Who's Got the Rhythm?: Individual Differences in Rhythmic Abilities

by
Ashley Perl

Senior Honors Thesis
Department of Psychology
University of Western Ontario
London, Ontario, CANADA
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Thesis Advisor: Jessica Grahn, Ph.D

Abstract

There are many different parts of music – one of them being rhythm. Though rhythm has been examined in relation to various factors (e.g. memory), differences that occur among individuals have never been examined as a whole. The current study will examine a set of variables known to contribute to differences in rhythmic abilities including: auditory short-term memory, temporal structure detection, basic timing abilities, and musical training. Scores for these variables were determined by performing a digit span test, duration discrimination test, Beat Alignment Test (BAT), and musical training questionnaire, respectively. The scores from the tasks were used to see how well they predict performance on the Rhythm Reproduction task. The rhythms in this task varied in beat (beat based or non-beat based) and length (short, medium, or long). Participants in this study include both male and female introductory psychology undergraduate students from the University of Western Ontario. A 2x3 repeated measures ANCOVA was used to analyze the relationship. The two factors included beat and length. In addition, all other variable scores were entered as covariates. The results revealed significant main effects for beat and length. Furthermore, a significant three-way interaction between beat, duration discrimination, and Beat Alignment Test scores were revealed. There was also a marginally significant four-way interaction found between beat, Digit Span, BAT scores, and musical training. Overall, the results suggest that beat, length, digit span, basic timing abilities, the ability to detect temporal structure, and musical training all contribute to an overall rhythmic ability.

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Who's got the rhythm?: Individuals Differences in Rhythmic Abilities

Music production requires the ability to comprehend timing, timbre, pitch, beat, accents (in other words, volume), and rhythm, to name a few. *Rhythm* is one of the key components of music; it incorporates timing, accents, and beat within a musical piece. Similarly, *rhythmic ability* refers to an individual's ability to perceive and process timing, accents, and a beat, within a musical context. Being able to perceive rhythm is considered something innate. It was found that even infants could be taught to differentiate rhythmic sequences (Phillips-Silver & Trainor, 2005). Despite the suggested innate nature of rhythmic ability, individual differences are apparent. Rhythmic reproduction abilities are known to be influence by different individual factors (eg. Saito, 2001). However, the collaborative contribution of these factors that contribute to rhythmic ability have never been considered at an individual level. This study will address the gap in the literature regarding underlying factors that contribute to individual differences in rhythmic abilities. In other words, this study will ask the question: what factors contribute an individual's rhythmic ability?

A relationship between short-term memory and rhythm reproduction has been established. For instance, it has been found that the presence of a rhythm aids memory in facilitating recall (Silverman, 2010). Additionally, a study conducted by Saito (2001) measured individual differences in the ability to reproduce rhythm, with respect to memory. This study also found there is in fact a relationship between short-term memory and rhythm reproduction– those with better short-term memories were also better at remembering and reproducing rhythms. Thus, it can be suggested that there is mechanism behind auditory short-term memory and rhythm reproduction.

In a musical sense, to have an understanding of timing suggests the capacity to distinguish between two perceptual events, known as duration (Keele, Pokorny, Corcos, & Ivry, 1985). Relationships between basic timing ability and rhythm reproduction have been revealed. For instance, a study conducted by Keele et al. (1985) found that participants who were able to accurately reproduce a rhythm by tapping their finger, were also able to reproduce rhythms accurately with their foot. Some participants were overall better at this task. This study concluded that some people were better at perceiving time than others.

Musical training is also thought to influence individual differences in rhythmic abilities. Past research has demonstrated that musicians are better at adapting to rhythm reproduction tasks where unnaturally long gaps between beats were present, in comparison to non-musicians (Repp & Doggett, 2007). Importantly, this study also found more variability on rhythm reproduction performance within the non-musician group than in the musician group. Thus, suggesting that musical training influences the ability to adapt to unusual rhythmic sequences. Similarly, another study illustrated that highly skilled piano players were better at perceptually timing rhythms than non-musicians (Keele et al., 1985). These studies highlight that musical training does in fact influence individual rhythmic abilities.

Another important component of rhythm is *temporal structure,* which refers to the organization of musical intervals into a rhythmic sequence (Ehrlé & Samson, 2004). These intervals can further be organized into different types of rhythms. For instance, there are *beat-based rhythms* where the intervals in the musical sequence are organized into regular integer numbers. In other words the intervals are more or less evenly spaced.

Alternatively, there are also *non-beat based rhythms* where the musical sequence is organized by intervals that are non-integer numbers. Simply, the intervals are unevenly spaced (described as *metric* and *nonmetric* rhythms in Grahn, 2009). Having the ability to detect temporal structure means that the individual is able to distinguish what the organization intervals are in a musical sequence. In simpler terms, this is often thought of the ability to "feel the beat."

Temporal structure has also been examined in relation to rhythm. A study by Grahn and Brett (2007) examined participant's ability to reproduce beat based and non-beat based rhythms. It was found that beat based rhythms were reproduced more accurately than non-beat based rhythms. This finding seems to be consistent across other studies as well (Grahn, 2009). Additionally, it was also found that musicians are more sensitive to detecting beat structure than non-musicians (Grahn and Rowe 2009). Thus, training helps to influence an individual's ability to perceive a beat, which in turn influences how rhythm is perceived. Furthermore, neurological based findings suggest that beat based rhythms are more easily perceived than non-beat based rhythms (Grahn, 2009). It is important to note that individual differences in the ability to detect temporal structure have not yet been examined.

Even though rhythm has received a lot of research attention, little is known about individual cognitive traits that contribute to an overall rhythmic aptitude. Past studies have looked at individual differences in rhythmic abilities however, there were variables missing that were known to be important in rhythmic ability (e.g. memory, Satio, 2005; timing, Keele et al., 1985; musical training, Repp & Doggett, 2007). The aim of the current study is to provide more conclusive evidence as to what individual factors contribute to an overall rhythmic ability. More specifically, this study will examine four factors that previous literature suggests may influence individual rhythmic abilities: *short- term auditory memory capacity, basic timing ability, temporal structure detection,* and *musical training*. To clarify, *short-term auditory memory capacity* refers to an individual's ability to retain auditory memories. *Basic timing ability* refers to an individual's ability to perceive and measure time in a musical sequence. *Temporal structure detection* insinuates the ability to detect the structure of timing used within a rhythm sequence. Finally, *musical training* refers to how much musical training an individual has received. These four factors will be analyzed to help determine which factor, or combination of factors, best predict an individual's overall rhythmic ability.

Participants in the current study will be required to complete an Auditory Digit Span test, Duration Discrimination test, Beat Alignment test, and a Musical Training Questionnaire. These tests determine individual scores for the four predictor factors: *auditory short-term memory*, *basic timing abilities, the ability to detect temporal structure,* and *musical training,* respectively (see Table 1 for clarification). Additionally participants are required to complete a Rhythm Reproduction Test which determine each participants ability to reproduce rhythms. All predictor variables were used to predict performance on the rhythm reproduction task.

Analysis of the previous literature suggests that there should be underlying individual differences in rhythmic ability. Based on previous findings, five different hypotheses can be generated: 1) those with a better auditory short-term memory will also be better at rhythm reproduction; 2) those who demonstrate the ability to detect temporal structure will also be better at reproducing rhythms, when a beat based rhythm is present;

3) there will be a relationship between auditory short-term memory and rhythm length; 4) those with basic timing abilities will be overall better at reproducing rhythms; and finally 5) musical training will influence overall abilities to reproduce rhythms.

Table 1.

Predictor factors and tests used to assess them.

Predictor Factor	**Test**
Short-term Auditory Memory	Auditory Digit Span Test
Basic Timing Abilities	Duration Discrimination Test
Ability to detect Temporal Structure	Beat Alignment Test
Musical Training	Musical Training Questionnaire

Method

Participants

Thirty-three participants took part in the study (16 females, 17 males). Participants ranged from 18 to 20 years old (M = 18.33, SD = 0.60). All participants were undergraduate students enrolled in the introductory psychology course at the University of Western Ontario and received academic credit for their participation in this study.

Materials

Participants were required to complete five separate tasks: digit span test, duration discrimination test, Beat Alignment Task (BAT), Rhythm Reproduction Test (RRT), and a musical training questionnaire. All tests, with the exception of the musical training questionnaire, were performed on a PC laptop using E-prime software (2.0).

Digit span test. The digit span test presented was a standard auditory digit span test. Each participant was presented with a string of digits and asked to repeat the digits back to the experimenter. The number of digits increased in a sequential manner, and there were two versions of each possible sequence length. Participants continued with new trials until they either successfully repeated two nine-digit sequences or got both trials of a shorter digit sequences wrong. Digit span is defined as the number of digits at which a participant can successfully recall in one trial.

Duration discrimination test. The duration discrimination test assessed participants basic timing abilities. This standard duration discrimination test presented participants with trials containing a standard tone and a target tone. The standard tone was held constant at 100ms, whereas the target tone varied in length from 35ms to 165ms. Participants were to determine if the target tone was longer or shorter than the standard tone. Each participant completed 10 different trials that were randomly repeated over four cycles in the duration discrimination test. Participants were given 10 practice trials before data was actually recorded to ensure that they completely understood the task.

Beat Alignment Test. The Beat Alignment Test (BAT) (Iversen & Patel, 2008) determines participants ability to detect temporal structure. The test has participants determine if a series of beeps superimposed over a song are “on” or “off” beat. There are two possible “off” beat conditions: one where the beeps are consistently early or late, and the other where the time interval between beeps are too short or too long (with respect to the beat of the music). For further details see Iversen and Patel (2008). Participants were randomly assigned to one of two groups. For each song, one group received an on beat version and two off beat versions: one where the beep interval was consistently too fast or too slow, and one where the beep interval was shorter or longer than the beep interval. The other group received the on beat trial as well as the two off beat trials not presented to the first group, for each song. In total, there were 12 songs, with three different versions of each, thus each participant was exposed to 36 different trials. Participants were given a sample of what the beeps would sound like prior to the first task.

Rhythm Reproduction Test. The Rhythm Reproduction test required participants to listen to a rhythm and tap it back using the space bar on the keyboard. Rhythms differed in Length; either short, medium, or long; and in Beat; either beat based or non-beat based rhythms. Each participant heard eight short, eight medium, and eight long rhythm sequences for both regular and non-regular beat patterns. Thus, each participant completed 48 trials on the Rhythm Reproduction Test. All rhythms were presented twice to allow participants to comprehend the entire rhythmic sequence before asking participants to reproduce it. This was done in light of a study done by Grahn (unpublished data), where it was found that the non-beat based rhythms were too difficult to reproduce after only hearing them once. Participants could practice examples for the short, medium, and long lengths, as well as rhythms with a regular beat and those lacking a regular beat before data were actually collected.

Procedure

Prior to completing any of the tasks, participants were given a letter of information and asked to sign a form indicating their consent to partake in the study. Following consent, participants were asked to try out the head phones to ensure that they fit properly and the volume was at comfortable level by having them listen to a novel song.

Once set up, the digit span test was administered. The experimenter sat across from the participant and recorded the responses to the digit span. Following the digit span test, the duration discrimination test was administered. Upon completion of the duration discrimination test, the Beat Alignment Test, and Rhythm reproduction tests were administered, respectively. Following the completion of these tests, participants were required to complete a musical training questionnaire (Appendix). At the end of the questionnaire, participants were debriefed about the study.

Statistical Analyses

A 2x3 repeated measures ANCOVA was be used to analyze the rhythm reproduction data collected. Each participant's scores from the digit span test, duration discrimination test, Beat Alignment Test, and musical training questionnaire were entered as covariates. In addition, the ANCOVA included the factors Length (short, medium, long) and Beat (beat and non-beat) from the Rhythm Reproduction Test. All tests were conducted at $\alpha = .05$ confidence level. Data were analyzed using SPSS and Microsoft Excel software.

Results

The average scores on each of the covariates are as follows: mean Digit Span score = 6.94 (*SD* = 1.39), mean Duration Discrimination = 0.90 (*SD* = 0.05), the mean BAT score = 0.75 (*SD* = 0.15), and mean years of Musical Training = 6.33 (*SD* = 4.46).

Mauchly's Test of Sphericity was not significant (Length: $W = 0.94$, $X^2 (2) = .99$, $p = 0.61$; Beat x length: $W = 0.71$, $X^2 (2) = 5.44$, $p = 0.066$), therefore, equal variances can be assumed. The 2x3 repeated measures ANCOVA revealed significant main effects for both Beat ($F (1, 17) = 99.80$, $P < 0.001$) and Length ($F (2, 34) = 55.15$, $p < 0.001$). For mean performance for Beat based and Non-beat based conditions at all three lengths see Figure 1. The interaction between Beat and Length was also found to be significant ($F = 55.15$, $p < 0.001$). In light of this significant interaction, the main effects of Beat and Length should be interpreted with caution. In general, it is clear that Beat based rhythms are reproduced more accurately than Non-beat based rhythms, and that the shorter a Beat based rhythm is, the greater accuracy that was observed. The effect of Length, although present, is not as pronounced for the Non-beat rhythms.

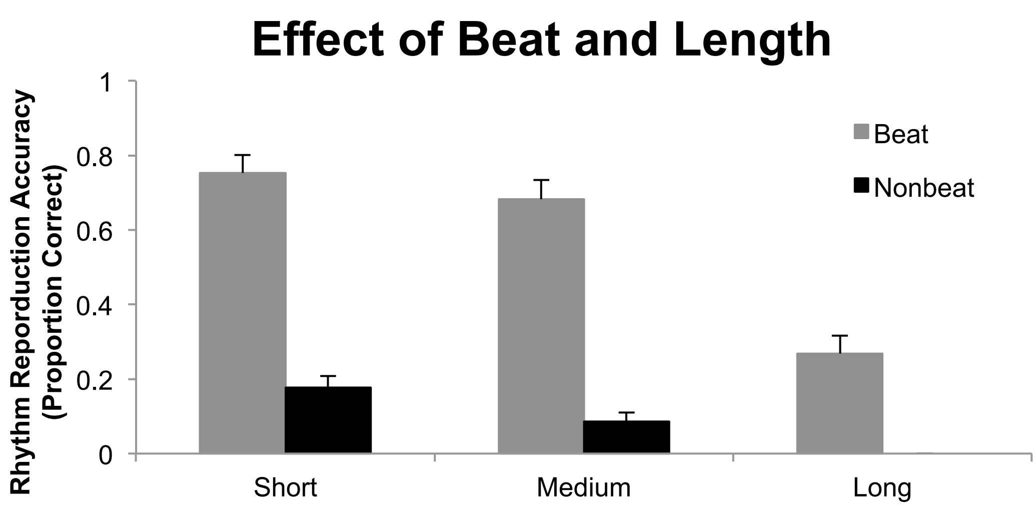

Figure 1. Effect of beat and length on rhythm reproduction accuracy. *M+SD of portion correct is represented for beat based and non-beat based rhythms that were short medium or long.*

Significant main effects and 2-way interactions were found with the four covariates (see Table 2 for a complete list of significant effects), however, they occurred in light of 3-way or 4-way interactions, and therefore will be not be described in further detail than that presented in Table 2. The significant three-way interaction was found between Beat, Duration Discrimination scores, and BAT scores (F (1, 17) = 5.23, p = 0.035). To examine the nature of the interaction, correlations were computed for 2 groups, created by a median split of the data into high BAT (n = 17) and low BAT (n = 16) groups. For Beat based rhythms, the high BAT groups correlation between Duration Discrimination and rhythm performance is similar to the low BAT groups (high BAT r = .48, low BAT r = .30; Figure 2). For the Non-beat based rhythm, the high BAT correlation is still high (r = .50) whereas the low BAT groups' correlation is near zero (r = -.04), as shown in Figure 3. In other words, for participants with a high BAT score, as their performance on the Duration Discrimination task increases, so does their ability to reproduce rhythms. For high BAT score individuals, this is true of both Beat based and Non-beat based rhythms. For participants with low BAT scores, this relationship is only true in the Beat based conditions, whereas, this relationship disappears in the Non-beat based conditions.

Table 2.

Significant Main Effects and Interactions of Beat, Length, Digit Span (DS), Duration Discrimination (DD), Beat Alignment Scores (BAT), and Musical Training (MT) in light of the (a) four-way interaction and (b) three-way interaction.

Effect	**Degrees of freedom**	**F-value**	**p-value**
Beat x DS[(a)]	1, 34	7.07	0.017
Beat x BAT[(a), (b)]	1, 34	6.73	0.019
DS[(b)]	1, 17	4.43	0.050

BAT[(a), (b)]	1, 17	5.24	0.035
MT x DS[(b)]	1, 17	5.18	0.036
MT x DS x BAT[(b)]	1, 17	4.72	0.044

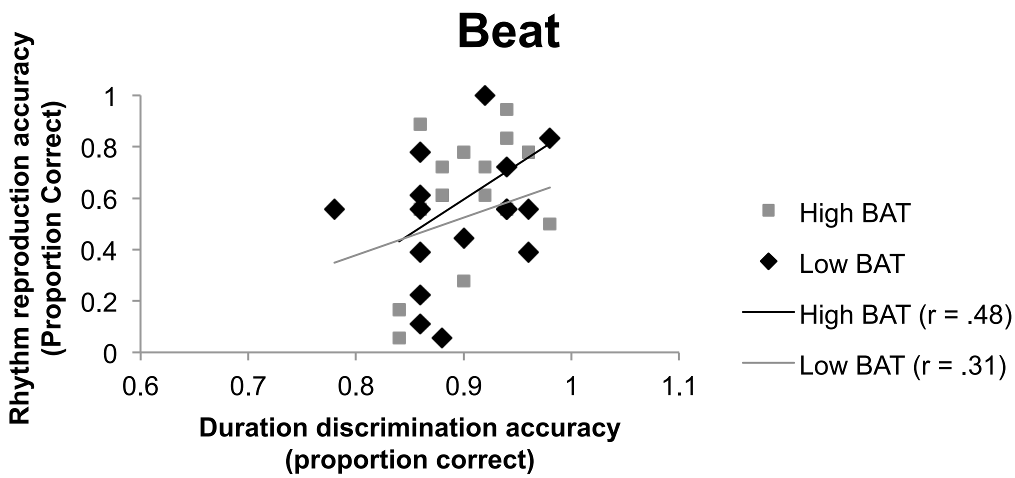

Figure 2. Effect of duration discrimination accuracy on rhythm reproduction accuracy for beat based rhythms. *Each point represents an individual participant score. Participants were dived by the median into high BAT score and low BAT score groups. Correlations were calculated for the high and low BAT score groups.*

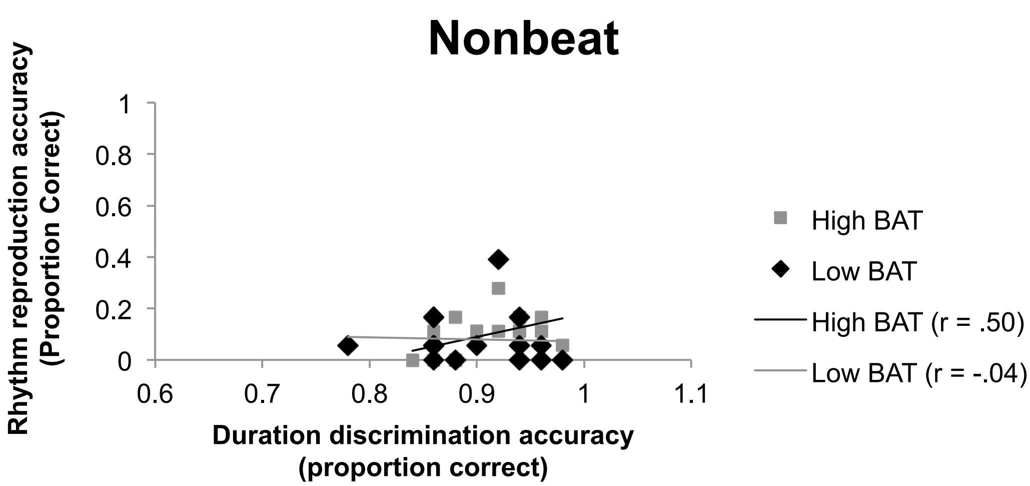

Figure 3. Effect of duration discrimination accuracy on rhythm reproduction accuracy for

non-beat based rhythms. *Each point represents an individual participant score. Participants were dived by the median into high BAT score and low BAT score groups. Correlations were calculated for the high and low BAT score groups.*

A marginally significant four-way interaction between Beat, Musical Training, Digit Span, and BAT scores was also revealed (F (1, 17)= 4.17, p = 0.057). To illustrate the nature of this marginally significant 4-way interaction, participants were divided into four groups: low Musical Training, low BAT (n = 6); low Musical Training, high BAT (n = 9); high Musical Training, low BAT (n = 10); as well as high Musical Training, high BAT (n = 8). For the Beat based rhythms, the correlation between rhythm reproduction and Digit Span (Figure 4) for the low Musical Training, low BAT group was much lower than the correlation between Rhythm Reproduction accuracy and Digit Span for the other three groups (r = -0.42, compared to low Musical Training, high BAT r = 0.57; high Musical Training, low BAT r = 0.39; and high Musical Training, high BAT, r = 0.74,). For Non-beat based rhythms (Figure 5), the high Musical Training, high BAT group retained a high correlation between rhythm reproduction and Digit Span (r = 0.76). However, the other three groups showed low or negative correlations (low Musical Training, low BAT, r = -0.60; low Musical Training, high BAT, r = -0.10; and high Musical Training, low BAT, r = 0.09). In the Beat based rhythms, those who have either high Musical Training or a high BAT score display the relationship that as Digit Span increases, so does performance on the Rhythm Reproduction task. However, if a low Musical Training and a low BAT score are displayed, then there is no relationship between Digit Span and Rhythm Reproduction. In the Non-beat condition, this relationship only remains true for those with both high Musical Training and high BAT score. There is no relationship for any of the other groups in the Non-beat based condition.

All other interactions were not significant (listed in Table 3).

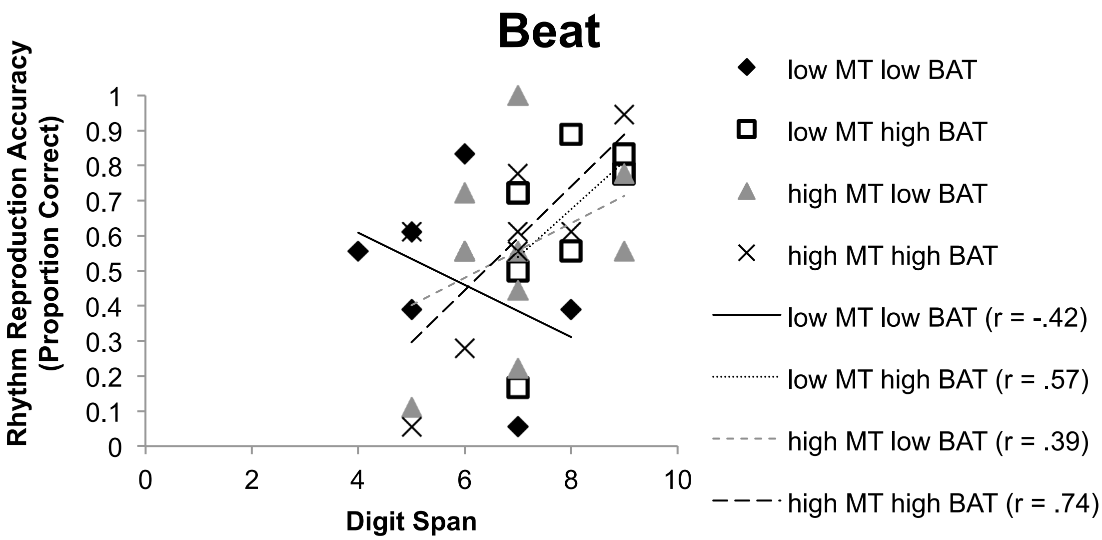

Figure 4. Effect of digit span, BAT score, and amount of musical training on rhythm reproduction accuracy for beat based rhythms. *Each point represents an individual participant score. Participants were divided in low or high musical training as well as low or high BAT score groups. Correlations were calculated for each group.*

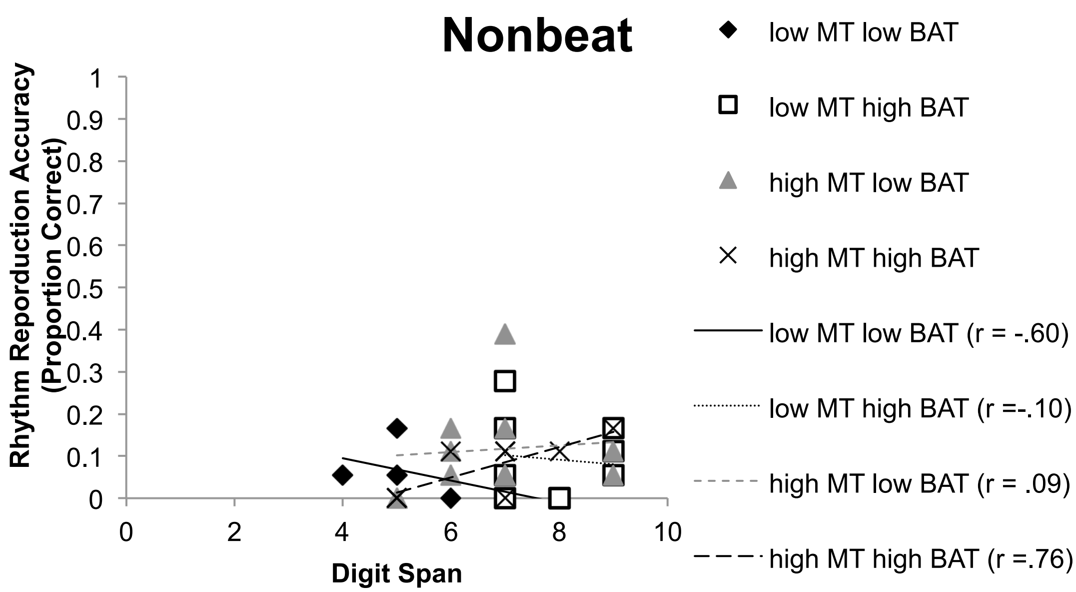

Figure 4. Effect of digit span, BAT score, and amount of musical training on rhythm reproduction accuracy for non-beat based rhythms. *Each point represents an individual participant score. Participants were divided in low or high musical training as well as low or high BAT score groups. Correlations were calculated for each group.*

Table 3.

Main Effects Interactions of Beat, Length, Digit Span (DS), Duration Discrimination (DD), Beat Alignment Scores (BAT), and Musical Training (MT) that were not significant.

Effect	**Degrees of freedom**	**F-value**	**p-value**
Beat x Length x MT	2, 34	0.37	0.695
Beat x Length x DS	2, 34	0.24	0.791
Beat x Length x DD	2, 34	0.04	0.960
Beat x Length x BAT	2, 34	1.04	0.365

Beat x Length x MT x DS	2, 34	0.85	0.438
Beat x Length x MT x DD	2, 34	0.19	0.826
Beat x Length x MT x BAT	2, 34	1.19	0.316
Beat x Length x DS x DD	2, 34	0.78	0.467
Beat x Length x DS x BAT	2, 34	0.28	0.761
Beat x Length x DD x BAT	2, 34	0.46	0.634
Beat x Length x MT x DS x DD	2, 34	0.91	0.414
Beat x Length x MT x DS x BAT	2, 34	1.96	0.156
Beat x Length x DS x DD x BAT	2, 34	1.03	0.367
Beat x Length x MT x DD x BAT	2, 34	0.07	0.931
Beat x Length x MT x DS x DD x BAT	2, 34	0.42	0.661
Beat x MT	1, 17	0.72	0.408
Beat x DD	1, 17	3.05	0.099
Beat x MT x DS	1, 17	3.73	0.070
Beat x MT x DD	1, 17	0.60	0.449
Beat x MT x BAT	1, 17	1.02	0.328
Beat x DS x DD	1, 17	2.18	0.159
Beat x DS x BAT	1, 17	0.41	0.532
Beat x MT x DS x DD	1, 17	0.17	0.682
Beat x DS x DD x BAT	1, 17	0.11	0.741
Beat x MT x DD x BAT	1, 17	2.15	0.161
Beat x MT x DS x DD x BAT	1, 17	0.01	0.931
Length x MT	2, 34	1.25	0.298

Length x DS	2, 34	0.33	0.718
Length x DD	2, 34	0.85	0.438
Length x BAT	2, 34	0.03	0.966
Length x MT x DS	2, 34	1.63	0.211
Length x MT x DD	2, 34	0.02	0.980
Length x MT x BAT	2, 34	0.05	0.947
Length x DS x DD	2, 34	0.58	0.565
Length x DS x BAT	2, 34	0.07	0.930
Length x DD x BAT	2, 34	0.37	0.692
Length x MT x DS x DD	2, 34	0.45	0.642
Length x MT x DS x BAT	2, 34	0.56	0.578
Length x DS x DD x BAT	2, 34	1.48	0.242
Length x MT x DD x BAT	2, 34	0.72	0496
Length x MT x DS x DD x BAT	2, 34	2.37	0.108
MT	1, 17	4.28	0.054
DD	1,17	2.39	0.141
MT x DD	1,17	0.04	0.840
MT x BAT	1, 17	2.76	0.115
DS x DD	1, 17	0.83	0.374
DS x BAT	1, 17	1.17	0.294
DD x BAT	1, 17	3.43	0.081
MT x DS x DD	1, 17	0.01	0.908
DS x DD x BAT	1, 17	0.49	0.495

MT x DD x BAT	1, 17	1.91	0.184
MT x DS x DD x BAT	1, 17	0.78	0.391

Discussion

This study examined individual differences in the ability to reproduce rhythms. Specifically, this study considered individual differences in auditory STM, basic timing abilities, temporal structure detection, and musical training in the ability to reproduce rhythms. These rhythms varied by either being beat based or non-beat based, as well as in length, where they were short, medium, or long. Findings from this study suggest that there is support for hypothesis 2), in that having the ability to detect temporal structure increases the ability to reproduce rhythms when a beat is present. There was also some support for hypotheses 1) auditory short-term memory influences rhythm reproduction; 4) possessing basic timing abilities influence rhythm reproduction abilities; and 5) musical training enhances rhythm reproduction skills. However, findings from this study do not directly support hypothesis 3), there is no direct link between auditory short-term memory and rhythm reproduction abilities, specifically for the reproduction of longer rhythms.

It appears that auditory short-term memory, basic timing abilities, and musical training all influence rhythm reproduction in combination with one another in a number of different ways. First, it was found that the ability to reproduce both beat based and non-beat based rhythms increased as basic timing abilities increased, but only for those who had a strong ability to detect temporal structure. This is consistent with previous findings that those with basic timing abilities perform better on rhythm reproduction tasks (Keele et al., 1985). Similarly, this is consistent with the finding that rhythms with a beat-based temporal structure are more easily reproduced than those that are non-beat based (Grahn & Brett, 2007). However, these findings also add to the literature by suggesting that there are additional influences of individual differences in the ability to detect temporal structure. It should be noted, that this relationship was also present for those with a less robust ability to detect temporal structure. However, this was only true for beat based rhythms and the relationship was not as robust. This finding contributes to the literature suggesting that non-beat based rhythms can be reproduced more accurately by those that have both good basic timing abilities and a good ability to detect temporal structure.

Secondly, it was found that those with a strong ability to detect temporal structure, or those who had some sort of musical training, were better at reproducing beat based rhythms. For those participants, rhythm reproduction accuracy increased as short-term auditory memory ability increased. This was also true for non-beat based rhythms, but only for participants who had both had a large amount of musical training *and* a good ability to detect temporal structure. This finding is consistent with previous literature that suggests short-term auditory memory, musical training, and the ability to detect temporal structure all influence rhythm reproduction ability (Saito, 2001; Repp & Doggett, 2007; Keele et al. (1985); respectively). However, it has not been considered until now that these factors may interact and influence each other in a way that is represented here. These findings also suggest that having certain skills, such as musical training and the ability to detect temporal structure, may actually help in reproducing non-beat based rhythms. It has been found that reproduction performance of complex rhythm patterns (Snyder, Hannon, Large, & Christiansen, 2006) or non-beat based rhythms is generally poor. However, other studies also suggest that having musical training may help to improve the ability to reproduce non-beat based rhythms. For example, it was found that individuals who had musical training in percussion were better at reproducing non-beat based rhythms than non-musicians or other instrumentalists. Additionally, the same study found that musical training as well as working memory account for a large amount of variance in rhythm reproduction (Ehrlé & Samson, 2005), which is consistent with the present results.

In addition, it was found that the presence of a beat influences overall rhythm reproduction ability. More specifically, beat-based rhythms were easily reproduced, whereas non-beat based rhythms were hardly ever reproduced correctly. This is consistent with previous findings that proposed beat-based rhythms are more easily perceived than non-beat based rhythms (Grahn & Brett, 2007). Thus, even though there are cases where some individuals, provided they have certain abilities, can reproduce non-beat based rhythms, they are still not as accurately reproduced as rhythms with a beat.

Despite a suspected direct relationship between ability to produce longer rhythms length and auditory short-term memory ability, no such pattern was revealed. Although, auditory short-term memory ability does not appear to interact with the ability to produce longer rhythms sequences, there is an effect of length – as a rhythm gets longer, reproduction accuracy declines. This finding is consistent with previous studies (Ehrlé & Samson, 2005).

Overall, these findings suggest that the rhythm reproduction ability is influenced by auditory short-term memory, basic timing abilities, the ability to detect temporal structure, and musical training ability, as well as the beat type and length of the rhythm presented. This study also suggests that there are individual differences in the ability to detect temporal structure in a rhythm sequence, which has never been directly examined before. The individual differences of rhythmic ability have never been considered in combination with each other. The individual differences approach used here was able to demonstrate not only that individual factors affect rhythmic ability, but that these factors interact and influence each other.

These research findings should be considered in the context of three limitations that should be noted. First, due to constraints on resources, only thirty-three participants could be included in this study. Including more participants in this study would have helped to clarify the relationships found; especially the marginally significant interaction between beat, short-term auditory memory, temporal structure detection, and musical training. Second, all participants from the study were from an introductory psychology course, thus the sample is only representative of junior undergraduate students. Lastly, even though it was demonstrated that non-beat based rhythms are reproduced more accurately by individuals with good basic timing abilities, the ability to detect temporal structure, and musical training, performance was still overall poor. This could be due to the fact that reproduction of the non-beat based rhythms is so difficult that there may not be a correlation, and the results are simply revealing a floor effect.

Future research in this area should look to consider a variety of factors that were not considered here. For starters, if this study was to be replicated, a larger and more diverse sample could help to further distinguish the trends represented here. Additionally, it would be interesting to take into consideration the type of musical training that each individual has received, such as formal or self-taught, as well as what instrument each participant plays, as was done in Ehrlé and Samson's (2005) study. This would further help to distinguish the influence that musical training has on rhythm reproduction abilities. Finally, it would be interesting to look at if practice could diminish the ceiling effect found in reproduction of non-beat based rhythms. If so, this relationship could be further examined to determine which other factors influence individuals ability to learn non-beat based rhythms as well as individual differences in the speed of learning the non-beat based rhythms.

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