributed to vestibular stimulation through movement (Phillips-Silver & Trainor, 2008; Trainor et al., 2009). Stupacher et al. (2025) highlighted that participants' spontaneous motor tempo predicts the metrical level they choose (i.e. half time, double time, etc.) when tapping to metrically ambiguous stimuli. In two other tapping studies (Drake et al., 2000; Duke et al., 1991), musicians showed a propensity to tap to slower metrical levels, although this finding could not be replicated in another study (McKinney & Moelants, 2006) and could have been caused by other mechanisms than movement. Todd et al. (2007) used anthropomorphic measurements (e.g. body mass, stature) to predict preferred beat rate. In light of Todd et al.'s findings, Repp (2007) and Honing (2013) suggested that body height should reliably have an impact on preferred musical tempo.

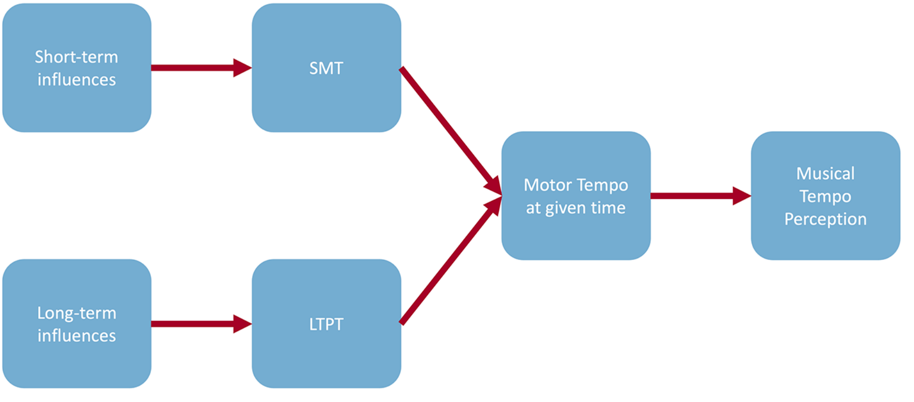
Long-Term Preferred Tempo (LTPT)

Multiple studies indicate that humans have an intrinsic tendency to perform repetitive movements at a certain tempo that differs between individuals (Collyer et al., 1994; Kroger et al., 2024; Smoll, 1975; Smoll & Schutz, 1978; Spiech et al., 2025; van Emmerik et al., 1989). This tempo is referred to as preferred (motor) tempo or spontaneous motor tempo (SMT), typically measured by asking participants to tap at a self-selected and comfortable rate (Kroger et al., 2024). However, 'preferred' in the context of motor tempo does not imply the evaluation of subjective preference, but rather a subconscious tendency to a specific tempo. As early as 1982, Fraisse (1982) suspected that SMT is involved in preferred musical tempi. However, at the time of his writing, empirical findings did not fully support this notion.

While research into SMT sufficiently validated it as a construct measuring internal tempo, there is one shortcoming: SMT is prone to reflect short-term circumstances (Desbernats et al., 2023). As such, more long-term influential factors such as musical expertise do not consistently predict SMT (see Table 4 in Desbernats et al., 2023). The evidence for anthropomorphic measurements' impact on SMT-similar constructs (e.g. other repetitive movements) is also contradictory (MacDougall & Moore, 2005; van Emmerik et al., 1989). The inconsistency in these results may stem from long-term influences having too small an impact to be detected in many of the given sample sizes. While Engler et al. (2024) found some evidence for SMT's intra-individual stability across different biomechanical systems (i.e. clapping, finger tapping and walking) and measuring times, SMT's intra-class correlations do vary (M = .49, Confidence Interval [.33, .63], percentage of confidence interval not reported). This suggests that either SMT is not sufficiently intra-individually stable over time, or that SMT is not the appropriate construct for identifying long-term individual motor tempo tendencies. Therefore, we assume the existence of a more stable preferred motor tempo that is formed over longer periods of time (i.e. months or years) and is less susceptible to short-term influences (see also Figure 1). In the remainder of this paper, we will refer to this tempo as the long-term preferred tempo (LTPT). We suggest that LTPT develops over time and that its influencing factors are individual characteristics that change rather slowly (e.g. growth during childhood or ageing in adulthood). To the best of our knowledge, no longitudinal studies have tried to differentiate between a short-term and long-term preferred motor tempo, although some studies have investigated the stability of musical tempo preferences (Auhagen, 1995; Lapidaki, 2000), which could be considered to be related. We propose that the LTPT creates a framework from which individuals derive their subjective tempo perception: when a given musical piece's tempo is above the LTPT, individuals perceive it as fast; if it is below, it is perceived as slow.

Figure 1

Visualization of Impact of SMT and LTPT on Music Tempo Perception



Note. SMT = Spontaneous Motor Tempo. LTPT = Long-Term Preferred Tempo.

Individual Development of LTPT

Lakoff and Johnson (1980) claimed that metaphors often underlie human understanding. These are grounded in human experiences, which include bodily experiences such as the perception of movement. Following this line of thought, the concept of musical tempo (or any beat-related concept of speed) could be initially understood by mapping it onto the concept of movement speed (Zbikowski, 2002). This is in line with theories of embodied music cognition (Leman et al., 2018). As music and movement co-occur, and evidence suggests entrainment effects in infants aged between 5–24 months (Zentner & Eerola, 2010), it is plausible that humans learn to associate movement with music from an early age.

The existence of the LTPT and its relation to body movement is in line with several neuroscientific models of beat detection. In recent years, three models in particular have been influential: filter models (e.g. Todd & Lee, 2015), oscillator-based models (e.g. Harding et al., 2025) and predictive-coding models (Denham & Winkler, 2020). Whether these should be viewed as competing or complementary models is an ongoing discussion (Snyder et al., 2024). However, the formation of an individual's LTPT is compatible with all of them as they all assume neural populations that have the capacity to learn and represent frequently occurring beat frequencies more strongly (e.g. through Hebbian learning). For example, Todd and Lee propose a model in which two distinct sensory-motor systems act: the so-called "beat 'finders'" in the auditory-parieto-cerebellar-premotor pathways (Todd & Lee, 2015, p. 13), which are responsible for analysing external sound signals to detect rhythmic information; and the "beat 'feelers'" or "beat keepers" system (Todd & Lee, 2015, p. 14), which invokes movement that is compatible to the rhythms detected in the audio signal ("auditory-striatal-cingulate-motor pathways", Todd & Lee, 2015, p. 13). Both systems are informed by the vestibular system, which is influenced by head and/or whole-body movement (or any other movement affecting the ear). As a result, individual movement tendencies resulting in the LTPT may be hardwired into the beat keepers system. This could be achieved through the hippocampus, acting as a memory space for rhythmic motion, and the basal ganglia (of which the striatum is a part) acting as a "repositorium for habitual rhythmic movements" (Todd & Lee, 2015, p. 12). Similar learning processes can be hypothesized in the case of oscillator-based models: so-called "attunement" could be dependent on individual exposure to certain "natural frequencies" (Harding et al., 2025, p. 299), of which LTPT may be one form. In predictive coding-models, learning is a central part of the system and therefore it is likely that individuals establish some form of LTPT when experiencing the tempi of their own body movement and comparing these to perceived musical tempi.

Influencing Factors of LTPT

In the following, we will substantiate predictors of LTPT. Due to the lack of research explicitly investigating LTPT, we partly relied on literature that investigates predictors of SMT. We consider this approach appropriate, as LTPT and SMT can be expected to be related to a certain degree, and, therefore, long-term predictors of SMT should also impact LTPT.

In a systematic review of factors influencing SMT, Desbernats et al. (2023) established age as a predictor, with few contradictory studies. Most results support the notion that SMT slows with increasing age from childhood to older adulthood (Hammerschmidt et al., 2021). The exact nature of its relation, however, is unclear. While a linear relationship is possible, McAuley et al.'s (2006) findings suggest a plateau in adulthood and a rather sharp decrease beyond the age of 75. In our study, we assumed a negative relationship between age and LTPT.

There seem to be no studies that explicitly investigate the effect of anthropomorphic measurements (e.g. body height and weight) on SMT. However, some studies have examined comparable dependent variables. For example, investigating frequencies of human locomotion, MacDougall and Moore (2005) found no significant relationship between body height, weight, or age; however, this may be due to a small effect size that could not be detected in a small sample ($N = 20$). While van Emmerik et al. (1989) found a negative relationship between individual body weight and preferred motor tempo in a ski-training exercise (i.e. higher weight led to slower tempo), the authors limited their claim to “well-trained” individuals (van Emmerik et al., 1989, p. 255). Additionally, Dahl et al. (2014) observed that preferred dance movement tempo is negatively correlated with body height and leg length. On the basis of these results, we assumed that greater body height or weight would be associated with slower LTPT.

We are unaware of the existence of any studies regarding the impact of dance expertise on SMT. Since dance skills widen the range of achievable (synchronized) body movement tempi (Nam et al., 2024; Uzunovic et al., 2010), we decided to also include dance expertise as a predictor. As this was an exploratory investigation, we did not hypothesize whether dance expertise positively or negatively impacts LTPT.

Desbernats et al. (2023) found that musical expertise is somewhat related to SMT. However, the nature of this relation remains unclear, and the definition of musical expertise differs between the reviewed studies. While musical sophistication can be achieved through many practices, not all of which are necessarily related to body movement, it can also be acquired partly through instrumental practice (Müllensiefen et al., 2014). Instrumental practice, in turn, is closely related to body movement. One possible issue is Müllensiefen et al.’s (2014) finding of a negative relationship between age and musical sophistication (i.e. older participants tended to score lower), resulting in a collinearity problem. We address this possibility in the results section. Similarly to dance expertise, we did not assume a direction for the relationship between musical expertise and LTPT.

Hypotheses

Based on the literature presented, we chose five predictors: body height and weight, age, musical and dance sophistication. We formulated our hypotheses according to the available evidence as follows:

$\mathbf{H_1}$ / $\mathbf{H_2}$ / $\mathbf{H_3}$ Taller/older/heavier persons perceive musical tempo as faster than shorter/younger/lighter persons.

$\mathbf{H_4}$ / $\mathbf{H_5}$ Persons with greater musical/dance expertise perceive musical tempo differently from persons with less musical/dance expertise.

Method

Measurements

Body height, weight, and age were self-reported. Musical sophistication was measured using the 18-item Goldsmiths Musical Sophistication Index (Gold-MSI, Müllensiefen et al., 2014), published in a validated German translation by Schaal et al. (2014). The 18-item version of the Gold-MSI is a shortened version that provides an index of general musical sophistication. It consists of several subfactors that describe individual engagement with and skill in music: Active Engagement (four items), Emotions (one item), Musical Training (five items), Perceptual Abilities (two items), and Singing Abilities (six items). The single-item scores, ranging from 1 to 7, are added up to form the general musical sophistication index. To measure dance sophistication, we applied the Goldsmiths Dance Sophistication Index (Gold-DSI, Rose et al., 2022), which was translated into German for the present study. The Gold-DSI consists of two inventories (participatory dance experience and observational dance experience), of which we applied only the former. This inventory incorporates four subfactors: Body Awareness (six items), Social Dancing (six items), Urge to Dance (five items), and Dance Training (three items). A list of all questionnaire items is retrievable online (see Statement on Data Availability).

Procedure

Our study was performed online, utilizing the platform *soscisurvey.de*. The link to the study was distributed in student courses, social networks and via mailing lists. Participants were instructed to use headphones and refrain from performing the experiments directly after listening to music or while situated in a moving vehicle.

All participants listened to 20 stimuli varying only in tempo (40–135 beats per minute (BPM), 5-BPM intervals) and evaluated the perceived tempo of each stimulus immediately after presentation on a scale from 1 to 5 (*very slow* to *very fast*). The presentation order of the stimuli was randomized for each participant. The stimuli differed only in tempo. The stimuli were constructed using a trial version of the commercial audio software *Ableton Live* 12.0.2, containing a four-chord progression in C major (I–V–IV–VI) on the piano (see Figure 2 for a visualization of the sheet music). One chord corresponded to one beat. After participants pressed the start button, the chord progression was repeated indefinitely until they pressed the pause button, allowing them to control the stimulus duration freely. To prevent the time signature of the media player creating a tempo framework, participants' control interface consisted only of the start and pause buttons. After evaluating all 20 stimuli, participants indicated their height (in cm), weight (in kg), age (in years), sex and gender. Subsequently, participants filled out the Gold-MSI and Gold-DSI.

Figure 2

Stimulus Chord Progression

Participants

The required sample size was computed by an a priori power analysis using the freeware *G*Power* 3.1.9.7 (Faul et al., 2009). We assumed a medium effect size based on Dahl et al. (2014), resulting in a required minimum sample size of 89 participants. A total of 127 participants completed the survey. Four participants were excluded from analysis due to unrealistically small body height (n = 3, indicating < 3 cm) and elevated body weight (n = 1, indicating 654 kg), resulting in N = 123 participants. 89 indicated female as their sex given at birth; 88 identified as female. 34 were assigned the male sex at birth; 35 identified as such. Accordingly, one participant considered himself trans male. Most sample descriptives were approximately normally distributed; however, age was positively skewed (see Figure 3). For other descriptives of the sample, see Table 1. Participants gave informed consent prior to the experiment and were debriefed regarding the study's research questions after completing the survey. Participant data was anonymized and could not be traced back to individual participants.

Figure 3

Histogram of Age Distribution in the Sample

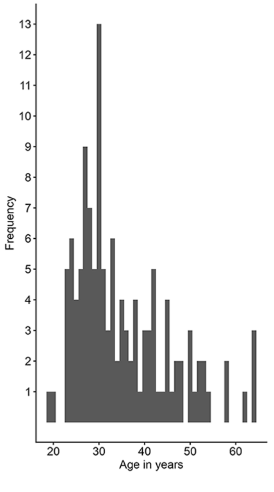


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Table 1

Sample Descriptives

		M	*SD*	Range
Body Height (cm)	All	171.3	10	150–195
	Female	167	7.1	150–187
	Male	182.5	7.2	165–195
Body Weight (kg)	All	73.9	14.3	50–117
	Female	69.9	12.7	50–115
	Male	84.3	13.2	61–117
Age (years)	All	35.1	10.3	19–64
Musical Sophistication (Gold-MSI)	General	68.2	22.7	20–123
	AE	14.3	5.4	5–28
	EM	4.4	1.6	1–7
	PA	9.3	3.3	2–14
	SA	23.7	8.4	6–42
	MT	16.4	7.9	5–35
Participatory Dance Experience (Gold-DSI)	General	4.3	1.1	1.4–6.7
	BA	4.9	1.2	1.7–7
	SD	4.7	1.6	1–7
	UD	4.5	1.3	1.2–7
	DT	2.3	1.4	1–6.3

Note. N = 123. Anthropomorphic measures are divided by sex rather than gender. Musical sophistication subfactors include Active Engagement (AE), Emotion (EM), Perceptual Abilities (PA), Singing Abilities (SA), and Musical Training (MT). Participatory Dance Expertise subfactors include Body Awareness (BA), Social Dancing (SD), Urge to Dance (UD), and Dance Training (DT).

Analysis

The analysis was performed using *R* (Version 4.5.0) in the RStudio environment (Posit Team, 2025) and the *lme4* package (Bates et al., 2015) for linear mixed models. We defined stimulus tempo (measured in beats per minute), body height, body weight, age, Gold-MSI, and Gold-DSI scores as fixed effects, and participant as a random intercept as each participant rated each stimulus, resulting in a repeated-measures design. All fixed effects are continuous. Sex was considered a fixed effect. However, due to its high point-biserial correlations with body height (Pearson's r_{pb} = 0.7, t(121) = 10.7, p < .001) and weight (Pearson's r_{pb} = 0.45, t(121) = 5.6, p < .001), we chose not to include it in the model, as current theoretical understanding does not support sex differences in musical tempo perception. For example, Dahl et al.'s (2014) results suggest that, in preferred dance tempo, sex differences appear to be caused by height differences. As an exploratory analysis, we also tested for interactions between stimulus tempo and the other fixed effects to assess whether their effects may occur only in certain tempo

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ranges. Due to large scaling differences, all predictor variables were z-normalized. We defined a significance level of alpha < .05. The outcome variable was perceived tempo on a 5-point scale, with higher values indicating higher perceived tempo.

To identify important predictors of tempo perception in our study, we included all proposed fixed effects and the random intercept in the model. Using the *buildmer* package (Voeten, 2025), we reduced the fixed-effects structure, applying backward elimination based on likelihood-ratio tests fitted with maximum likelihood rather than restricted maximum likelihood, as is suggested in statistical methodological literature (West et al., 2014, p. 35, 39). The final model was refitted using restricted maximum likelihood for inference. In the final model, we assessed multicollinearity between all main effects using correlations and variance inflation factors (VIFs), with VIFs calculated using the *performance* package (Lüdecke et al., 2021).

Results

The backward elimination removed weight as a fixed effect but retained all other predictors. While all predictors interact significantly with stimulus tempo, only body height and age are significant as main effects. See Table 2 for beta estimates, standard errors, and p-values.

Table 2

Predictors of Perceived Stimulus Tempo in a Linear Mixed Model (z-Standardized Values)

	β	*SE*	*p*	VIF
Stimulus tempo	**0.8**	**0.01**	**< .001**	1
Height	**0.07**	**0.03**	**.038**	1.03
Age	**-0.07**	**0.03**	**.037**	1.02
Gold-MSI	0.03	0.03	.305	1.08
Gold-DSI	0.01	0.03	.758	1.08
Stimulus tempo * Height	**0.03**	**0.01**	**.001**	
Stimulus tempo * Age	**-0.04**	**0.01**	**< .001**	
Stimulus tempo * Gold-MSI	**-0.06**	**0.01**	**< .001**	
Stimulus tempo * Gold-DSI	**0.04**	**0.01**	**< .001**	

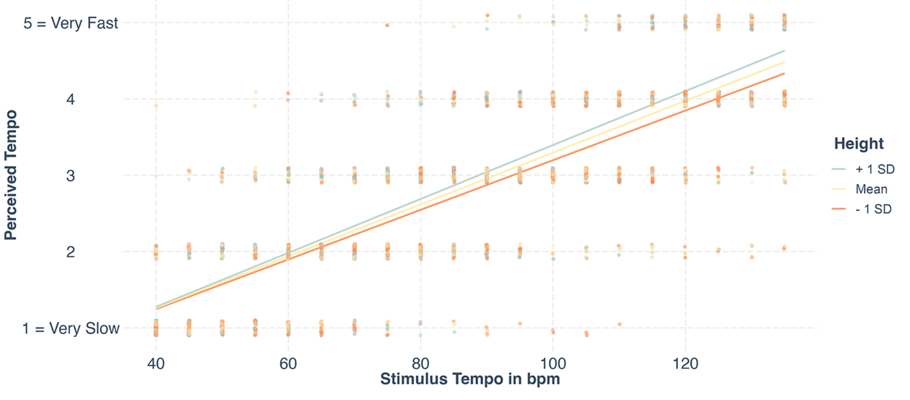
Note. N = 123. Significant values (p < .05) printed in bold.

When significant interaction effects are detected in regression models, previous literature suggests focusing on the interaction effects, as they may alter the coefficients of main effects (Dalal & Zickar, 2012). Therefore, in the following we will focus on describing interaction effects.

As can be seen in Figure 4a, the slope for taller participants is steeper than that for shorter participants, resulting in different tempo perceptions, mainly in faster tempo ranges. In Figure 4b, the slope for younger participants is steeper than that for older participants, indicating a tendency of younger participants to perceive music as faster in faster tempo ranges. Figure 4c indicates that the slope for musically sophisticated participants is more horizontal than that for participants with less musical sophistication, suggesting differences in perceived tempo at both higher and lower tempo ranges. As can be seen in Figure 4d, the slope for participants with higher dance sophistication is steeper than that for participants with lower dance sophistication, again resulting in differences at the higher and lower tempo ranges.

Figure 4a

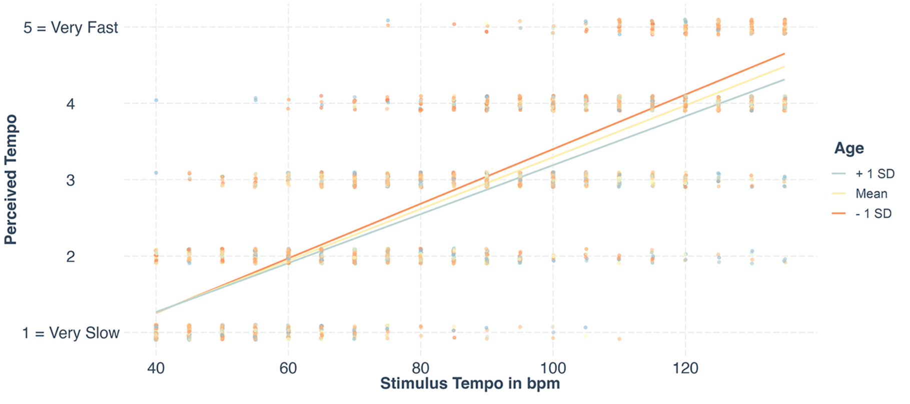
Scatterplots of the Effects of Height Interacting With Stimulus Tempo on Perceived Tempo



Note. Values are unstandardized to allow for more intuitive understanding. For visualization purposes, regression lines are distinguished by 1 Standard Deviation above and below the sample mean.

Figure 4b

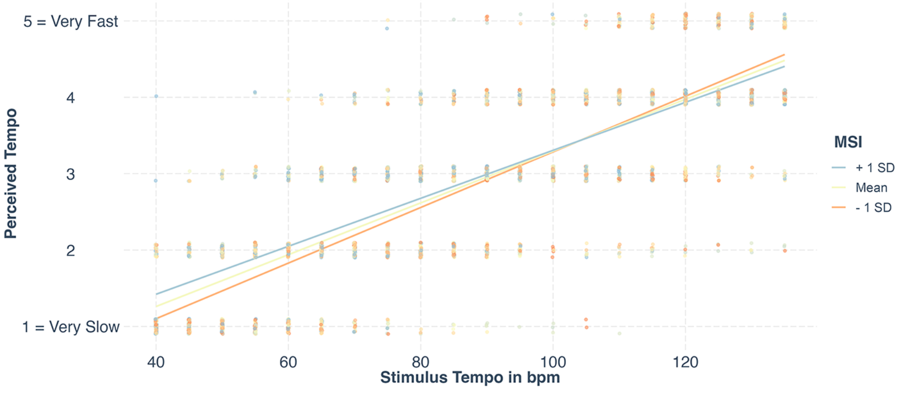
Scatterplots of the Effects of Age Interacting With Stimulus Tempo on Perceived Tempo



Note. Values are unstandardized to allow for more intuitive understanding. For visualization purposes, regression lines are distinguished by 1 Standard Deviation above and below the sample mean.

Figure 4c

Scatterplots of the Effects of Musical Sophistication Interacting With Stimulus Tempo on Perceived Tempo



Note. Values are unstandardized to allow for more intuitive understanding. For visualization purposes, regression lines are distinguished by 1 Standard Deviation above and below the sample mean. MSI = Musical Sophistication Index.

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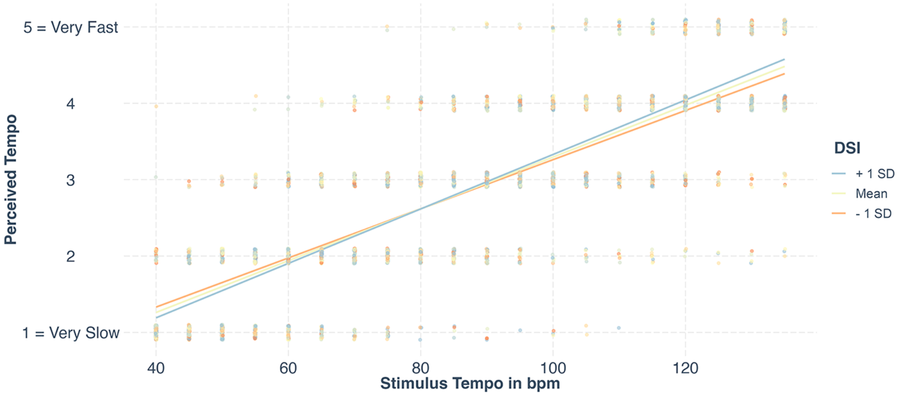
Figure 4d

Scatterplots of the Effects of Dance Sophistication Interacting With Stimulus Tempo on Perceived Tempo



Note. Values are unstandardized to allow for more intuitive understanding. For visualization purposes, regression lines are distinguished by 1 Standard Deviation above and below the sample mean. DSI = Dance Sophistication Index.

Regarding multicollinearity, according to the thresholds suggested by Field (2018, p. 402), none of the fixed effects were strongly correlated (maximum r = -.26 of Gold-DSI and Gold-MSI). VIFs of fixed effects did not indicate collinearity (see Table 2). As the literature suggests that VIFs of interactions can be ignored (Kalnins & Praitis Hill, 2025), we did not examine VIFs for interaction terms.

Discussion

We present evidence that body height, age, and musical and dance sophistication influence individual perceptions of musical tempo. We propose that this is due to an individual tendency to perform repetitive movements at a certain tempo, which is formed over longer periods of time. We call this intrinsic tendency long-term preferred tempo (LTPT) and hypothesize several factors that may influence LTPT. Of these predictors (body height and weight, age, musical and dance sophistication), four significantly interact with stimulus tempo, influencing subjective perceptions of musical tempo. In our sample, body weight (H_3) does not have a significant impact on tempo perception. This could be due to measurement errors in self-reported weight data as participants tend to underestimate their weight in online studies (Taylor et al., 2006). Nevertheless, this is an unexpected finding as body weight and height are positively correlated in our sample (Pearson's $r = 0.53$, $t(121) = 6.9$, $p < .001$), causing us to expect both anthropometric measurements to have a similar impact on LTPT. Another possible explanation is that higher body weight may reflect more muscle mass, which could have a different impact on LTPT.

Regarding H_1, our data suggests that taller participants tend to perceive music as faster than shorter participants, indicating that greater body height reduces LTPT. This effect, however, appears only in higher tempo ranges.

In contrast to H_2, older participants tend to perceive music as slower in higher tempo ranges compared to younger participants. This could be caused by the relatively young sample, with a majority of participants between age 20 and 30 and an age range of 19 to 69. Consequently, no participant was aged 75 or above, an age at which SMT (and therefore, possibly LTPT) decreases much more substantially (McAuley et al., 2006, p. 355). Still, this explanation is unsatisfactory, as age should not be a significant predictor in this case. Future studies may be able to address this problem.

Regarding musical sophistication (H_4), tempo perception only diverges between musically sophisticated and less musically sophisticated persons at the higher and lower ends of the applied musical tempo scale. Results indicate that musically sophisticated participants tend to perceive music as faster or slower only at more extreme tempi compared to less musically sophisticated participants. This could be explained by more regular exposure to these musical tempi, for example during music practice (assuming that practice commonly occurs at slow tempi when beginning to learn a piece of music and at fast tempi shortly before an exam or recital). This exposure may widen the reference framework of LTPT and therefore influence the individual perception of musical tempo. Thus, further research should investigate whether musical sophistication influences LTPT through the practice of a musical instrument or whether this is a phenomenon independent of LTPT. As specified in the introduction, we view LTPT as predominantly influenced by the motor system, an assumption that can itself be discussed. Musical sophistication may influence tempo perception through acoustical exposure to less common musical tempi; therefore the effect may be independent of motor activity. If it is caused by motor activity through instrumental practice, it could be expected that the Musical Training subfactor should then be a better predictor for perceived musical tempo. We could not reliably test this explanation, as all the other subfactors of the Gold-MSI correlated strongly with Musical Training in our sample, resulting in confounding between the variables.

Dance sophistication (H_5) seems to have the opposite effect, indicating that individuals with more participatory dance experience perceive music as faster or slower compared to individuals with less participatory dance experience. A possible explanation could be that the former tend to rely more heavily on their own body perceptions to perceive their environment and are more accustomed to appraising musical tempo using their own body. As music intended for dancing is usually situated in a tempo range between 81 and 162 BPM (Moelants, 2002, p. 582), individuals with more participatory dance experience may use a similar range as a reference when appraising musical tempo.

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Interestingly, across all significant effects, the analysis indicates that they take place only in higher and lower musical tempo ranges.

There are limitations to our study. As previously mentioned, the age range of the sample was between 19 and 69. As such, our oldest participants may not have reached an age at which motor tempo decreases, which lies around age 75 according to McAuley et al. (2006). Additionally, due to the decision to limit the number of stimuli to twenty, stimulus tempi did not exceed 135 BPM. The number of stimuli was limited to prevent participants from not completing the study due to boredom and to avoid the effects of decreased task attention. We decided to place the stimulus tempo range at the lower end of usual tempi somewhat arbitrarily. Future studies could investigate whether the direction and magnitude of these effects remain similar at higher tempo ranges or could use more sophisticated stimulus selection methods (e.g. Senn et al., 2023).

Furthermore, we could not control for movement in our participants due to the online setting. However, previous studies have demonstrated that the supplementary motor area can be activated without overt movement when participants are asked to concentrate on the rhythmic properties of music (Gordon et al., 2018; Kasdan et al., 2022). This could indicate that, for the LTPT to have an impact on musical tempo perception, concurrent movement may not be necessary. Additionally, we assume that any movement should be randomly distributed across participants; if not, it would have reduced the effect sizes of our fixed effects. Moreover, in an online study, it seems unlikely that participants moved substantially. Still, future studies should control for the absence of movement. Another confounding factor could be the perceptual grouping of beats which could have influenced the perceived tempo, as has been demonstrated in musicians (Duke et al., 1991). As such, musicians may have grouped faster beats in a hierarchical fashion, resulting in a slower perceived tempo, and divided slower beats into smaller units, resulting in a faster perceived tempo. Further, the perceived pulse could be evaluated in future studies.

Conclusion

In an online quasi-experimental study, we found evidence for effects of body height, age, musical and dance sophistication on subjective perceptions of musical tempo. We assume that these effects are caused by a proposed long-term preferred tempo, which is influenced by our predictors.

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Ethics Statement: The study was carried out in accordance with relevant institutional and national guidelines and regulations (Föderation deutscher Psychologenvereinigungen, 2022) and with the principles outlined in the Declaration of Helsinki. Formal approval of the study by the ethics committee of the University of Cologne was not mandatory, as the study adhered to all required regulations. All participants provided informed consent and were assured of their right to withdraw from the study at any time without incurring any negative consequences.

Data Availability: The research data (including stimuli and questionnaire items, raw and processed data, and code used for statistical analyses) for this article is available on the GitHub/Zenodo Repository (see Matsukawa & Egermann, 2026).

Supplementary Materials

The research data (including stimuli and questionnaire items, raw and processed data, and code used for statistical analyses) for this article is available on the GitHub/Zenodo Repository (see Matsukawa & Egermann, 2026).

Index of Supplementary Materials

Matsukawa, L., & Egermann, H. (2026). *lmatsuk/tempoPerception: Version after completed peer-review* [Data, study materials, code]. Zenodo. https://doi.org/10.5281/zenodo.22093565

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