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RUNNING HEAD: SYNCOPATION AND GROOVE IN GHANAIANS AND
AMERICANS

**A critical cross-cultural study of sensorimotor and groove responses to syncopation
among Ghanaian and American university students and staff**

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Abstract

The pleasurable desire to move to a beat is known as groove and is partly explained by rhythmic syncopation. While many contemporary groove-directed genres originated in the African diaspora, groove music psychology has almost exclusively studied European or North American listeners. While cross-cultural approaches can help us understand how different populations respond to music, comparing African and Western musical behaviours has historically tended to rely on stereotypes. Here we report on two studies in which sensorimotor and groove responses to syncopation were measured in university students and staff from Cape Coast, Ghana and Williamstown, US. In our experimental designs and interpretations, we show sensitivity towards the ethical implications of doing cross-cultural research in an African context. The Ghanaian group showed greater synchronization precision than Americans during monophonic syncopated patterns, but this was not reflected in synchronization accuracy. There was no significant group difference in the pleasurable desire to move. Our results have implications for how we understand the relationship between exposure and synchronization, and how we define syncopation in cultural and musical contexts. We hope our critical approach to cross-cultural comparison contributes to developing music psychology into a more inclusive and culturally grounded field.

Keywords: groove, syncopation, synchronization, rhythm, exposure, cross-cultural research.

Introduction

In psychological research, the pleasurable desire to move to a beat is known as *groove* (Janata, Tomic, & Haberman, 2012). Studies show that the sensation of groove is affected by rhythmic syncopation (Matthews, Witek, Heggli, Penhune, & Vuust, 2019; Sioros, Mirron, Davies, Gouyon, & Madison, 2014; Witek, Clarke, Wallentin, Kringelbach, & Vuust, 2014) - a form of rhythmic complexity where the placements of rhythmic stresses or accents fall between the beats of a musical pulse. Many of the most popular forms of groove-directed music, such as funk, soul, disco, hip-hop, house, techno, jazz, blues, son cubano, rumba and reggae, originated in the African diaspora, and some of the most studied forms of rhythmic complexity, such as syncopation, are prominent features in traditional African music. For example, the syncopations of Afro-Cuban clave-derived patterns, which are pervasive in these genres, largely overlap with many common bell patterns used in Sub-Saharan African traditional music (Washburne, 1997). Furthermore, many African popular music genres, such as Highlife and Hiplife (West-African Hip Hop), are groove-directed and have links to traditional African as well as North American and Western European music (Collins, 2012). In other words, there has been significant cross-pollination between musics across these continents. Despite the undeniable significance of African influence in popular groove-based music, psychological studies of groove have almost exclusively been conducted in Europe and North America.

The overrepresentation of certain participant samples is emblematic in the Behavioural Sciences (Henrich, Heine, & Norenzayan, 2010). A study from 2008 showed that 96% of research participants came from Western industrialised countries, which represent only 12% of the world's population (Arnett, 2008). Cross-cultural psychology enables the study of such underrepresented populations and can also show the extent to which culture affects music perception and cognition. In two experiments, we compare how

university students and staff from Ghana and America respond to rhythmic syncopation and groove. However, comparing African and Western music behaviours raises certain ethical issues, and historically such research has tended to rest upon stereotyped assumptions about cultural and racial difference (Toner, 2007). Therefore, it is important to consider the ethical implications of cross-cultural comparison and to design experiments that are sensitive to the specifics of the African context. In addition to reporting on empirical findings, this paper briefly reviews of some of the history of comparing African to Western music listening and explains how the experiments were designed in order to prevent stereotyping.

Syncopation and Groove

Syncopation is a form of rhythmic complexity that is defined in music psychology as notes occurring on metrically weak accents followed by rests on metrically strong accents, in an otherwise regular metric framework of alternating strong and weak accents (Longuet-Higgins & Lee, 1984). Because, in Western art music, notes usually occur on strong metric beats and rests on weak beats (Palmer & Krumhansl, 1990), syncopations are thought to be complex because they violate metric expectations. As a result, syncopation adversely affects the ability to perceive and synchronize to a beat in finger-tapping experiments (Witek, Clarke, Kringelbach, & Vuust, 2014).

Syncopation has also been used to test metric expectations, based on the assumption that the more a syncopation disrupts the listener's sense of beat, the more violated the metric expectations (Snyder & Krumhansl, 2001). In Western formal music theory, there is a strict hierarchy in the metric salience of note values. The basic hierarchy of a bar in 4/4 time is recursively subdivided into beat 1 or what is known as the downbeat (whole note) as the most salient position, followed by beat 3 (half note), and beat 2 and 4 with equal salience (crotchets). Ladinig et al. (2009) confirmed that syncopations on the downbeat are perceived

as more unexpected than syncopations on beat 3, indicating that the downbeat is a more metrically salient position. However, Witek et al. (2014) found little evidence for a metric hierarchy beyond the salience of the downbeat. It thus remains unclear whether listeners' metric frameworks are as strictly hierarchical as Western music theory predicts.

Instead, they showed that if a syncopated drum-kit pattern was monophonic, it produced lower levels of finger-tapping synchronization and ratings of stability than if it was accompanied by one or two other instrumental streams emphasizing the beat. In addition, there was an interaction between number of streams and instrumentation, such that syncopations in the bass drum with the snare and the hi-hat emphasizing the beat were rated as less stable than syncopations in the snare drum with the bass and hi-hat on the beat. Thus, the polyphonic context of drum-kit patterns affected finger-tapping synchrony and ratings of rhythmic stability, not just the metric location at which the syncopation occurred.

Some argue that defining syncopations solely in terms of metric expectancy violations is problematic, since expectations highly depend on listeners' long-term musical exposure (London, Polak, & Jacoby, 2017). In much West-African music, the distribution of notes and rests on strong and weak beats is more equal, leading some Africanist music theorists to claim that the meter is not organised by alternating salience (e.g. Arom, 1989). Listeners exposed to such music may thus perceive syncopations as less unexpected (Haumann, Vuust, Bertelsen, & Garza-Villarreal, 2018). In groove, syncopated patterns are often continuously repeated and may thus become stylistically predicted. Some African and African-American music theorists refer to such patterns in different ways, in order to avoid defining them in terms of expectancy deviation. Examples of this are 'off-beat timing', 'cross-rhythm' (Locke, 2006) 'contra-metricity' (Kolinski, 1973) or 'tendency towards cross-rhythm' (Danielsen, 2006). Related to this, London et al. (2017) performed a corpus study of Malian drumming and found that while certain note onset patterns were recurring and thus predictable, the

metric positions with which they most frequently cooccurred did not always correspond with the most salient positions of the meter. This finding contrasts earlier research in Western music, where the most frequent onsets occurred at the most salient metric positions (Palmer & Krumhansl 1990). The authors thus propose that the consistency of configuration in rhythmic patterns in a particular musical style has a greater effect than previously thought on the forming of mental representations of meter. In other words, as long as the pattern is a stable and recurring figure in the music, it will contribute to metrical predictability, regardless of whether its onsets occur on the most metrically salient positions or not. Accordingly, a repeated syncopated pattern, such as the Afro-Cuban clave pattern, may be better described as a rhythmic figure that reinforces rather than weakens a meter or beat, depending on the musical context and exposure of the listener.

This is consistent with studies showing that medium levels of syncopation promote increased sensation of groove, as evidenced by an inverted U-shaped relationship between degree of syncopation and ratings of wanting to move and pleasure (Matthews et al., 2019; Sioros et al., 2014; Witek, Clarke, Wallentin, et al., 2014). Medium syncopation creates rhythmic tension but does not completely obscure the sense of beat, and thus may be ideal for inviting physical embodiment of the beat (Witek, 2017). In a motion-capture study, Witek et al. (2017) found that amount of movement and degree of movement synchrony were equal for patterns with medium and low syncopation, but dropped significantly for high syncopation. This suggests that, in the context of groove, moderate levels of syncopation do not retract from a sense of beat (Vuust, Dietz, Witek, & Kringelbach, 2018). However, it may be that even in the context of groove, the extent to which syncopations are experienced as reinforcing or retracting from the sense of beat depends on the musical exposure of the listener.

Complexity, Exposure and Preference

The preference for medium syncopation is in accordance with the inverted U hypothesis in aesthetics, according to which listeners prefer intermediate levels of complexity in art due to the optimal arousal that such levels induce (Berlyne, 1971; North & Hargreaves, 1995).

However, there is still disagreement about how complexity interacts with exposure in the effect on liking. On the one hand, the ‘mere exposure effect’ is a widely evidenced principle showing that just being exposed to a new and neutral stimulus is enough to increase liking for it (Zajonc, 1968). In music research, familiarity is one of the most powerful predictors of musical preference. On the other hand, repeated listening is thought to lead to boredom and satiation, suggesting an inverted U-shaped relationship between familiarity and liking as well. Based on the inference that more familiarity leads to less perceived complexity, Madison and Schiolde (2017) tested the interaction of musical complexity and familiarity on liking.

However, they found no evidence of a U-shaped relation, suggesting that familiarity may override effects of complexity in determining musical preference. Therefore, it is unclear whether exposure to syncopated groove-based music will lead to overall increases in liking or a change in the shape of the inverted U-shape.

Music Exposure in Ghana and the US

In order to record musical exposure, researchers have used the Experience Sampling Method (ESM) (Csikszentmihalyi, Larson, & Prescott, 1977; Juslin, Liljeström, Västfjäll, Barradas, & Silva, 2008; Rana & North, 2007). By paging or texting participants at random times, prompting them to document their current musical environment, researchers record how often and what type of music people hear or listen to during the course of their day. While we are not aware of an ESM music study in the region where we recruited our American group (Massachusetts, USA) there are studies of British populations (Greasley & Lamont, 2011;

Sloboda, O'Neill, & Ivaldi, 2001), whose listening habits have been shown to largely align with those of Americans (Bonneville-Roussy et al. 2013). Greasley & Lamont (2011) found that UK students were exposed to music 35% of the times sampled with ESM. They mostly listened to pop music (19.2%), followed by Soundtrack (9.2%), Rock (6.3%), Indie (5.4%), Drum'n'Bass (5.4%), RnB (5%), Classical (4.2%), Dance (3.3%), other Pop/Rock (2.9%) and other Rock/Indie (2.9%).

We have a good understanding of the musical exposure of our Ghanaian group, due to an ESM study with students at Cape Coast University, among whom we recruited our participants around the same time. Carl and Kutsidzo (2016) report that their participants were exposed to music 53% of the times sampled. The most common types of music exposed to were Gospel (38%), Hiplife/Hiphop (21%), RnB/country/'cool' (13.1%), Highlife (10.7%), Reggae (4.9%) and traditional music (3.9%) (see also Otchere & Carl, 2016). In addition, they found that dance accompanied 30% of music episodes, primarily in church. Compared to Western students, then, it appears Ghanaian university students and staff are exposed to music, and particularly groove-directed music, more frequently. Furthermore, dance seems to be a more common activity with which music is enjoyed, especially in religious contexts.

Cross-Cultural Rhythm and Pleasure Research

Music exposure is the primary factor used to explain cross-cultural differences in music psychology research. In general, listeners' rhythmic priors (or expectations) reflect preferences for ratio complexities that are present in the music that they are the most familiar with (Hannon, Soley, & Ullal, 2012; Hannon & Trehub, 2005b, 2005a; Jacoby & McDermott, 2017; Polak et al., 2018). Cultural familiarity can also affect how people synchronize to rhythms (Drake & El Heni, 2003). Cameron et al (2017) found that familiarity was associated with more accurate finger tapping in two groups of East African (Rwandan)

and North American (Canadian) participants. However, greater familiarity does not always mean better synchronization. Will et al. (2015) found that North Indian musicians were in fact less synchronized than American musicians when tapping to North Indian music, reflecting greater inter-individual phase variability and more flexible response strategies in the North Indian group. In other words, while familiarity might be an important predictor of synchronization accuracy in some cultures and contexts (Kirschner & Ilari, 2014), performance style idiosyncrasies might override familiarity in others (Clayton, Sager, & Will, 2004; Will, 2017).

To date, few studies have addressed groove cross-culturally; Etani et al. (2018) compared Western groove to the overlapping Japanese concept known as *nori*. Compared to Western groove, *nori* has a distinctively directional character, with different types of *nori* being associated with either vertical or horizontal body-movement. Furthermore, the authors found that while both correlated with ratings of pleasure and wanting to move, the correlations for pleasure were weaker for *nori*, suggesting some cultural difference in its affective significance.

Cross-cultural studies of musical pleasantness more broadly show both consistency and diversity across groups. While Fritz et al. (2009) found that Cameroonian Mafa and Western listeners (nationalities not stated) both rated consonant music more pleasant than dissonant (spectrally manipulated) music, McDermott et al. (2016) found that indigenous Amazonian Tzimané living in a remote village in the Amazonian rainforest showed lower preference for consonant music compared to city-dwelling Bolivians and Americans. This study supports a culturally determined view of musical pleasure arising from consonance produced by harmonic frequencies.

The nuance with which researchers define the cultural categories applied in cross-cultural music studies is mixed. Some have compared a specific African population to a

wider ‘Western’ population made up of a mix of nationalities from Western Europe and North America, without specifying which Western countries their sample is taken from (Fritz et al., 2009). Studies investigating musicians are often better able to draw conclusions about population differences, since musical training provides a more concrete indication of musical exposure than enculturation through listening (Polak et al., 2018; Will, 2017). It is also common to recruit what is often referred to as ‘uncontacted’ or ‘isolated’ groups whose musical exposure is free from any ‘cross-pollination’ from global musical trends, usually with the goal of assessing universalist hypotheses (Fritz et al., 2009; McDermott et al., 2016). However, cultural isolation is the exception and not the norm. In our research, we treat the partial overlap in musical exposure between Ghanaian and North American listeners not as an impediment to cross-cultural conclusions but as a more realistic representation of cultural context.

The Ethics of Cross-Cultural Music Research in Africa

Depending on how they are defined, the recruitment of isolated groups in cross-cultural psychology can be seen as an example of pigeon-holing. Along with stereotyping, pigeon-holing poses significant ethical implications to cross-cultural research. One significant risk is that results from cross-cultural studies can be used to vindicate or perpetuate harmful stereotypes or to oppress the cultural groups they differentiate (Matsumoto & Leong Jones, 2009). For example, recorded IQ differences between black and white Americans have in the past been incorrectly related to race, which has enabled misinformed readers to develop racist interpretations (Ma & Schapira, 2017). Cross-cultural psychology researchers thus have a responsibility to design experiments and devise interpretations that minimize harmful and unjustified stereotyping (Matsumoto & Leong Jones, 2009).

There is a history of stereotyping in the early ethnographic research of Comparative Musicology, which aimed to classify the properties of the world's musics by comparing different cultures, usually against a Western 'norm' and often according to evolutionist agendas (Savage & Brown, 2013; Toner, 2007). Music theorist Kofi Agawu (2003) has accused Ethnomusicology of exoticising African music by relying on myths stemming from this early research in Africa. For example, he challenged the view that West-African music is polymetric (involving multiple simultaneous meters) and argued instead that it is polyrhythmic (involving multiple rhythms with different subdivisions that have the same meter). Agawu claimed that many of the misconceptions stem from Western scholars' continued investment in defining Africa as an exotic and complex 'other' (Agawu, 2003, p. 86). While there is truth in many of Agawu's claims, he has been criticized for ignoring more recent, postcolonial Ethnomusicology, which explicitly rejects cultural exoticism (Erlmann, 2004; Meintjes, 2006). Today, most African music scholars agree that African and Western music share many basic structural properties, such as the presence of a main beat (Agawu, 2006; Kubik, 2010). Early comparative musicologists, however, worked from a presumption that Africans were essentially different from Europeans, and so their work tended to ignore such similarities.

Conducting ethically sensitive cross-cultural psychological experiments may seem like a tall order. One might even question the implications of the most basic principle of experimental science, hypothesis-testing, which by definition requires making assumptions (or predictions) about differences between study populations or between theories. Directional research hypotheses are the most powerful statistically, but they are especially biased, as they make predictions about the direction of difference (e.g. group one is more synchronized than group two). Non-directional hypotheses expect a difference but do not predict the direction of the difference (e.g. the two groups synchronize differently but it is unclear which group is

more synchronized). Platt's model of 'strong inference' (Platt, 1964) highlights the benefits of pitting competing hypotheses against each other (group one tends to synchronize to music and group two does not, versus neither group tends to synchronize). For cross-cultural researchers, it is important to ensure that their hypotheses – whether directional or not – are based on valid assumptions as opposed to unfounded stereotypes (Matsumoto & Leong Jones 2009).

In order to further avoid misrepresenting difference in cross-cultural research, Matsumoto and Leong Jones (2009) encourage researchers to emphasize effect-sizes rather than statistical significance, and where possible, account for the specific aspects of behaviour that drive the demonstrated group differences. We further suggest reporting confidence intervals, because they indicate the range of possible 'true' differences, thus stipulating the precision of the group statistics as estimates of their total populations (Altman, Machin, Bryant, & Gardner, 2013). A nuanced operationalisation of culture - one that represents specific behaviours and practices and not just nations or regions - can help to specify explanations (Will, 2017), and involving local collaborators in the research process can further prevent making ill-informed assumptions about what cultural categories are meaningful (Matsumoto & Leong Jones, 2009).

Research Question, Aims and Hypotheses

In the current studies, we have attempted to follow these recommendations and pursue an ethically informed comparison of responses to syncopation among one Ghanaian and one American group. We chose the groups partly for theoretical reasons – they represent different levels of exposure to groove-based music – and because of opportunity: at the time of data collection, the researchers responsible for collecting the data were based in Aarhus, Denmark (Witek) and Williamstown, US (Liu). Ghana is a former colony of Denmark, and there are formal links (e.g. exchange programs, joint performance groups) between the Royal

Academy of Music in Aarhus, Denmark, and music organisations in Cape Coast, Ghana. We defined our cultural groups similar to Polak et al. (2018, p. 4), with country of residence ‘only as a rough proxy of partly overlapping yet partly non-overlapping social fields and music-cultural environments’. While there is significant overlap in the cultural influences of American and West-African groove-based music, Ghanaians appear to be more exposed to groove-based music and dance overall (Carl & Kutsidzo, 2016).

Our research question was: Considering that there is both overlap and non-overlap in the popular groove-based musics of Ghana and the US, how do Ghanaians and Americans compare in their sensorimotor and groove responses to syncopation in music? We aimed to compare responses to syncopation between our groups using measures of sensorimotor synchronization, ratings of stability as well as ratings of the sensation of groove.

Being mindful of the pitfalls in cross-cultural research and the tendency to rely on stereotypes when comparing African and Western musical experiences, we based our predictions on previously demonstrated differences in exposure; Ghanaian students are more exposed to groove-based music (Carl & Kutsidzo, 2016) than British students (Greasley & Lamont, 2011), who have comparable music listening preferences to Americans (Bonneville-Roussy et al. 2013). Exposure has been shown to both increase (Cameron, Bentley, & Grahn, 2015) and reduce synchronization accuracy (Clayton et al. 2004; Will, 2017). In other words, different cultures value the accuracy of synchronization to differing extents. Therefore we posed a non-directional hypothesis for study 1:

Research hypothesis 1: We predicted that Ghanaians and Americans would synchronize to syncopated patterns differently, but we made no predictions as to how this difference would manifest. We tested this in Study 1 by measuring finger-tapping and ratings of stability in response to rhythmic patterns with syncopations occurring at different metrical

locations, among different number of instrumental streams and with different instrumental configurations. The design of Study 1 is based on Witek, Clarke, Kringelbach & Vuust, 2014.

There is also disagreement regarding the interaction between familiarity and complexity in music enjoyment. While some show that there is an inverted U-shaped relationship between structural complexity and liking (North & Hargreaves, 1995) and between syncopation and groove specifically (Matthews et al., 2019; Witek, Clarke, Wallentin, et al., 2014), others have found that the effect of familiarity overrides the effect of complexity (Madison & Schiölde, 2017). Therefore, we also posed a non-directional hypothesis for study 2:

Research hypothesis 2: We hypothesized that Ghanaians and Americans would differ in their sensation of groove in response to varying levels of syncopation, but we made no predictions as to whether this would amount to an overall difference in ratings or a difference in the shape of the U-shaped response. We tested this in Study 2 by recording how much the two groups wanted to move and how much pleasure they experienced in response to rhythmic drum-kit patterns varying in degree of syncopation (low, medium and high). The design of Study 2 is based on Witek, Clarke, Wallentin, Kringelbach, Vuust, 2014.

We continue to use the term ‘syncopation’ in order to maintain consistency with previous research, but acknowledge its shortcomings in a West-African music context. As mentioned, syncopated patterns are conceptualised somewhat differently in African music theory (e.g. contra-metricity), and may not be experienced as violating of metric expectations (London et al., 2017).

Study 1: Finger-tapping and ratings of stability among Ghanaians and Americans in response to syncopation

Methods

Participants

We recruited 28 right-handed participants, exclusively non-musicians and non-dancers with normal hearing and English as their primary language. Data from three participants (two from the US, one from Ghana) were excluded entirely due to problems with recording of the tapping data, leading to a final N of 25 for Study 1. Non-musicians were defined as persons with less than one year of formal or informal musical training and not currently practising music formally. Non-dancers were defined as persons with less than one year of formal dance training and not currently practising dance formally.

Thirteen persons (12 after one was excluded) were recruited at Cape Coast University, Ghana, aged between 19-35 (7 female). They were from a variety of regions, including Central, Ashanti, Volta, East and West regions. They had all completed education at high school level, minimum. The Ghanaian participants consisted of four students, three teachers, three administrators, two service workers and one research assistant. We exclusively recruited Ghanaians who were born and raised in Ghana, had Ghanaian parents and had spent a minimal amount of time outside Ghana.

Fifteen persons (13 after two were excluded) were recruited at Williams College, US, aged between 18-23 (6 female). They were from a wide variety of States, including Massachusetts, California, Pennsylvania and Texas. All of the American participants were undergraduate students, and had thus completed high school education. We exclusively recruited Americans who were born and raised in the United States, had American parents and had never visited West Africa nor were familiar with West African music.

The small sample size was a result of limited time to collect data in Ghana. Thus, the results of this study should be considered preliminary, and will need to be replicated before strong conclusions can be drawn.

All participants were asked to indicate their familiarity with groove and dance on 5-point scales, asking ‘how often do you listen to groove-based music/dance to music’ (from ‘never’ to ‘very frequently’) and ‘how much do you like groove-based music/dancing to music’ (from ‘not at all’ to ‘very much’). For groove-based music, we gave the following examples; funk, soul, hip-hop, electronic dance music, reggae, hiplife, highlife, RnB and African drumming. Frequency of listening to and liking groove music correlated ($r = 0.510$, $p = .008$), as did frequency of and liking dancing ($r = 0.419$, $p = .033$). As in previous studies (Matthews et al., 2019; Witek, Clarke, Wallentin, et al., 2014), we performed principal component analyses (PCA) on the two pairs of measures (groove familiarity with groove liking, and dance frequency with dance liking) to reduce the number of covariates in our analysis. The two paired measures were entered into two separate PCAs, and we used the first principal components as the resulting continuous fixed effects, one representing groove listening and another representing dance experience.

Participants also completed the rhythm part of the Musical Ear Test (Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010), which involves listening to 52 pairs of rhythmic patterns of varying complexity and indicating whether they are same or different. MET performance is scored as amount of correct responses, with 32 as chance level. Performance on the MET test has previously been shown to indicate rhythmic skill (Wallentin et al., 2010), and could thus influence our participants’ responses to rhythmic syncopation.

With independent t-tests, we investigated demographic and skill differences in the two groups (Table 1). Only age was found to be significantly different between the two

groups, with the Ghanaian participants being on average 5 years older than the American group. This may further add to the greater amount of overall exposure to groove-based music in the Ghanaian group. However, since sensorimotor synchronization abilities remain relatively stable after the late teens (Drewing, Aschersleben, & Li, 2006; Repp & Su, 2013), we do not expect age to confound any of our demonstrated results. This was also corroborated by the lack of difference in the groups' MET scores. However, the lack of difference in MET will need to be replicated with a bigger sample before we can draw firm conclusions about the rhythm discrimination abilities in American compared to Ghanaian groups.

Stimuli

The same stimuli and procedure were used for this study as in Witek, Clarke, Kringelbach and Vuust (2014). Stimuli can be downloaded from OSF on <https://osf.io/zerh4/>. Participants heard 55 rhythmic patterns constructed using the software GarageBand 5.1 (Apple, Inc.) in 4/4 time at a tempo of 120 bpm. The sounds used for the different instruments were the standard bass drum, snare drum and hihat sounds of the 'Rock Kit' in GarageBand. The bass drum sound lasted for 212 ms, the snare drum 73 ms and the hihat 67 ms, with rise times of 24 ms, 2 ms and 1 ms, respectively.

Each trial started with one measure of a voice counting in to four on the main quarter note pulse, followed by one measure of a metronome on the quarter note pulse, followed by the pattern itself. Each rhythmic pattern was then presented four times in a continuously repeating fashion. Rhythmic events occurred only on the quarter notes, apart from at the syncopations, where one instrumental event occurred on the preceding sixteenth-note. We chose to test sixteenth-note syncopation as opposed to eighth-note syncopations, because a pilot study had shown that sixteenth-note syncopations were perceived as more destabilising.

In any given pattern, a syncopated event occurred on the sixteenth-note before any one of the four quarter notes, as played by one of the three instruments of the drum kit – bass, snare or hihat – and in the context of one, two or three instrumental streams. Each possible combination of instruments was included for the different conditions. We also included entirely isochronous patterns, i.e. with no syncopations, in all stream- and instrumentation conditions, as a control. Each stimulus, consisting of the introductory count in, the bar of metronome and the repeated pattern, lasted 12 s.

Figure 1 shows the different polyphonic and instrumental configurations in which syncopations occurred on the second quarter note, as an example. In the actual experiment, participants heard a series of patterns in which syncopations occurred on all four quarter note positions (one per pattern) within the possible stream and instrumental configurations.

Procedure

Following instructions and training, participants performed the task on a computer, by tapping along with the metronome and throughout the subsequent rhythmic pattern, after the voice had counted them in, with their right index finger on the computer keyboard.

Importantly, they were instructed to always tap to the main pulse of the rhythm and to tap to beat 1 (the downbeat) on the G key, with the rest of the beats on the J key, in order to ensure that they performed according to the intended metrical framework (i.e. that they timed the downbeat to the correct metrical location). Despite having no musical training, participants were overall able to tap on these relatively small keys with ease. Between patterns, which were fully randomized, a continuously variable visual analogue rating scale (VAS) appeared on the screen, with which participants had 12 s to rate the perceived ‘stability’ of the rhythmic patterns. The endpoints of the scale were marked with plus and minus signs, and participants used the arrow keys on the keyboard to move the rating indicator to the judged

position on the scale. Stability ratings have been successfully used previously to test effects of syncopations (Witek, Clarke, Kringelbach, et al., 2014).

Ratings and tapping performance were recorded using Presentation (Neurobehavioral Systems, Inc.) on a computer running Windows. Presentation measures timing with a latency of below 1 ms. The continuous ratings were recorded onto a scale from -4 to 4, where -4 corresponded to the most negative position and +4 to the positive position on the VAS. The stimuli were presented to the participants over high quality headphones and at a comfortable volume, which was held constant across participants. This study lasted just over 20 minutes.

Analysis

All tapping trials in which participants did not tap according to the intended metrical framework or made other obvious tapping mistakes (e.g. tapped the downbeat repeatedly or missed the downbeat entirely) were removed from further analysis (9.5% of all trials). Tapping mistakes could be automatically identified due to the different key tapped at downbeats. We then used circular statistics (Fisher, 1995) in MATLAB to measure the synchronization between tapping and the main pulse of the stimuli. Using this approach, each tap is mapped onto a circular scale, with a range between -3.14 and 3.14 radians (or -1π to 1π), with the pulse beat at 0, and negative and positive radians values indicating early and late taps, respectively. We were interested in both the precision and accuracy of participants' synchronization. Precision, i.e. the consistency of the temporal distribution of taps, is represented in the 'mean resultant length' (MRL) of the 'mean resultant vector' of the taps on the circular scale. Synchronization accuracy is a measure of the asynchrony from the tapping target, represented by the phase angles of the taps on the circular scale. The MRL is a linear measure, ranging from 0 – 1, with higher scores indicating greater synchronization precision. Angular data are circular (here reported in radians), but by transforming to absolute values,

linear models could be applied. We calculated Rayleigh's test statistic on all tapping trials and confirmed that all trials were statistically significantly non-uniform (all p 's < 0.05).

To test our effects, we performed linear mixed effects analysis in R (Bates, Mächler, Bolker, & Walker, 2014), separately for MRL, absolute phase angle and stability ratings, with metric location (beat1, beat2, beat3, beat4), number of streams (1stream, 2streams, 3streams), instrumentation (hihat, snare, bass) and group (Ghana and US) as fixed effects and by-subject intercepts as the random effect. The study had an unbalanced design, due to the different number of combinations of instrumentation for the different stream conditions. We also included three continuous fixed effects; groove listening, dance experience (which had previously been prepared using PCA) and MET scores.

The total number of fixed effects (group, metric location, number of streams, instrumentation, MET, groove listening and dance experience) was seven. Thus, in order to avoid an overly complex model, we started off by setting up three models separately with the following fixed effects: 1) metric location, group, groove, dance, MET, 2) stream, group, groove, dance, MET, and 3) instrumentation, stream, groove, dance, MET. In model 3, we tested instrumentation-by-stream instead of by-group (as in the other two models), since instrumentation had been found to interact with number of streams previously (Witek, Clarke, Kringelbach, et al., 2014), and we did not expect differences between the two groups to depend on instrumentation. Finally, we set up a grand model 4) including all terms found to be significant in models 1-3, also using the forward hierarchical approach. The statistical significance of each fixed effect within each model was tested hierarchically, starting off with a random intercept-only model, then adding fixed effects incrementally. Increases in model fit were assessed from Chi square and p values estimated with a likelihood ratio test. The residuals were found to be non-normal and there was evidence of heteroscedasticity of variances, thus the MRL data were transformed using arcsine and Box Cox transformations,

with $\lambda = 3$ (Box & Cox, 1964; Venables & Ripley, 2002). The absolute angle data were transformed using hyperbolic arcsine and Box-Cox transformation with $\lambda = 0.5$. We confirmed that the transformed values produced comparable results to non-transformed values.

We specified Helmert contrasts for metric location, number of streams and instrumentation, and pairwise contrasts for group, using the `emmeans` package (Lenth, Singmann, Love, Buerkner, & Herve, 2018) and scaled coefficients. Confidence intervals were calculated using degrees of freedom approximated with the Satterthwaite method and were adjusted for multiple comparisons using the multivariate *t* method.

An identical approach was used for analysing the stability ratings. The rating data residuals were normally distributed and the variances homoscedastic, hence no transformations were used.

In a supplementary mixed effects model, we tested whether tapping to syncopated patterns reduced synchronization and stability ratings compared to the control patterns without syncopations (i.e. isochronous beat). This could not be investigated in the main analyses described above, because the instrumentation condition introduced different effects in the syncopated compared to unsyncopated patterns. See supplementary materials for a description of this analysis.

Results

We report results from the grand mixed effects model of finger-tapping synchronization, which includes all terms that were found to be significant in previous models. Significant terms for MRL included group ($\chi^2(1) = 6.10, p = 0.013$), metric location ($\chi^2(3) = 21.70, p < .001$), stream ($\chi^2(2) = 142.83, p < .001$) and a group-by-stream interaction ($\chi^2(2) = 12.05, p = 0.002$). Neither instrumentation nor any of the covariates (dance

experience, groove familiarity and MET score) were significant. The regression coefficients for each contrast are reported in Table 2. We found that Ghanaians' synchronization precision was greater compared to Americans, with a medium effect, but this difference did not reach statistical significance following correction for multiple comparisons. For metric location, it was found that tapping to patterns with syncopations on beat1 was less precise than tapping to patterns with syncopations on beat2, beat3 and beat4 (Figure 2). We found an overall increase in synchronization precision to two- and three-stream syncopated patterns compared to one-stream syncopated patterns, with a medium effect. There was also a significant interaction between group and number of streams (Figure 2), showing that the deteriorated synchronization precision to one-stream syncopated patterns was significant for both groups but greater for the American than the Ghanaian participants, with a small-to-medium effect.

Significant terms for absolute phase angle included metric location ($\chi^2(3) = 32.313, p < .001$) and stream ($\chi^2(2) = 67.765, p < .001$), but no effects of group or interactions. Table 3 reports regression coefficients. We found that tapping to patterns with syncopations on beat 1 had an absolute phase angle on average further away from the tapping target, i.e. producing less accurate synchronization, than on beats 2, 3 and 4 (Figure 3). Furthermore, tapping to one-stream syncopated patterns produced phase angles further away from the tapping target than two- and three-stream syncopated patterns. These effects were small.

While it was not possible to perform linear mixed effects on the relative (signed) angle data, due to their circular nature, we plotted the distribution of data points for each trial in each factor to illustrate the general tendencies of relative angle, using raincloud plots (Figure 4) (Allen, Poggiali, Whitaker, Marshall, & Kievit, 2019). Visual inspection of the distributions suggests that the asynchronies were generally negative, i.e. anticipatory, for group, number of streams, metric location and instrumentation. On the graph, Americans'

tapping is clustered around - 0.5 radians, while the distribution of angle data for the Ghanaian group suggests bimodality, with one cluster around 0 radians and another around -1 radians. However, this bimodality was not found to be statistically significant according to the Hartigan's Dip Test Statistic for Unimodality (R package "diptest" by Maechler, 2015) and as reported in the methods above, the Rayleigh's test was significant across all trial. We further investigated the distributions by plotting the groups by the number of streams in Figure 5. This indicated that while Ghanaians tapped close to the tapping target (0 radians) during two- and three-stream syncopations, there was notable variability of phase angles and no clear single mode during one-stream syncopations. Further manual inspection of this condition confirmed that this uniformity was not due to intra-individual but inter-individual differences in phase angles (again corroborated by the Rayleigh's test). There appeared to be no difference in modality for the American group, with the distributions peaking at -0.5 for all stream conditions.

The grand mixed effects model of stability ratings showed significant terms for metric location ($\chi^2(3) = 20.065, p < .001$), stream ($\chi^2(2) = 143.450, p < .001$ and instrumentation $\chi^2(2) = 7.595, p = .022$). There were no effects of group, no interactions and no effects of covariates. Table 4 reports regression coefficients for the planned contrasts, and shows that patterns with syncopations on beat1 were rated as being more stable than patterns with syncopations on all other beats (Figure 6). Furthermore, syncopations on beat 3 were rated as less stable than beat 4. Consistent with the tapping synchronization data, we found a decrease in stability ratings for one-stream compared to two-stream and three-stream patterns (Figure 6). Finally, hihat syncopations were rated as more stable than bass and snare drum syncopations (Figure 6). The regression coefficients for these effects were small-to-medium sized.

Supplementary materials report the full results of the comparison of syncopated versus nonsyncopated patterns, for MRL, absolute phase angle and stability ratings. To summarise, patterns with no syncopations produced significantly higher MRL and stability ratings compared to all other syncopated patterns, especially during one-stream patterns. The difference in stability ratings for nonsyncopated compared to syncopated patterns was greater for Americans than for Ghanaians. Phase angles were smaller for patterns with no syncopation compared to patterns with syncopation, and larger for one-stream syncopated patterns compared to two- and three-stream patterns.

Discussion

In Study 1, we found main effects of number of streams for MRL, absolute phase angle and stability ratings, statistically significant with medium size coefficients. This means that when syncopations were not accompanied by any other instrument emphasising the beat, both the precision and accuracy of sensorimotor synchronization as well as the perceived stability was reduced. This finding replicates our previous study (Witek, Clarke, Kringelbach, et al., 2014). More importantly, we supported our hypothesis by demonstrating that Ghanaians and Americans differ in synchronization responses to syncopated patterns. Our comparisons with the isochronous control conditions, reported in supplementary materials, confirm that these effects are due to syncopation specifically, as opposed to rhythm more generally.

The most significant finding was that the reduction in synchronization precision (MRL) was greater for Americans compared to Ghanaians during one-stream syncopated patterns, as evidenced by the significant interaction with medium effect size between number of streams and group. This supports our hypothesis 1 that there are synchronization differences between the two groups and further indicates that the difference is dependent on the number of instrumental streams. Our findings suggest that Ghanaian listeners are able to

perceive and reproduce a regular beat in a temporally more consistent way when it is only partly emphasized by acoustic sound. Many African music scholars have noted a resilience of beat perception despite the rhythmic complexity in West-African music (Kubik, 2010; Waterman, 1952), and studies show that students at Cape Coast University are exposed to traditional Ghanaian music 3.5% of the time (Carl & Kutsidzo, 2016). According to Kubik (2010), the basic, regular pulse is significant in West-Africa precisely because it does not need to be emphasized by instruments but can be totally silent and instead embodied in listeners' imagination or body-movements. Our results are consistent with this observation, and might be further explained by the increased exposure to dance among students at Cape Coast university (Carl & Kutsidzo, 2016). Since we found no group differences in rhythmic discrimination abilities as measured by the MET Test, as well as no group differences in tapping to isochronous rhythms (control condition), any difference in synchronization is unlikely due to a difference in basic rhythmic skills but may rather be a result of differences in exposure to syncopated rhythm, such as in groove-based music, or exposure to dance (Carl & Kutsidzo, 2016). However, it should be noted that we did not find any differences between our groups with regard to self-reported frequency of listening to and liking of groove-based music or frequency of dance and liking dance, but since this was recorded on a relative rating scale (from not at all/never to very much/a lot), any between-group differences may not have been adequately addressed, due to possibly different response biases in the groups.

An important caveat to the conclusion that Ghanaians are better able to synchronize to syncopated patterns than Americans is the finding that there was no group difference nor group-by-stream interaction for absolute phase angle data, i.e. synchronization accuracy. Furthermore, visual inspection of the distribution of relative phase angle trial data suggested that while Ghanaians tapped close to the tapping target during two- and three-stream syncopations, there was more variability in relative phase angles and no clear pattern during

one-stream syncopations (and this may have caused the lack of significant group-by-stream effects in the mixed effects model for absolute angle data). In other words, despite being more temporally consistent in their finger-tapping (as shown in the MRL data), Ghanaians' synchronization did not appear to be very accurate during monophonic syncopations. This did not appear to be due to intra-individual variability in the asynchronies of the Ghanaian group, as indicated by both manual inspection and the increased consistency in synchronization found in the MRL data. Instead, it appeared to be a result of inter-individual differences, with some participants tapping at a more negative angle than others. This combination of highly consistent tapping across the group but with inter-individual differences in tapping asynchrony may be an indication that when syncopations are not accompanied by another instrumental stream emphasising the beat, there is more flexibility in the temporal position of the beat to which Ghanaians synchronize. This observation does not support the conclusion that greater exposure to groove-based music leads to unambiguously 'better' synchronization to syncopated patterns, but instead falls in line with research showing that different cultures value synchronization in different ways (Will, 2017; Will et al., 2015). However, it does still support our non-directional hypothesis that Ghanaians' tapping would be different to Americans.

With regard to effects of metric location, we found that both precision (MRL) and accuracy (absolute phase angle) were reduced for syncopations occurring on beat 1 compared to beat 2, 3 and 4, suggesting that syncopations on the downbeat were perceived as the most disruptive to the sense of beat, regardless of group. However, these effects were small. The results are broadly in accordance with findings from Witek Clarke, Kringelbach and Vuust (2014), where little difference in metric salience was found beyond the downbeat being more salient in general. They are also in alignment with studies on Malian drumming music, in which beat 1 is the metric position at which onsets most frequently occur (London et al.,

2017). The similarity in responses in our two groups may be a reflection of the shared basic metric frameworks of much West-African and Western music (Polak et al., 2018). In particular, contemporary popular music in Ghana, such as Gospel and Hiplife, share a similar metric structure to North American RnB and Hiphop, with repeating rhythmic patterns in a 4/4 time signature and a strong downbeat. Our research suggests that the downbeat is the most and possibly only salient position in the metric expectations of non-musician listeners in both North America and West Africa.

However, our participants' stability ratings in response to syncopations on different metric locations reflected a different pattern than the synchronization MRL and phase angle data. While still showing no between-group difference, patterns with syncopations on beat 3 were rated as the least stable, and patterns with syncopations on the downbeat were rated as the most stable. These effects were also small. Furthermore, since stability ratings rely on conscious reflection and subjective report, they could be more susceptible to noise than the more implicit measure of sensorimotor synchronization. Nonetheless, the patterns of synchronization effects we found for metric location need to be replicated with a larger sample before more confident conclusions can be drawn.

For instrumentation, we found that syncopations in the hihat were perceived as less destabilising than syncopations in the bass- and snare drum, in accordance with our older study (Witek, Clarke, Kringelbach, et al., 2014). However, the coefficient for this result was small. Sensorimotor synchronization has previously been found to be more affected by lower than higher frequency sounds, consistent with the superior and earlier physiological encoding of lower compared to higher pitches (Hove, Marie, Bruce, & Trainor, 2014). We found no between-group differences for instrumentation, and in contrast to the earlier study, we found no interaction between instrumentation and number of streams (Witek, Clarke, Kringelbach, et al., 2014).

We interpret the differences found in this study between Ghanaians and Americans in relation to their differing degrees of exposure to groove-based music and dance (Carl & Kutsidzo, 2016). Our data suggests that the difference in exposure may affect the synchronization precision (MRL) and accuracy (angle) differently, and depends on the polyphonic context of the music. While previous research has shown that when tapping along to a beat, participants from Rwanda and Canada tapped more accurately to culturally more familiar than less familiar rhythms (Cameron et al., 2015), we show that, under certain conditions, Ghanaians tapped more consistently but not more accurately to music containing rhythmic structures that they are more exposed to. Specifically, during monophonic syncopations with no other instrument accompanying the beat, there was notable inter-individual variability in how far from the tapping target Ghanaians consistently placed their taps. This finding aligns with studies showing that different cultures may value the accuracy of synchronization to differing extents (Will, 2017; Will et al., 2015) and suggests that depending on context, increased exposure and familiarity does not necessarily lead to increased synchronization.

Study 2: Sensation of groove among Ghanaians and Americans in response to syncopation

In study 2, we compared Ghanaians and Americans on subjective ratings of groove in response to drum-kit patterns varying in levels of syncopation (low, medium and high). We aimed to test whether there would be an overall group difference in ratings, or whether the shape of the relationship between syncopation and groove ratings would change depending on the group.

Methods

Participants

The same participants and measurements for groove familiarity, dance experience and MET scores were used as in the finger-tapping study. No data was excluded from this dataset, but the sample ($N = 28$) is nonetheless small, and results must be interpreted as exploratory until replications can confirm the observed patterns.

Stimuli

The stimuli consisted of 15 rhythmic drum-kit patterns, taken from a larger pool of 50 drum-breaks used in a previous study with the same design (Witek, Clarke, Wallentin, et al., 2014). They can be downloaded from OSF on <https://osf.io/vnjek/>. The drum patterns were programmed using GarageBand 5.1 and consisted of bass drum, snare drum and hihat, with the hihat constant on the quarter note pulse. Each pattern comprised a two-bar phrase looped four times in 4/4 time, at 120 bpm, lasting 16 s in total. The 15 stimuli chosen were overlapping with but not identical to the 15 stimuli used in Witek et al. 2017.

Drum patterns were organized into three categories of syncopation degree (5 patterns in each category) – low, medium and high – calculated based on a modified version of Longuet-Higgins and Lee's (1984) syncopation index, according to which a rhythm's

syncopation degree depends on both the metric location and instrumental configuration of its syncopations (Witek, Clarke, Wallentin, Kringelbach, & Vuust, 2015; Witek, Clarke, Wallentin, et al., 2014). Notational transcripts of the patterns can be found in supplementary materials Figure S4. The mean (SD) syncopation degree for the three syncopation categories are as follows: low = 9.8(3.19), medium = 28.4(11.26), high = 69.2(9.84). The patterns' syncopation degree did not significantly correlate with the total number of notes in the patterns ($r = .024$, ns).

Procedure

Participants heard over good-quality headphones all 15 drum patterns once, in randomized order, and rated each pattern on a 5 point scale according to a) How much the pattern made them want to move ('not at all' to 'very much', and b) how much pleasure they experienced ('none' to 'a lot'), using pen and a paper answer-sheet. Drum patterns were presented using Presentation (Neurobehavioral Systems, Inc.).

Analysis

For the groove ratings, we performed linear mixed effects models with a maximal random structure and three categorical fixed effects: group (Ghana, US), syncopation (low, medium, high) and rating question (wanting to move, pleasure). Three continuous fixed effects were included: groove familiarity, dance experience and MET score. We specified by-subject random intercepts and slopes, as well as by-item random intercepts. Residuals were normally distributed. We tested each effect hierarchically, setting up a random structure model first, then adding each term and interaction incrementally, testing their significance with Maximum Likelihood Chi square and p-values. For the syncopation condition, we specified a

polynomial contrast, in accordance with previous research (Witek, Clarke, Wallentin, et al., 2014).

Results

Our mixed effects model showed significant contributions for group ($\chi^2(1) = 4.186, p = .041$) and syncopation conditions ($\chi^2(2) = 42.421, p < .001$), with no interactions. Planned contrasts show that Ghanaians rated the patterns higher than Americans overall, although this did not survive corrections for multiple comparisons, and that there was a negative quadratic relationship between groove ratings and syncopation (Table 5, Figure 7). There was no effect of rating question, hence results are reported for groove ratings as a combination of wanting to move and pleasure.

Discussion

The results from Study 2 showed that following correction for multiple comparisons, the increase in groove ratings for Ghanaians compared to Americans was not significant and the effect size was small. Therefore, our data did not support hypothesis 2. This suggests that the increased exposure to groove-based music and dance among Ghanaians (Carl & Kutsidzo, 2016; Otchere & Carl, 2016) may have little effect on how much synthesized drum-kit patterns elicits the desire to move and feelings of pleasure. Previous research shows that listeners prefer music to which they have been more exposed (Madison & Schiölde, 2017). Our research could not provide further support for this.

We replicated our previous results (Witek, Clarke, Wallentin, et al., 2014) by finding an inverted U-shaped relationship between levels of syncopation and ratings of wanting to move and pleasure. There was no interaction with group, hence Ghanaian and American listeners appear to both prefer medium levels of rhythmic complexity in groove, and the magnitude of this preference is similar for the two groups. Wanting to move and pleasure

were rated similarly across the levels of syncopation and the two groups. The shared inverted U-shaped relationship between syncopation and sensation of groove among the two groups suggests that despite Ghanaians' increased exposure to groove-based music and dance (Carl & Kutsidzo, 2016), syncopation affects Ghanaians' and Americans' wanting to move and feelings of pleasure similarly.

We did not find a group difference in rated groove enjoyment and listening frequency in the present study, but as noted in the discussion for Study 1, this may be due to the relative rating scales used. We also did not find an effect of rated relative dance experience on groove ratings, contrary to our previous study which showed that those who enjoy and often dance to music rate syncopated drum patterns as eliciting more groove overall (Witek, Clarke, Wallentin, et al., 2014). While the study by Carl & Kutsidzo (2016) suggests that dance is involved in 30% of the times that students at Cape Coast University are exposed to music, the extent to which students actively dance during these events was not tested. Therefore, the effect of active dance experience on groove sensation requires further study.

It could also be that the results of this study were affected by the self-report measure used to indicate wanting to move and pleasure. We used a relative rating scale (from not at all/none to very much/a lot), and it may be that the two groups used this scale in different ways, affecting the outcome. The terms rated, 'wanting to move' and 'pleasure', may have been interpreted differently among the two groups. While English is the first language of Ghana, many Ghanaians speak a number of other indigenous languages and there are cultural differences in how Americans and Ghanaians refer to emotional experiences (Dzokoto, Opare-Henaku, & Kpobi, 2013). However, these cultural differences are more likely to have affected the overall difference in responses rather than the shape of their response. Thus, while the non-significant increase in sensation of groove among Ghanaians must be

interpreted with caution, we can be more confident with regard to the similarity in the inverted U-shaped response to syncopation. Nonetheless, other more implicit or physiological measurements of emotion may offer further insights on any differences in sensation of groove among Ghanaians and Americans, as well as other groups.

General Discussion

In two studies, we show for the first time how syncopated patterns affect sensorimotor synchronization and the sensation of groove in people living in Ghana - a country whose musical traditions have impacted contemporary groove-based music. We found both similarities and differences in responses to syncopation and the sensation of groove among Ghanaian and American university students and staff. However, due to the small sample size, we recommend that our interpretations be considered with caution until the observed patterns are replicated with larger participant groups.

In Study 1, we show that Ghanaians were moderately more precise (i.e. temporally consistent) in their synchronization to syncopated rhythms than Americans when tapping to monophonic patterns in which syncopations had no other instrument emphasizing the underlying beat. This suggests that Ghanaians are more consistent in their synchronization to a beat when it is only partly emphasized acoustically. Since the two groups performed similarly on a test assessing their rhythmic discrimination abilities, this difference is unlikely due to a difference in rhythmic skill. Instead, it may be that the increased exposure that Ghanaians have to syncopated groove-based music and dance (Carl & Kutsidzo, 2016; Otchere & Carl, 2016) explains the increased synchronization precision to syncopated patterns seen in our study. Syncopations on the downbeat produced the least precise and accurate synchronization, regardless of group, suggesting that the most basic metric frameworks are shared among Ghanaians and Americans (Polak et al., 2018). However, this effect was small and was not replicated in stability ratings.

While Ghanaians showed greater synchronization precision than Americans during monophonic patterns, there appeared to be inter-individual variability in their accuracy during these same patterns. This suggests that exposure may not be sufficient in predicting all aspects of synchronized behaviour to rhythmic music patterns. A potential explanation for

this may be that different cultures may value and promote strict synchrony in different ways, depending on the musical context (Will, 2017; Will et al., 2015).

Study 2 found no group difference in ratings of wanting to move and feelings of pleasure in response to syncopated groove-patterns and no group difference in the inverted U-shaped relationship between syncopation and sensation of groove. This suggests that, although Ghanaians have more exposure to syncopated groove-based music (Carl & Kutsidzo, 2016), syncopation affects how much they want to move and how much pleasure they experience in a similar way to Americans. There is significant overlap in musical influence among West-African and American groove-based genres, and this overlap might be more significant than the difference in *amount* of exposure (Carl & Kutsidzo, 2016) in affecting wanting to move and pleasure in response to syncopated drum-kit patterns.

Our findings highlight the importance of how we define syncopation in cultural and musical contexts. Compared to Americans, syncopations were less disruptive to Ghanaians' sense of beat when they were heard in a monophonic context, as indicated by their increased synchronization precision in Study 1 (although the temporal placement of the consistently tapped beat in relation to the stimulus beat was variable across participants). This might suggest that syncopations did not violate metric expectations as strongly for Ghanaians. Therefore, syncopations might not be best defined in terms of violation of expectation in a Ghanaian context, echoing earlier suggestions based on research with music from another West-African country, Mali (London et al., 2017).

These results also align with claims by Africanist music theorists, some made more than half a century ago (Waterman, 1952), that we should be careful when modelling African music and African listeners according to Western conceptions of rhythm and meter (Arom, 1989; Kolinski, 1973; Locke, 2006). Longuet-Higgins and Lee's definition of syncopation according to metric expectancy violation (1984), for example, becomes problematic if the

metric expectations of some groups, such as Ghanaians, are not violated by syncopations (at least not to the same extent or in the same way). However, the fact that Western psychological models of syncopation do not apply to all types of music or listeners does not mean that those listeners have fundamentally different psychological mechanisms underlying their musical experiences. Instead, it means that we should reconsider how we define syncopation, psychologically.

This is supported further by our findings in study 2, in which both Ghanaians and Americans rated medium levels of syncopation as eliciting the most desire to move and the most pleasure, compared to low and high levels. Thus our study indicates, along with previous studies showing similar patterns (Matthews et al., 2019; Sioros et al., 2014; Witek, Clarke, Wallentin, et al., 2014), that in the context of groove, syncopations may be better understood in terms of beat reinforcement than beat violation.

With this research, we have attempted to show sensitivity towards the ethics of cross-cultural research and the colonial history of comparing African music listeners to Western listeners. While it may be impossible to fully reconcile hypothesis testing in psychological research with all ethical and historical considerations, acknowledging their existence and questioning our assumptions about cultural categories can help develop music psychology into a more inclusive and less Western-centric field.

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Table 1. Testing demographic differences in Ghanaian and American participants.

*Statistically significant at 95%, corrected for multiple comparisons.

	Mean(SD)		t(df)	95% Confidence intervals
	<i>Ghana</i>	<i>US</i>		
Age	26.00 (4.73)	21.20 (1.42)	3.257(11.34)	[1.568, 8.032]*
Groove Familiarity	0.10 (1.49)	0.13 (1.35)	0.067(20.41)	[-1.223, 1.146]
Dance Experience	0.02 (1.33)	0.03 (1.17)	0.096(20.07)	[-0.998, 1.094]
MET score	33.91 (4.66)	36.93 (4.40)	-1.674(20.96)	[-6.781, 0.732]

Table 2 Standardized regression coefficients and statistics for Helmert and pairwise contrasts investigating effects on synchronization, measured as MRL (mean resultant length).

Contrasts are shown for group, metric location, stream and group-by-stream interaction, corrected for multiple comparisons. *Statistically significant at 95%.

Term	Contrast	Estimate	95% Confidence Intervals
Group	Ghana > US	0.378	[-0.071, 0.828]
Metric Location	beat1 > beat2+beat3+beat4	-0.162	[-0.265, -0.059]*
	beat2 > beat3+beat4	-0.069	[-0.179, 0.041]
	beat3 > beat4	0.030	[-0.098, 0.157]
Stream	1stream > 2stream+3stream	-0.454	[-0.560, -0.348]*
	2stream > 3stream	0.012	[-0.098, 0.122]
Group*Stream	Ghana > US * 1stream > 2stream+3stream	0.256	[0.045, 0.468]*
	Ghana > US * 2stream > 3stream	0.094	[-0.126, 0.314]
	Ghana: 1stream > 2stream+3stream	-0.326	[-0.477, -0.175]*
	Ghana: 2stream > 3stream	0.059	[-0.099, 0.217]
	US: 1stream > 2stream+3stream	-0.582	[-0.730, -0.434]*
	US: 2stream > 3stream	-0.035	[-0.189, 0.118]

Table 3. Standardized regression coefficients and statistics for Helmert contrasts

investigating effects on synchronization, measured as absolute phase angle. Contrasts are shown for metric location and stream, corrected for multiple comparisons. *Statistically significant at 95%.

Term	Contrast	Estimate	95% Confidence Intervals
Metric Location	beat1 > beat2+beat3+beat4	0.062	[0.033, 0.091]*
	beat2 > beat3+beat4	-0.024	[-0.059, 0.007]
	beat3 > beat4	-0.006	[-0.042, 0.030]
Stream	1stream > 2stream+3stream	0.097	[0.067, 0.127]*
	2stream > 3stream	0.015	[-0.017, 0.046]

Table 4. Standardized regression coefficients and statistics for Helmert contrasts

investigating effects of syncopation on stability ratings. Contrasts are shown for metric location, number of streams and instrumentation, corrected for multiple comparisons.

*Statistically significant at 95%.

Term	Contrast	Estimate	95% Confidence Intervals
Metric Location	beat1 > beat2+beat3+beat4	0.286	[0.013, 0.558]*
	beat2 > beat3+beat4	0.008	[-0.281, 0.298]
	beat3 > beat4	-0.480	[-0.814, -0.146]*
Stream	1stream > 2stream+3stream	-1.273	[-1.550, -0.996]*
	2stream > 3stream	-0.252	[-0.541, 0.037]
Instrumentation	hihat > bass+snare	0.256	[0.005, 0.506]*
	snare > bass	0.024	[-0.265, 0.313]

Table 5. Standardized regression coefficients and statistics for quadratic and pairwise contrasts investigating effects of syncopation degree and group on groove ratings, corrected for multiple comparisons. *Statistically significant at 95%.

Term	Contrast	Estimate	95% Confidence Intervals
Group	Ghana>US	0.438	[-0.04, 0.921]
Syncopation Degree	Medium > Low+High	-1.779	[-2.292, -1.266]*

Figure 1. Instrumental configurations of syncopations in one-stream (a-c), two-stream (d-i) and three-stream patterns (j-k). Black bars = onsets on the quarter note pulse. Grey bars = syncopated onsets. Circles denote syncopations. a) Syncopated bass drum, b) syncopated snare drum, c) syncopated hihat, d) Syncopated bass drum with snare drum on the pulse, e) syncopated snare drum with bass drum on the pulse, f) syncopated bass drum with hihat on the pulse, g) syncopated snare drum with hihat on the pulse, h) syncopated hihat with bass drum on the pulse, i) syncopated hihat with snare drum on the pulse, j) Syncopated bass drum with snare drum and hihat on the pulse, k) syncopated snare drum with bass drum and hihat on the pulse, l) syncopated hihat with bass drum and snare drum on the pulse.

Figure 2. Effects of syncopation on finger-tapping synchronization, measured as MRL (mean resultant length), plotted as raw (not transformed) data. a) Effect of the syncopation's metric location and b) the number of instrumental streams interacting with group.

Figure 3. Effects of syncopation on finger-tapping synchronization, measured as phase angle (in radians), plotted as raw (not transformed) data. a) Effect of the syncopation's metric location and b) the number of instrumental streams in the pattern.

Figure 4. Data distributions for relative (signed) angle per group, number of streams, metric location and instrumentation, measured in radians. Raw trial data are plotted, overlaid with a box plot and supplemented with a distribution plot.

Figure 5. Data distributions for relative (signed) angle across group and number of streams. Raw trial data are plotted, overlaid with a box plot and supplemented with a distribution plot.

Figure 6. Effects of syncopation on stability ratings. a) Effect of the syncopation's metric location, b) the number of instrumental streams in the pattern and c) the syncopation's instrumentation.

Figure 7. Effects of group and syncopation degree on groove ratings (wanting to move and pleasure).

Figure 1

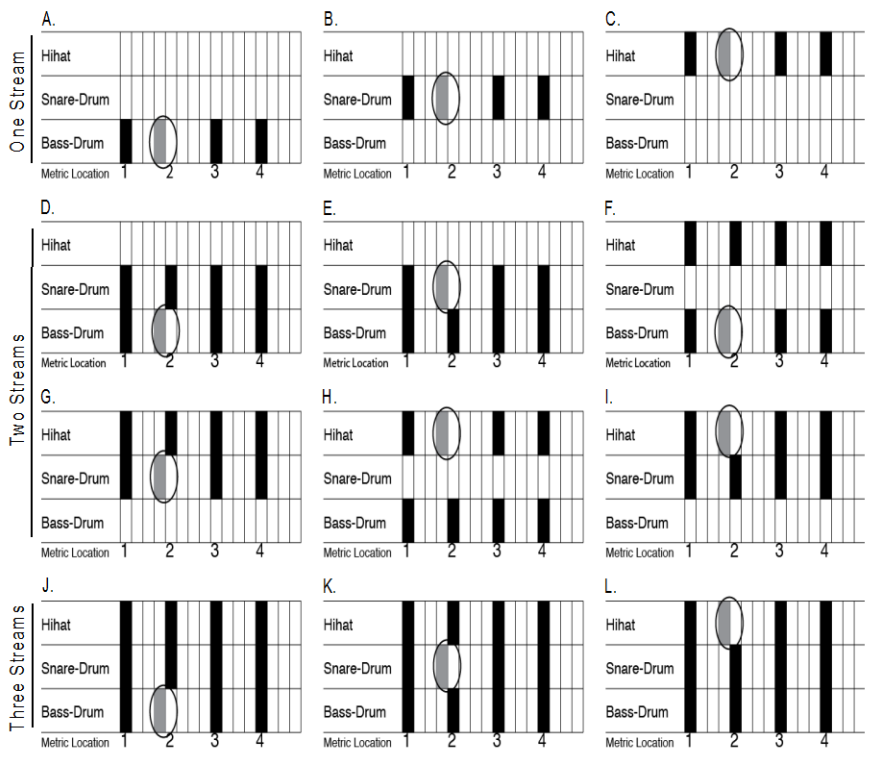


Figure 2

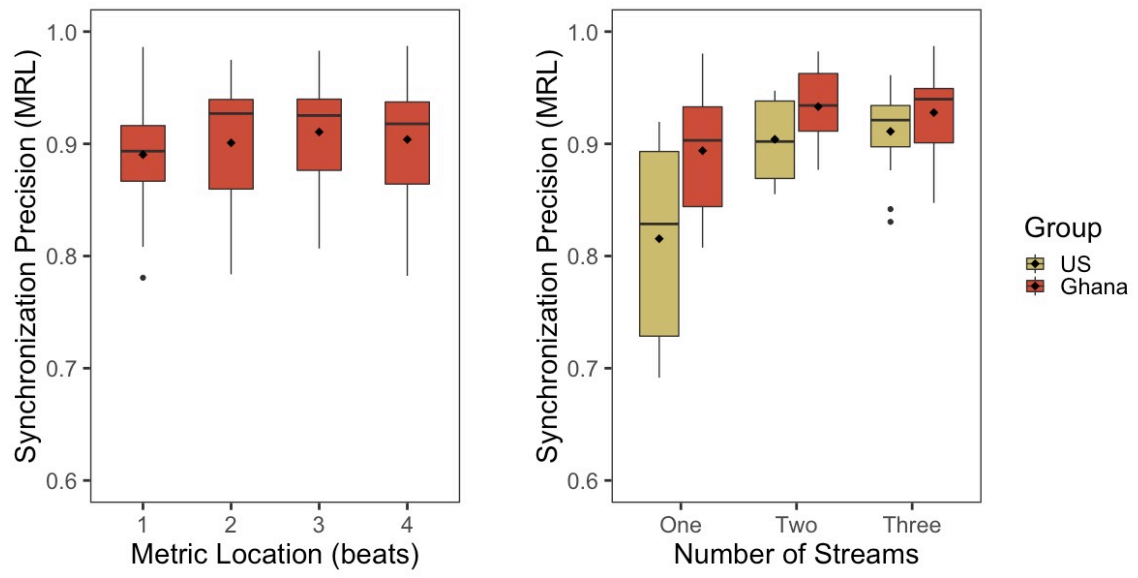


Figure 3

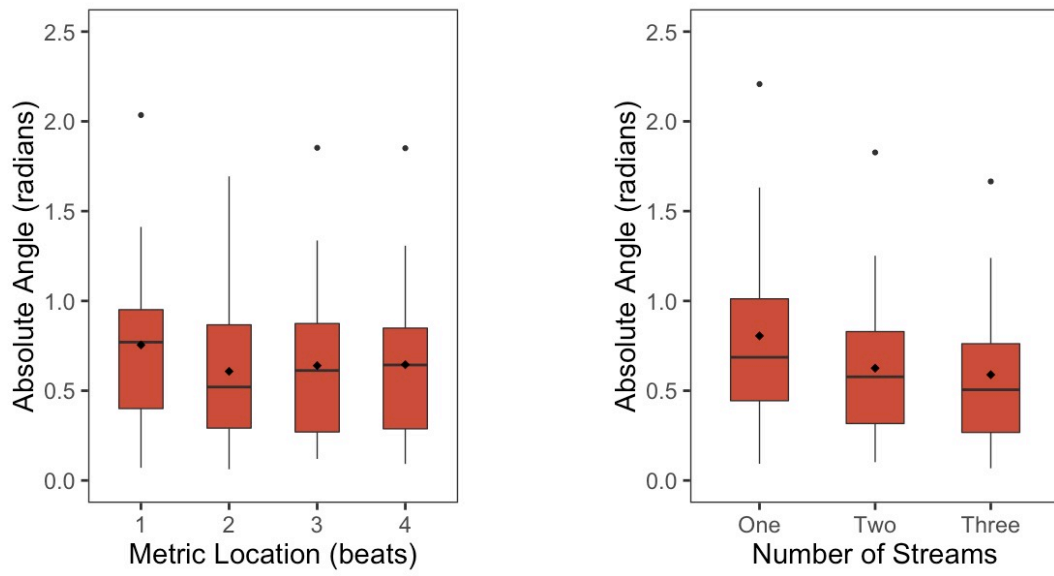


Figure 4

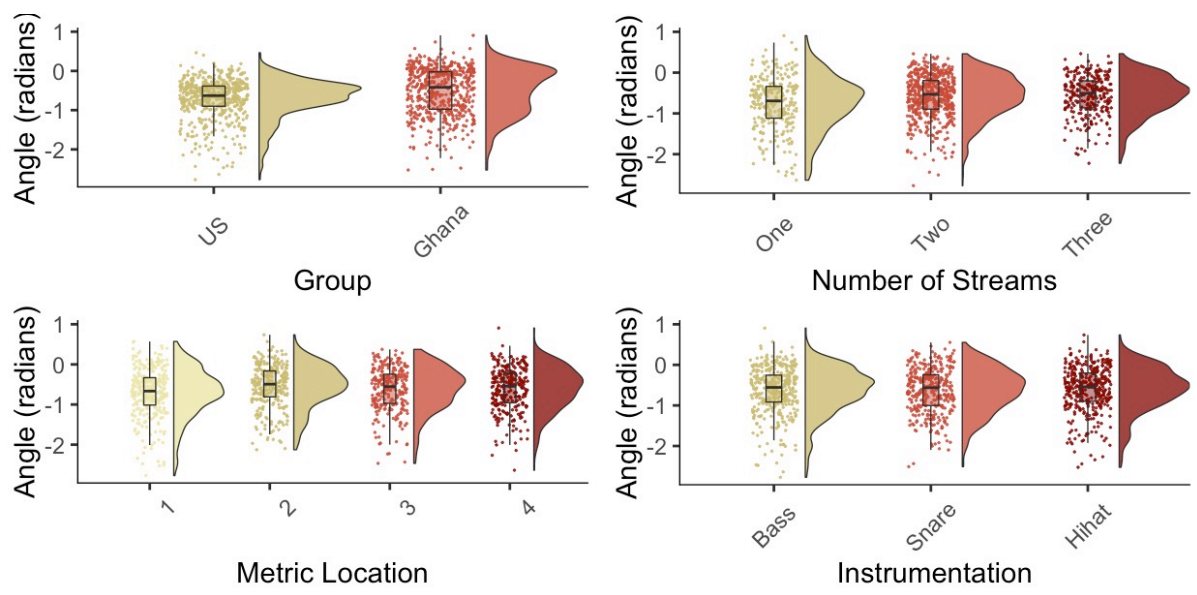


Figure 5

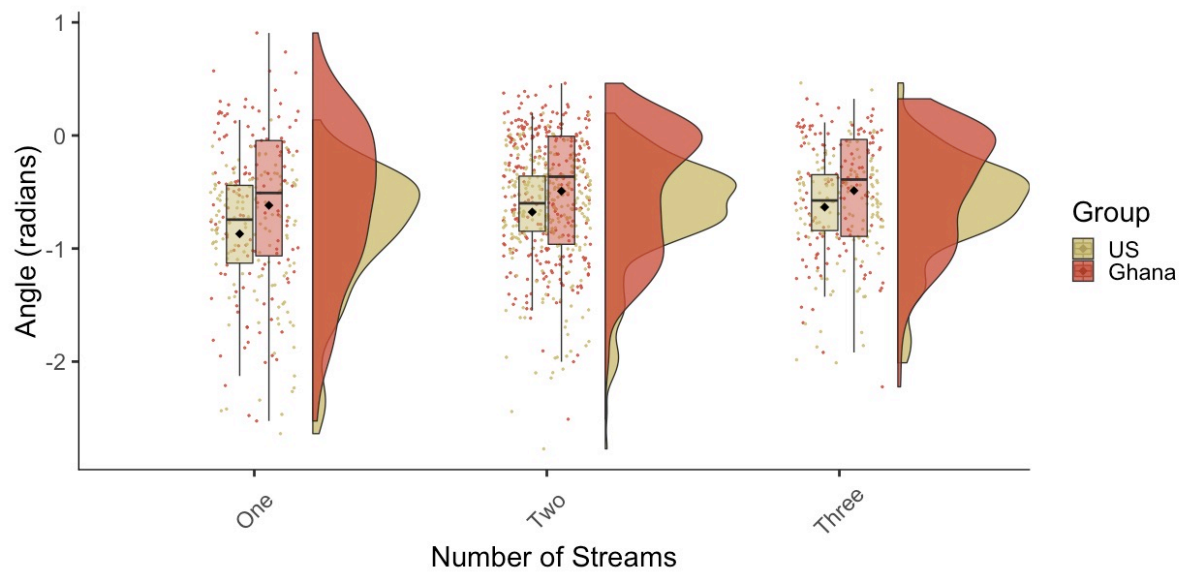


Figure 6

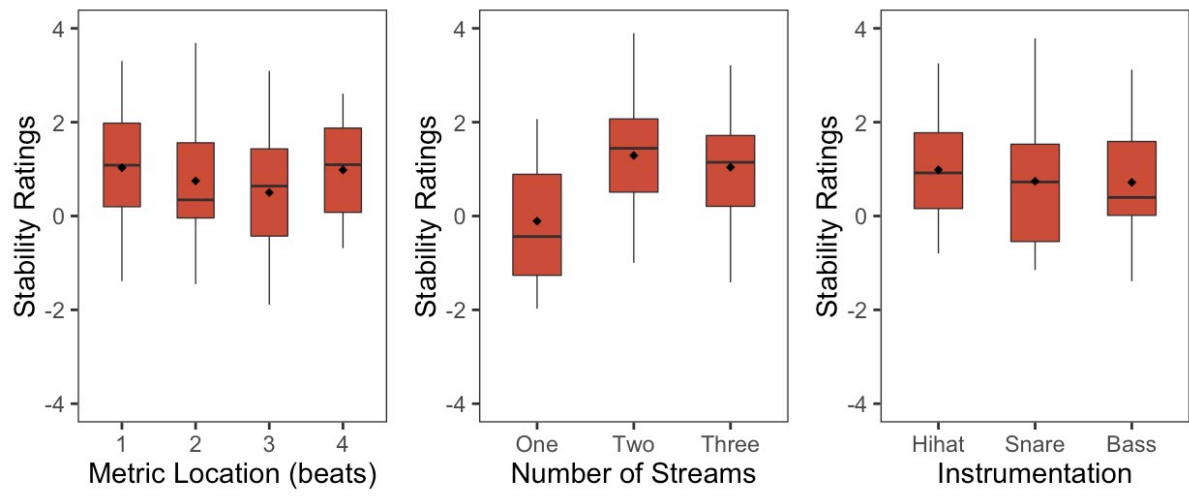


Figure 7

