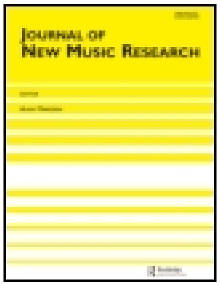

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Abstract

In two experiments participants tuned a drum machine to their preferred dance tempo. Measurements of height, shoulder width, leg length, and weight were taken for each participant, and their sex recorded. Using a multiple regression analysis, height and leg length combined was found to be the best predictors of preferred dance tempo in Experiment 1. A second experiment, where males and females were matched in terms of height, resulted in no significant correlation between sex and preferred dance tempo. In the matched sample, height was found to be the single best predictor but with a relatively small effect size. These results are consistent with a biomechanical 'resonance' model of dancing.

Keywords: timing, perception, social aspects, audience, body morphology, dance tempo

1. Introduction

Movement to music is widespread and comes in many different forms ranging from foot tapping and head nodding to full body dance movements. The types of movements used when moving to music, and the type of musical rhythms that induces dance related movement has recently gained some interest (e.g. Burger, Thompson, Saarikallio, Luck, & Toiviainen, 2013; Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010; Naveda & Leman, 2009; Toiviainen, Luck, & Thompson, 2010). These recent studies have recorded dancers using video or motion capture and described the types of movements performed to various types of music. Our question stems from a slightly different angle, namely whether the preferred tempo when dancing is related to body morphology or sex.

In previously unpublished work, Huron and several of his students observed the dance behaviours of males and females at a popular university discotheque. A one-hour music programme was presented in which successive dance tunes were randomly varied in tempo. While female dancers always outnumbered male dancers, there was a significant association between sex ratio and tempo: a greater proportion of males was evident for those selections exhibiting a slower tempo.

Such apparent preferences may be stylistic in origin. For example, women appear to have a greater stylistic affinity for 'dance' or 'disco' rhythms, whereas a greater proportion of men appear to have a stylistic preference for 'rock' or 'reggae' rhythms.

While an association between sex and style would seem to provide the most parsimonious account for the observed link, other interpretations are also possible. In general, males are larger than females. From a biomechanical perspective, the act of dancing can be regarded as a stylized form of 'bouncing', where optimum bouncing rates would depend primarily on kinematic factors, such as the mass of the body or the elasticity of the Achilles tendon. It may be the case that the observed sex-related differences in preferred dance tempos are an artifact of differences in body morphology between men and women.

The production of repeated events, such as steps or taps, is dependent on motor control limitations. Keeping a steady rate is difficult both for very slow or very fast tempi. There is also a perceptual limit to how close or separated in time events can be. Specifically in the context of music, notes tend to be regarded as fused when they are separated by less than 100 ms, and as isolated events if the separation is more than 2 s (for comprehensive reviews, see e.g. Clarke 1999; Repp 2006). Between these extremes, however, there ought to be a tempo for which performance is optimal. The concept of such

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a *preferred tempo* has been the focus for a number of studies on tempo perception and production (see e.g. Collyer, Broadbent, & Church, 1994; Fraisse, 1982; McAuley, Jones, Holub, Johnston, & Miller, 2006; Moelants, 2002; Van Noorden & Moelants, 1999).

Several studies have shown a tendency for participants to spontaneously aim for a particular tempo. This preferred tempo is different between individuals, but Fraisse (1982) found that it typically lies in the range 100–133 *beats per minute* (bpm). More recently, McAuley et al. (2006) have shown the preference to change during the life span, with young children inclined towards faster and elderly towards slower tempi than the population average.

The range of preferred tempi, approximately centred around 120 bpm, corresponds well to the distribution of tempi in music. Moelants (2002) combined data from a large database of 'bpm-lists' (used by DJs) with experimentally collected data where participants tapped to excerpts of Western music. The resulting distributions were primarily concentrated in the region of 115 to 127 bpm, with a pronounced peak at 125 bpm (or 480 ms period). Relating perceived tempo to movement patterns, Moelants modelled the distribution of musical tempi using a physical resonance model (see also Van Noorden & Moelants, 1999).

The possible link between body movement and rhythm-related behaviours has figured prominently in the work of Todd (1992, 1995, 1999, 2000). In the first instance, Todd has noted that the vestibular system is shared with the sense of hearing within a single anatomical organ, which includes both the cochlea and the semi-circular canals. Todd has proposed a physiologically-based model that attempts to account for the often observed parallel between musical 'motion' and corporeal motion.

In a series of experiments Phillips-Silver and Trainor (2005, 2007, 2008) have demonstrated that body movement shapes our perception of rhythmic patterns. They used a paradigm where participants were asked to 'bounce' to ambiguous rhythms. That is, following the example of the experimenter, they bent their knees and then extended their legs, moving either on every second or third beat. In a forced choice listening task, participants who had bounced every second beat predominantly chose a duple in preference to a triple version of the rhythm as the one played before. Participants having moved every third beat instead indicated the triple meter as the one in the bouncing task. Merely watching someone else bouncing showed no effect on perceived rhythmic grouping. Thus, the influence of the bouncing on rhythmic perception appears to depend on vestibular activation.

Evidence in support of an association between rhythm and locomotion has appeared in previous research (see e.g. Friberg & Sundberg, 1999; MacDougall & Moore, 2005; Styns, Van Noorden, Moelants, & Leman, 2007). In their study of ritardandi, Friberg and Sundberg (1999) found that the final slowing in recorded music closely corresponds to the application of a constant breaking power similarly to the manner in which runners stop.

MacDougall and Moore (2005) had participants wear an accelerometer that continuously monitored head movements in three dimensions over the course of a day. In analysing the recorded data, MacDougall and Moore found a marked peak at about 2 Hz (corresponding to 120 bpm or 500 ms period) for vertical movements. Plotting their aggregate results against the histogram of tempi from Moelants (2002), MacDougall and Moore showed a clear similarity to the tempo distribution, also displaying a dominant peak at 2 Hz. The peak at 2 Hz was, however, also present for activities where locomotion was not especially involved.

Inspired by the findings of MacDougall and Moore, Styns et al. (2007) asked participants to synchronize to music excerpts by walking and by tapping for a wide range of tempi. For the walking condition, the participants were most successful in synchronizing to tempi in the range 106–130 bpm. When tapping to the music excerpts, 80.7% of the participants chose the same rate as when walking. A multiple regression model using walking tempo (linear and squared) in combination with leg length was able to explain 33% of the variation in walking step size. That is, the speed of walking (e.g. how long steps that were taken) was predicted both by the tempo and the leg length of participants.

In research by Todd, Cousins and Lee (2007), a significant correlation was found between tempo classification of different auditory rhythms and anthropometric measures. The results showed significant main effects for age, mass, height, leg length, and biacromial breadth (that is, shoulder width). However, the effect sizes for the anthropometric factors were small. No significant differences in preferred tempo between males and females were found.

Whereas much of the earlier work cited above suggest a relationship between body and perception or synchronization (e.g. Moelants, 2002; Phillips-Silver & Trainor, 2008; Styns et al., 2007; Todd et al., 2007) the current work investigates whether there might be a relationship between body and preferred dance tempo and/or whether such a relationship is connected to sex differences (as suggested in the study by Huron and colleagues mentioned at the start). By specifically focusing on dance, as opposed to finger tapping or locomotion, we study an activity which is normally performed in synchronization to a musical pulse and which involves large body movements. In light of the extant research, and assuming dance to be a more energy consuming activity than locomotion, it is not implausible that preferred dance tempos might relate to anthropometric factors like body mass or height.

In order to investigate the hypothesis that preferred dance tempo is related to anthropometric factors, we carried out two simple experiments. In brief, participants were asked to adjust the tempo of a 'drum machine' while dancing to their preferred dance tempo. We subsequently took morphological measures of each participant.

We predict that mass and height will be positively correlated with preferred beat period (calculated as $T = 60/\text{bpm}$). That is, we predict that larger body size (in height, weight, or width) will be associated with slower preferred dance movement.

Furthermore, we predict that any correlation between sex and preferred beat period will be explained by the variation in body size between sexes.

2. Experiment 1

The first experiment took place in Columbus, Ohio and an earlier report of the data was given in Dahl and Huron (2007).

2.1 Method

2.1.1 Subjects

Thirty subjects were recruited for the experiment, 18 females and 12 males. The participants were drawn from a convenient population of sophomore music students participating in an experimental subject pool at the Ohio State University. Subjects chose to participate in this experiment from a list of current studies. The soliciting materials included information indicating that participants would be asked to dance unobserved in a room by themselves and that physical measurements, including height and weight, would be recorded. As self-selected participants, it should be noted that significant sampling bias cannot be excluded. In particular, students who enjoy dancing are more likely to have participated, whereas students embarrassed by their weight or body features are less likely to have participated. Voluntary subject recruitment is apt to reduce the variation in body types, and therefore reduce the potential statistical power.

2.1.2 Procedure

Participants were tested individually in an isolated room. A computer display included a vertical slider that influenced the tempo of a Max MSP software patch. The patch implemented a drum-machine playing an alternating bass-drum/snare-drum rhythm (i.e. 'standard back-beat'). The sound stimuli were reproduced over two loudspeakers. The tempo slider could be controlled using a computer mouse. The range of possible tempos spanned 40–239 bpm, corresponding to beat periods ranging between 1.5 s and 251 ms. After receiving the instructions (see below) participants were left in the room alone to try out different tempi.

The instructions read to the participants were as follows:

> 'In this experiment we want to get an idea of your preferred dance tempo. That is, we want to find out at which speed you are most comfortable when dancing. When the time comes, I will leave you alone in this room, you'll be able to dance around without anyone seeing or hearing you. This is a drum machine which plays a standard back-beat rhythm. You turn it on by pressing the space bar [demonstrates]. You can adjust the volume here [demonstrates volume control]. You can adjust the tempo by moving this slider [demonstrates slider]. You stop it by pressing the space bar again [demonstrates]. We want you to try out different tempos until you find a tempo that you feel is most natural for the way you dance. That is, find a slider position that corresponds to the movement you find most comfortable. You may feel that there is more than one tempo that you like; if so, simply choose the tempo that you think is the best. Don't be afraid to take your time. When you have settled on the best tempo, don't move the slider; simply leave the room and come and get me.'

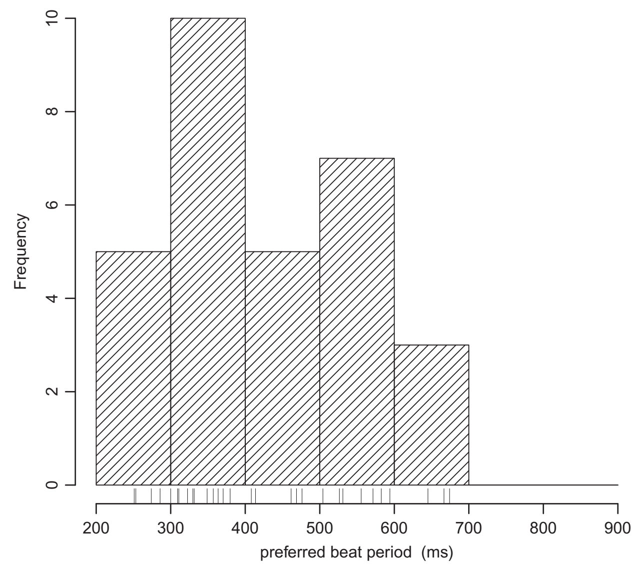

Fig. 1. Distribution of preferred beat periods (in ms) for the 30 participants in Experiment 1. The individual data points can be seen under the 100-ms bins.

After demonstrating the drum-machine patch, the tempo slider was left in an initial pseudo-random position in the area roughly between 25 and 75 percent of the maximum tempo value. The drum-machine was turned on as the experimenter left the room.

After the participant was satisfied with the selection of the tempo, the experimenter returned to record the tempo in beats per minute. Four anthropometric measurements were then taken: height, shoulder width, leg length, and weight. For the length and shoulder-width measures, the participant stood against a wall that had been marked with a measurement grid. By placing a ruler on the participant's head the experimenter read the height off of the wall grid. Similarly, the width of the shoulders was determined by the experimenter placing a ruler against the participant's shoulders and observing the corresponding left and right shoulder points along the horizontal wall grid.

The leg length was estimated by asking the participant to point to the lower part of the hip bone protuberance (anterior inferior iliac spine) on their left and right sides. After locating these points, the experimenter measured the length between the hip bone and the ankle (malleolus lateralis) using the wall grid behind the participant. The average between the measures of the left and right leg was taken as an estimate of the participant's leg length.

Finally, the participant stood on a domestic electronic scale and their weight was taken.

Table 1. Correlation matrix for the recorded variables in Experiment 1. Significant correlations (2-tailed) are marked with ** ($p < 0.01$) and * ($p < 0.05$). Point biserial correlations between the dichotomous variable sex and the continuous variables is interpreted as in the following example: as the sex variable increases from male (0) to female (1), there is a 0.6 decrease in preferred beat period.

	Period	Sex	Height	Shoulders	Leg	Weight
Period	1.00					
Sex	−0.60**	1.00				
Height	0.64**	−0.84**	1.00			
Shoulders	0.16	−0.32**	0.28	1.00		
Legs	0.66**	−0.65**	0.80**	0.11	1.00	
Weight	0.36*	−0.68**	0.65**	0.44*	0.42*	1.00

2.2 Results

Figure 1 shows the distribution of preferred beat periods selected by the 30 participants. The distribution is presented in bins of 100 ms. The mean tempo was 429 ms with a standard deviation of 129 ms. The response data does not appear to be fully normally distributed but is positively skewed with one third of selected beat periods falling between 300–400 ms. The selected tempi ranged between 89–239 beats per minute, corresponding to preferred beat periods of between 251 and 674 ms. This fairly large range might suggest that some participants were (‘doubling’ or (‘halving’) the tempo from the drum machine for a given dance gait. Unfortunately, we were not able to monitor or record the dance activity so this conjecture cannot be confirmed.

One might argue that the tempo range of the slider should have been narrowed so as to minimize inadvertent doubling or halving of the tempo. However, this presumes that forcing participants to respond using a more narrow distribution would represent the ‘true’ distribution, and there seemed little *a priori* logic to warrant this assumption. Acknowledging the messiness of our data, we nevertheless continued with our planned analysis (using IBM SPSS).

Table 1 shows a simple correlation matrix including both the dependent measure and the independent measures. The best predictor of beat period is average leg length ($r = 0.66$; $r^2 = 0.43$, bootstrapped confidence levels 0.39 and 0.86). The second and third best predictors of beat period are height ($r = 0.64$; $r^2 = 0.41$, bootstrapped confidence levels 0.35 and 0.85) and sex ($r_{pb} = -0.60$; $r^2 = 0.36$, bootstrapped confidence levels −0.79 and −0.32). In the case of sex, females preferred a faster dance tempo (lower beat period).

As seen in Table 1, some of the measured variables are fairly correlated. In particular, sex and height ($r_{pb} = -0.84$; $r_{pb}^2 = 0.71$, bootstrapped confidence levels −0.90 and −0.78) and height and leg length share a large portion of the variance ($r = 0.80$; $r^2 = 0.63$, bootstrapped confidence levels 0.66 and 0.90). In order to reduce possible problems with collinearity among variables and reduce the number of independent predictors, height and leg length was combined into a composite, standardized variable ‘Stature’. The new variable, calculated as the average of the z-scores for height and average leg length, is still highly negatively correlated with sex ($r_{pb} = -0.79$, $p < 0.001$, two tailed, bootstrapped confidence levels −0.88 and −0.67), which calls for cautious interpretation of the model. Figure 2 shows the preferred beat period versus stature (unfilled circles) and sex (grey plus signs).

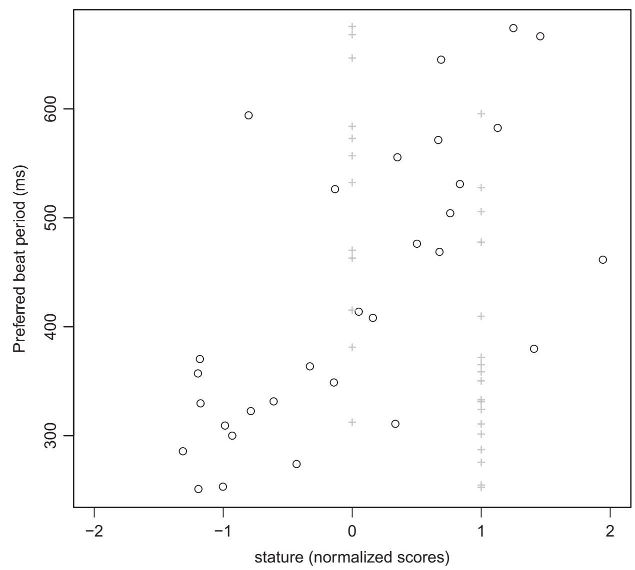

Fig. 2. Preferred beat period in ms versus stature: average standardized height and leg length (unfilled circles) and sex (grey +). The plot shows that a tall height and long average leg length is associated with a slow tempo. The overlapping relationship with sex (aligned vertically according to their coding as 0 = male and 1 = female) can also be seen.

Table 2. Linear model of predictors for preferred beat period (95% confidence intervals are reported in parenthesis.)

		b	SE *B*	*β*	*p*
Step 1					
	Constant	428.90) (393.06, 464.75)	17.50		$p = 0.000$
	Stature	93.71 (55.25, 132.18)	18.78	0.686	$p = 0.000$

$R^2 = 0.47$, adjusted $R^2 = 0.45$ for step 1.

A hierarchical regression was carried out to predict preferred beat period. The consideration of predictors to enter the regression model was made based on our hypothesis, results from previous research, and the data. In the results from the listening test by Todd et al. (2007), weight was an important factor for preferred beat period in absolute figures whereas body spatial dimensions would be more influential when considering effect size in relative terms. We are more interested in the relative influence and select the composite variable stature as our first predictor. In our data, shoulder width shows relatively low and insignificant correlation with preferred beat period, whereas the measurements of weight proved to violate the assumption of homoscedasticity. Therefore, weight was dropped as a predictor and shoulder width and sex was entered into the model in a second step. Thus, a hierarchical (sequential) regression was performed first entering stature, followed by shoulder width and sex in a second step (the latter two entered stepwise, $p_{\text{in}} = 0.05$, $p_{\text{out}} = 0.10$).

The results of the regression analysis can be seen in Table 2. As can be seen in the table, the only predictor to enter the model was stature (including height and average leg length). Neither sex nor shoulder width contributed significantly to determining the variance of the predicted variable, preferred beat period.

Figure 2 plots the significant relationship between preferred beat period and stature. As can be seen, there appears to be a positive correlation, with taller height and longer leg length associated with lower preferred beat period ($r_{\text{pb}} = 0.69$, $p < 0.001$, two tailed, bootstrapped confidence intervals 445 and 863). Note however, the relationship also with sex in the figure (indicated by plus signs), where the males in general are taller with longer legs and also, in general, chose longer beat periods (slower tempi).

2.3 Discussion

The results indicate that body morphology may be related to preferred dance tempo. However, the possible influence of sex cannot be excluded. Table 1 shows that there was an association between sex and preferred dance tempo, which is also seen in Figure 2. Nevertheless, the shared variance with stature resulted in sex being eliminated in the multiple-regression analysis. A larger sample of participants might yet reveal that sex has some impact on preferred dance tempo.

Since women generally have a lower centre-of-gravity than men, in some ways it would be surprising not to find some sex-related difference in dance movements. Note however, that such a difference might still implicate body morphology rather than social or psychological sex-related differences. In order to further investigate this, a second experiment was done.

3. Experiment 2

The second experiment was carried out at Hanover University of Music, Drama and Media in Germany and had two objectives: (1) to further investigate if sex had an impact, and (2) to see whether the found association between Stature and preferred dance tempo in Experiment 1 could be replicated. Furthermore, we chose to explore whether a measure of heart rate could help to indicate how actively participants were dancing.

In order to explore the possible influence of sex, the recruitment of participants was altered in order to control for some known differences between males and females. Specifically, we attempted to control for the fact that females in general are shorter and lighter than males by matching male and female participants in terms of height.

3.1 Method

3.1.1 Subjects

Forty-seven subjects were recruited for the experiment, 23 females and 24 males. The experiment was advertised in several University buildings in Hanover with information on how volunteers wanting to participate could contact the experimenters and book a time. The advertisement indicated that *women taller* than 170 cm and *men shorter* than 175 cm were particularly welcome as participants. A monetary inducement was offered to encourage participation. The experimenters also visited the cafeteria area, approaching persons fulfilling these requirements, asking if they would be interested in participating. As it proved harder to recruit male volunteers, the experiment was also advertised further outside the university.

The soliciting materials included information indicating that participants would be asked to dance unobserved in a room by themselves and that physical measurements, including height and weight, would be recorded. As in Experiment 1, sampling bias cannot be excluded as people who enjoy dancing would be more likely to have participated. Compared to Experiment 1, there was a larger spread in age (19 to 40 years), and therefore age was included in the initial analysis.

3.1.2 Procedure

The procedure and instructions were virtually identical to those used in Experiment 1. A software patch in pure data (Puckette, 1996) played a standard back-beat rhythm. The tempo could be controlled with a slider (using a computer mouse) and varied between 50–300 beats per minute (corresponding to beat periods between 200 and 1200 ms). To avoid the possible problem of subdividing or doubling the tempo, participants were asked to think in terms of one movement per beat.

No shoulder width was recorded, as the correlation between shoulder width and dance tempo in Experiment 1 was relatively poor. However, we chose to keep weight measures. In addition to the anthropometric measures the heart rate before and after dancing was taken as a way to monitor the ‘dance effort’ during the experiment. The heart rate was measured using a commercial system for pulse measurement during exercise (Sigma Sport pulse computer PC3). After obtaining informed consent, the participant was equipped with a girdle and a watch displaying the current heart rate.

After reading the instructions and demonstrating the patch, the experimenter recorded the current heart rate from the pulse computer and then left the participant alone to dance in a private room. Once the participant had established their preferred tempo, the experimenter was notified and immediately recorded the post-dancing heart rate. Following a brief set of questions, the body height, leg length and weight were recorded. For this experiment, an anthropometer, a gauge for measurement of body height, was used. For height measures, the participant stood on the bottom plate of the gauge and the height in centimeters was determined. The leg length was estimated by asking the participant to point to the lower part of the hip bone protuberance (anterior inferior iliac spine) on their left and right sides. For each leg the participant adjusted the gauge to the appropriate position and the experimenter read the height. Then the height of the ankle bone (malleolus lateralis) was deducted from the measured hip height and the average between the measures of the left and right leg was taken as an estimate of the participant's leg length. Next, the participant stood on a domestic electronic scale and their weight was taken. Finally, a third reading of the heart rate was done before the girdle was removed.

The measurement error was estimated by the experimenter taking all measurements 10 times for one person. For the height, and average leg length the error was estimated to ±0.6 cm, and ±1.6 cm respectively.

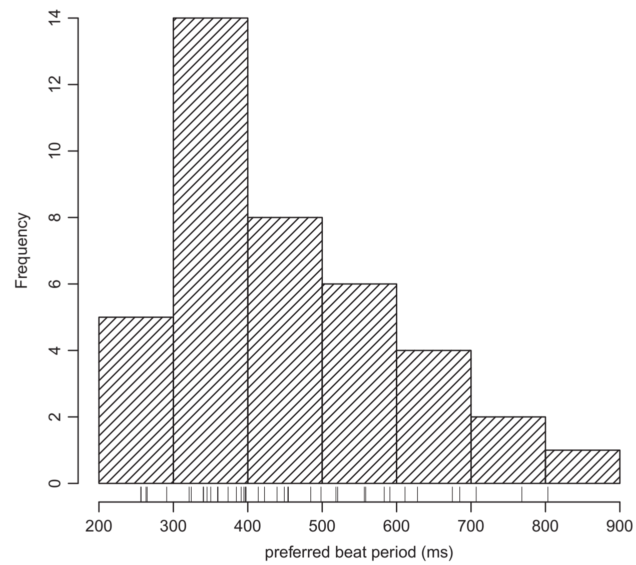

Fig. 3. Distribution of preferred beat periods for the 40 participants in Experiment 2. The individual data points are sorted in 100 ms bins and can be seen below the x-axis.

3.1.3 Initial analysis

Heart rate: In order to investigate possible correlations between heart rate and preferred dance tempo, two heart rate measures were used. A *baseline* for each participant was calculated as the average between the first and the third (last) reading. The *shift* in heart rate was calculated as the difference between the heart rate immediately after dancing and the baseline. The reasons for taking these measures were twofold (1) to determine whether the difference between the baseline heart rate and post-dancing heart rate would correlate with preferred dace tempo; and (2) to investigate possible relationships between participants' baseline heart rate and the preferred tempo.

For three participants, it was not possible to get three readings of heart rate because of poor contact between the girdle and the ribcage. Thus, three values for baseline and shift had to be discarded in the analysis.

No significant correlations were found, either between baseline heart rate and preferred beat period ($r = 0.255$, $p = 0.118$ two tailed, bootstrapped confidence interval −0.008, 507) or pulse shift and preferred beat period ($r = -0.271$, $p = 0.105$ two tailed, bootstrapped confidence interval −0.482, −0.017). The participants were unobserved while dancing and although the reading was done as soon as the experimenter was recalled, the heart rate might have settled some before the reading.

Height matching: After conducting the experiment, the frequency distribution of the heights of males and females were investigated. The height distribution of heights for females proved to be positively skewed compared to the distribution for male heights (skewness 0.0646 for female group and 0.026 for male) and therefore a matching of the distributions for the two groups was done. The matching was made by randomly removing participants from the height range overrepresented for each group. No consideration of other measures was made. From the females, three randomly selected females in the range 167.5–170 cm were removed, and from the male group four random participants with heights between 180–185 cm were removed. This resulted in a sample of 20 males (mean age 26.1 years, SD 6.2) and 20 females (mean age 25.2 years, SD 4.3) with mean heights of 176.6 (SD 4.8) and 176.3 (SD 5.1) centimetres for the two groups respectively.

3.2 Results

The objective in the second experiment was to investigate if the found association between stature (height and leg length) and preferred dance tempo in Experiment 1 was reproducible, and to see if balanced female and male participant groups in terms of the body height would eliminate the correlation between sex and preferred dance tempo.

By advertising for men shorter than, and women taller than the German national average (167 and 175 cm for females and males respectively) we aimed at minimizing correlations between height and sex. A two tailed t-test showing nonsignificant differences in height for male and female participants ($t(38) = 0.177$, $p = 0.86$) indicated that the groups were appropriately matched in this respect.

However, our recruiting approach also resulted in a slightly reduced variability for the measures height, average leg length, and weight as compared to Experiment 1. Table 3 shows the maximum, minimum, mean, and standard deviations for the measures taken in Experiments 1 and 2. As can be seen, the span between maximum and minimum values found for height, leg length, and weight is slightly wider for the measures in Experiment 1. Aware that this reduced range in height is likely to lessen any effect size, we nevertheless proceeded with the analysis.

Figure 3 shows the distribution of selected beat periods for the 40 participants in Experiment 2. In comparison with the distribution in Experiment 1, the mean selected beat period is marginally lower, 415 ms (corresponding to 132 bpm) with a standard deviation of 415 ms. This beat period still corresponds to a slightly higher tempo than would be expected from previous studies (e.g. MacDougall & Moore, 2005). Like

Table 3. Comparison between the anthropometric measures from Experiment 1 (30 participants in Columbus, Ohio) and 2 (40 participants in Hanover, Germany). Length measures (Height and Legs) are in cm and Weight in kg. Legs refer to the average length of left and right leg. Maximum and minimum measures for each experiment are shown in italics.

	Maximum			**Minimum**			**Mean**		
	Height	Legs	Weight	Height	Legs	Weight	Height	Legs	Weight
Exp. 1							170.1	86.1	71.1
male	*187.0*	*98.5*	*130.0*	173.0	84.5	62.7	180.3	90.5	85.9
female	173.5	92.8	93.5	*151.5*	*75.8*	*46.1*	163.3	83.2	61.3
Exp. 2							176.5	93.0	69.6
male	187.0	100.4	*109.0*	167.3	*85.1*	*53.1*	176.6	92.6	72.1
female	*189.0*	*103.3*	88.7	*166.7*	86.3	55.8	176.3	93.3	67.2

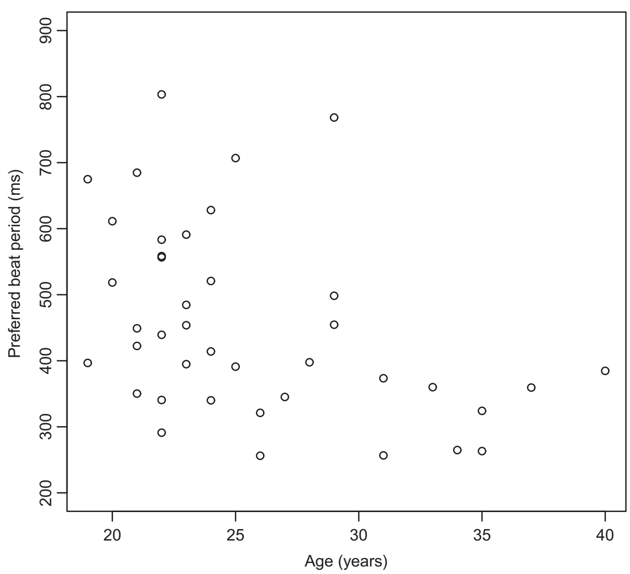

Fig. 4. Preferred beat period versus participants' age. The plot shows the reduced variability in beat range with increasing age.

Table 4. Correlation matrix for the recorded variables in Experiment 2. Significant correlations (2-tailed) are marked with ** ($p < 0.01$) and * ($p < 0.05$).

	LogBeat	Sex	Age	Height	Leg	Weight
LogBeat	1.00					
Sex	−0.04	1.00				
Age	−0.46**	−0.09	1.00			
Height	0.39*	−0.03	−0.05	1.00		
Legs	0.20	0.09	−0.01	0.77**	1.00	
Weight	−0.06	−0.24	0.32*	0.31	0.09	1.00

in Experiment 1, the distribution is still positively skewed and again the range (256 to 803 ms) might indicate that some participants were doubling or halving the tempo when dancing. For the purpose of the subsequent analysis, the preferred beat period data was logarithmically transformed to a new variable LogBeat (=ln(beat period)), which had a close to normal distribution.

Table 4 shows a simple correlation matrix including both the dependent measure and the independent measures. The best predictor of LogBeat is age ($r = -0.46$; $r^2 = 0.21$, bootstrapped confidence levels −0.67 and −0.21) followed by height ($r = 0.39$; $r^2 = 0.15$, bootstrapped confidence levels 0.14 and 0.58). The correlation between LogBeat and leg length is not significant. Sex shows no significant correlations with preferred tempo, age, or height.

The significant correlation between age and tempo (as LogBeat) was not expected and, after a closer look at the variable, also problematic. Since participants were only recruited according to sex and height, and the experiment advertised to a wider audience compared to Experiment 1, this resulted in a wider but also positively skewed distribution of ages, with the majority of participants between 20 and 25 years, and a only a couple between 35 and 40 (see Figure 4). This, in combination with the reduced variance in preferred beat period for the older participants, made us drop age as a predictor in the regression analysis and concentrate the model on the anthropomorphic measures. The results should be interpreted with caution but might nevertheless give an indication of a possible relationship.

Using LogBeat (transformed preferred beat period) as the predicted variable, we carried out a multiple regression analysis, with height, average leg length, and sex, as predictor variables. Using a hierarchical linear regression, height was forcedly entered in the model in a first step, and in a second step, leg length and sex was entered (using stepwise regression, $p_{in} = 0.05$, $p_{out} = 0.10$). The results of the analysis is shown in Table 5. Height was the only predictor to be retained in the model, explaining about 13% of the variance ($R^2_{adjusted} = 0.13$). None of the remaining predictor variables leg length or sex was found to contribute significantly in determining the variance of the predicted variable, (logarithm of) preferred beat period when dancing.

Figure 5 plots the significant relationships between preferred beat period for dancing and participants' height. There appears to be a positive correlation for height, with taller height associated with lower preferred tempo participants ($r = 0.40$; $p < 0.012$ two tailed, bootstrapped confidence interval 0.99, 0.60).

3.3 Discussion

The two main objectives for Experiment 2 were: (1) to investigate whether sex had an impact on preferred dance tempo in a matched sample, and (2) to see whether the found association between stature and preferred dance tempo in Experiment 1 could be replicated. There was no correlation between sex and preferred dance tempo, suggesting that the sex-related association observed in Experiment 1 was due to co-variability with other factors. It appears that by matching female and male heights, sex can thus be excluded as a significant predictor for preferred dance tempo.

The data for Experiment 2 appears to replicate a similar relationship between anthropomorphic measures – preferred

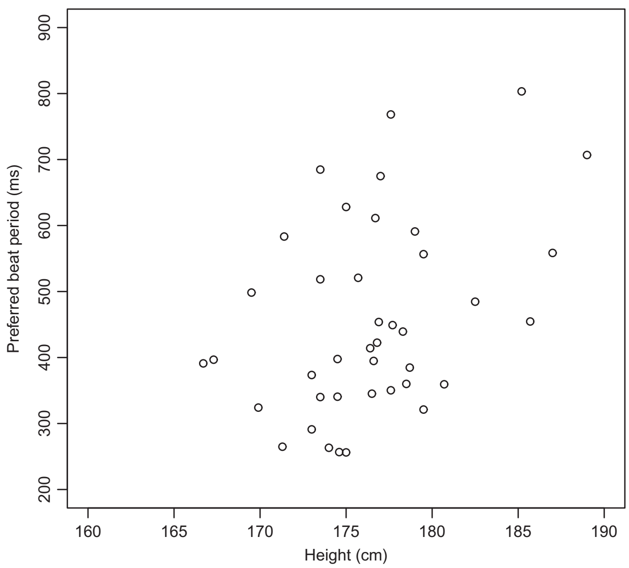

Fig. 5. Preferred beat period versus participants' height.

Table 5. Linear model of predictors for logarithmically transformed preferred beat period (95% confidence intervals are reported in parenthesis).

		b	SE B	β	p
Step 1					
	Constant	1.722 (−1.70, 5.13)	1.69		$p = 0.314$
	Height	0.03 (0.01, 0.04))	0.01	0.386	$p = 0.014$

$R^2 = 0.15$, adjusted $R^2 = 0.13$ for step 1.

beat period for dancing found in Experiment 1 (in the previous case stature height and leg length). In Experiment 2, body height was the only predictor to enter the model, which accounts for about 13% of the variance. The relatively weak effect in Experiment 2 would be expected considering the reduced variance in the sample – which in turn was induced by our approach of recruiting participants. This also led to a wider spread in ages, which also might have an influence. Indeed, age was the factor with the highest correlation with preferred beat period. The found correlation indicated a (somewhat surprisingly) negative relationship, meaning that the older participants were more likely to prefer faster dance tempo. However, as the assumption of homoscedasticity did not hold for the variable age, we chose to exclude it from the regression analysis.

4. General discussion and conclusions

This research was originally motivated by the observation of sex-related differences in preferred dance tempos. In the ecologically valid context of a discotheque, we had observed a significant association between musical tempo and the proportion of females-to-males on the dance floor. Consistent with these observations, Experiment 1 also revealed an association between sex and preferred dance tempo. However, in the multiple regression analysis, sex was eliminated as a significant co-variate due to its shared variance with stature. In Experiment 2, matching the heights of the male and female resulted in no significant correlation between sex and preferred dance tempo.

At face value, the results of Experiments 1 and 2 imply that the initially observed relationship between sex and preferred tempo may be an artifact of body size. In general, males are larger than females, and so more likely to move efficiently at a slower tempo. These findings are consistent with the view, expressed by MacDougall and Moore (2005), Todd and others (Todd, 2000; Todd et al., 2007), that the dynamics of body movement shape rhythm-related behaviours – at least with respect to dance tempo. It should be noted, moreover, that neither Todd et al. (2007) nor Styns et al. (2007) reported a (main) effect for sex, which might have been expected.

In a series of experiments where participants were asked to bounce to ambiguous rhythms, Phillips-Silver and Trainor (2005, 2007, 2008) have demonstrated that body movement shapes our perception of auditory patterns. With this in mind it is plausible to assume that body morphology could, albeit indirectly, shape our experience of music. Tall people with long legs that are more comfortable moving at a slow pace would then also be more likely to feel the rhythm accented at this tempo rather than at alternative (higher) metrical levels.

In accordance with earlier studies (Styns et al., 2007); Todd et al. (2007) we found that anthropometric factors correlate with preferred dance tempo with height or leg length emerging as the most important parameter. However, some caution is appropriate. The physics of moving objects suggests that mass is an important factor in any oscillating system. While increased weight was found to be correlated with longer preferred beat period in Experiment 1, the data was not entered into the model due to violation of the assumption of homoscedasticity. In Experiment 2, no significant correlation between weight and preferred beat period was found. This would be expected if the body shapes of our participants were fairly uniform, with the exception of overall height. In recruiting volunteers for this experiment, potential participants were informed that their weight would be measured. This might be expected to reduce the number of heavy-set volunteers, and so reduce the weight-related variance, with the predictable loss of statistical power.

As suggested by Todd et al. (2007) the biomechanical relationship leg length and preferred beat period can be investigated by fitting the model $Y = cL$, where

$$Y = (T/\pi)^2 g$$

(with T being preferred beat period and g the gravitational acceleration). We regressed this to the data for leg length used in Experiment 1 (which had more variance), yielding a value of $c = 0.23$. That is, closer to about $\frac{1}{4}$ rather than $\frac{1}{3}$ like the values found by Todd et al. (2007).

Body morphology, age, and sex are not the only factors that constitute possible candidates for influencing preferred tempo. Luck et al. (2010) showed a relationship between personality traits and music-induced movements, although their study did not investigate preferred tempo when dancing. Other influences can be stylistic preferences as mentioned in the introduction, but there are other parameters related to our bodies that also have an influence on how we perceive and act (e.g. arousal level, mood, caffeine intake, heart rate etc.).

Although not explicitly intended as a predictor variable, our measure of heart rate in Experiment 2 did not indicate any correlation between measured pulse base line and tempo. Nor did we find a relationship in the changed heart rate and preferred dance tempo. It should be noted, however, that reading the sport pulse computer was not done during dancing and the heart rate of participants might have settled quickly after dancing. Continuous monitoring of the heart rate throughout the experiment could well have given different results. Also, the last heart rate reading, taken after the other measurements and some relaxed discussion with the participants were frequently lower than the initial reading. This might indicate that participants reacted to the pulse measurement and initial instructions with high arousal, causing an increased pulse baseline compared to normal.

Could long-term, or fixed, states such as body morphology, or age influence our performance more than momentary states? In tapping experiments, McAuley et al. (2006) have shown that production and perception of preferred tempo varies with age. In Experiment 2, age was the variable with the highest correlation with preferred beat period, but not as might have been predicted from the overall 'slowing down' reported by McAuley et al. (2006). In our data, the correlation between age and preferred tempo suggests a higher preferred dance tempo with increasing age. Once again, the data need to be interpreted cautiously. It is possible that the highest tempi (around 230 bpm) found in Experiment 2 were double that to which the participants really moved when dancing. Here a more reliable measure of heart rate, indicating whether participants actually were dancing fast, could have been helpful. Similarly, monitoring the dance movements by means of accelerometers or similar could be a way to detect possible subdivisions of tempo during motion.

Finally, dance, seen as spontaneous movement to music, naturally includes a large variety of movements. Here we have departed from the assumption that a big influence on the preferred dance tempo would be regarded as a stylized form of 'bouncing'. However, different body parts are frequently used to mark different rhythmical levels in the music (as seen in e.g. Naveda & Leman, 2009; Toiviainen et al., 2010).

Obviously, the choice not to observe participants makes it impossible to judge whether the instructions to match one movement per beat were ignored. On the other hand, knowing that one is observed clearly also can have an influence on the spontaneous movements performed. Future studies might consider another approach, involving clandestine experimental settings.

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