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Exploring the Relation Between Musical and Dance Sophistication and Musical Groove Perception

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EXPLORING THE RELATION BETWEEN MUSICAL AND DANCE SOPHISTICATION AND MUSICAL GROOVE PERCEPTION

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Abstract

Listening to groovy music is an enjoyable experience and a ubiquitous human behavior in some cultures. Specifically, many listeners agree that high-groove songs are enjoyable, familiar, and likable compared to low-groove songs. While the pleasurable and dance-inducing effects of musical groove listening seem omnipresent, what is less known is how subjective feelings towards music, individual musical or dance experiences, or more objective musical perception abilities are correlated with the way we hear music with groove. Therefore, the present online study aimed to evaluate how musical and dance sophistication relates to musical groove perception. One-hundred and twenty-four participants completed an online study where they rated 20 total high- and low-groove songs and completed the Goldsmith Musical Sophistication Index, the Goldsmith Dance Sophistication Index, the Beat and Meter Sensitivity Task, and a modified short version of the Profile for Music Perception Skills. Our results show that perceptual abilities, musical training, body awareness, participatory dance experience, and performance on a variety of musical skills tasks could predict rating differences between high- and low-groove music. Overall, these findings support that listeners' individual experiences and innate abilities may shape their perception of musical groove, although other causal directions are possible as well. This research helps better understand the correlates and possible causes of musical groove perception in a wide range of listeners.

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Dedication

For Mamachan – thank you for giving me life and for always supporting my pursuit of the arts. I would not have made it here today without you.

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Chapter 1: Introduction

Moving to music is a natural and pleasurable human behavior. Certain songs *groove* in that they encourage spontaneous movement and feelings of enjoyment more than others (Janata et al., 2012; Madison, 2006; Madison et al., 2011; Matthews et al., 2020). Groove was first associated with *swing* music: a type of jazz music that is composed of "swinging" rhythms in which the beat is unevenly subdivided to sound like a lilt (Madison, 2006). This uneven rhythm became the basis for groove: a perpetual, undefinable sensation that became the catalyst to movement. This kinetic feeling was amplified with the accompaniment of swing dancing, a type of social dance first popular in the 1920's. As music evolved, however, groove became more of an umbrella term describing a phenomenon in which musical rhythms invoke movement (Iyer, 2002) driven by music rooted in West African rhythms (e.g., ragtime, blues, jazz, reggae, rock, gospel) (Pressing, 2002).

Presently, musical groove is recognized as a characteristic of songs that encompass genres such as jazz, pop, rock, hip hop, R&B, soul, and funk that have been made popular by artists like Stevie Wonder, Michael Jackson, and James Brown (Danielsen, 2006). Songs with groove are commonly played at social gatherings and are oftentimes the impetus of unprompted head-bobbing and foot-tapping (Brown & Jordania, 2013). In the scientific community, songs with musical groove have become popular, naturalistic stimuli to study interactions between auditory and motor brain regions (Patel & Iversen, 2014; Zatorre et al., 2007). Listening to songs with groove can enhance physical performance (Buhmann et al., 2016; Karageorghis & Terry, 1997; Styns et al., 2007) by eliciting longer strides and faster steps while walking (Leow et al., 2014), running (Edworthy & Waring, 2006), and rowing (Rendi et al., 2016). Even without accompanying movement, music with groove may have the power to excite neurons in the motor system (Martín-Fernández et al., 2021; Matthews et al., 2020; Ross et al., 2016; Stupacher et al., 2013; Wilson & Davey, 2002). As a result, musical groove listening is gaining traction as an enjoyable and therapeutic gait treatment for movement-related disorders such as Parkinson's disease (Leow et al., 2014; Nombela et al., 2013).

Auditory Properties of Musical Groove

To understand this musical phenomenon, researchers have studied the specific auditory components that may contribute to the sensation of groove (Stupacher, Hove, et al., 2016). Converging empirical evidence indicates that timing-based auditory properties may be the most influential in engendering musical groove. Specifically, musical qualities such as a salient, low-pitched beat (Burger et al., 2012; Drake et al., 2000; Hove et al., 2019; Janata et al., 2012; Madison et al., 2011; Stupacher, Hove, et al., 2016), moderate rhythmic complexity (Danielsen et al., 2014; Madison & Sioros, 2014; Matthews et al., 2019; Sioros et al., 2014; Temperley, 1999; Wesolowski & Hofmann, 2016; Witek, 2017; Witek et al., 2014), and a medium tempo (Etani et al., 2018; Janata et al., 2012; Kornysheva et al., 2010; Leow et al., 2014; Liu et al., 2018; MacDougall & Moore, 2005; Michaelis et al., 2014; Stupacher, Hove, et al., 2016; Styns et al., 2007) have all been found to be defining characteristics of musical groove. Beat-based musical elements have also shown to activate neural motor networks. Listening to a beat, without accompanying physical movement, has shown to engage auditory (Fujioka et al., 2009; Snyder & Large, 2005) and sensorimotor regions (Fujioka et al., 2012; Grahn & Brett, 2007; Grahn & Rowe, 2009, 2013). Interaction between these brain regions may be responsible for processing timing information during music listening (Patel & Iversen, 2014). Additionally, listening to beats and rhythms can encourage kinetic movement by providing a temporal anchor to synchronize our bodies to the music (Iyer, 2002; Leman, 2012) and with one another (Cirelli et al., 2014; Kokal et al., 2011; Stupacher, Maes, et al., 2017; Stupacher, Witte, et al., 2017). Performing synchronized movements can lead to activation of reward networks (Kokal et al., 2011; Menon & Levitin, 2005; Zatorre, 2015) and the release of feel-good neurotransmitters such as endorphins and oxytocin (Josef et al., 2019; Tarr et al., 2014, 2015), likely contributing to the overall enjoyable experience of being "in the groove" (De Bruyn et al., 2009; Janata et al., 2012; Madison, 2006).

Musical Experience

Throughout the scientific music literature, there is an overwhelming consensus that formal music training may be associated with enhanced auditory perception (Habibi et al., 2016; Kraus et al., 2014; Kraus & Chandrasekaran, 2010; Slater et al., 2015; Strait et al., 2012, 2014, 2015) and may impact the way we emotionally respond to music (Blood & Zatorre, 2001; Liu et al., 2018). When it comes to musical groove, however, there are mixed theories on how musical expertise may shape its perception. In some cases, research indicates that musicians' perception of groove may be more enhanced than in non-musicians (Matthews et al., 2019; Ross et al., 2016; Stupacher et al., 2013). Their responsiveness to musical groove may be attributed to their ability to hear minute changes in acoustic elements better than non-musicians (Stupacher, Witte, et al., 2016). Musicians, compared to non-musicians, have shown to potentially have more sensitivity toward musical elements important to musical groove such as harmonic complexity (Matthews et al., 2019), rhythmic complexity (Grahn & Rowe, 2009; Matthews et al., 2019; Stupacher, Wood, et al., 2017), tempo (Etani et al., 2018), syncopation (Madison & Sioros, 2014; Matthews et al., 2019; Senn et al., 2018; Witek et al., 2014), micro-timing deviations (Davies et al., 2013; Kilchenmann & Senn, 2015; Senn et al., 2016), and beat perception (Grahn & Rowe, 2009; Nguyen, 2017; Stupacher, Wood, et al., 2017). Additionally, musicians' motor systems may react to music with groove more robustly than non-musicians (Stupacher et al., 2013), possibly allowing for better balance control (Ross et al., 2016). This may be due to their extensive training involving the synchronization of movements to the beat when producing musical sounds (Stupacher et al., 2013), and as a result, strengthening integration among perceptual and motor brain networks (Luo et al., 2012; Martín-Fernández et al., 2021; Patel & Iversen, 2014; Zatorre et al., 2007).

On the other hand, movement to music with groove may be universal (Janata et al., 2012; Madison, 2006; Madison et al., 2011), and thus expertise alone may not be necessary for musical groove perception. For example, multiple studies have found no differences between musicians and non-musicians in their susceptibility to groove (Butterfield, 2010; Frühauf et al., 2013; Hofmann et al., 2017). Most recently, Senn et al. (2019) showed only marginal main effects of musical expertise on groove ratings when compared across musicians, amateur musicians, and non-musicians. In another study, non-musicians perceived music as groovier than musicians (Witek et al., 2014). Across these studies, there seems to be agreement among both musicians and non-musicians as to which songs are more or less "groovy"; however, their musical experiences may drive their preference for groove genres with more or less musical complexity. While musicians may rate more complex music, like jazz and funk, to be "groovier" (Matthews et al., 2019; Pressing, 2002), non-musicians may be inclined to rate pop and rock higher in groove because it is less complex and more familiar (Senn, Bechtold, et al., 2019). Additionally, Stupacher et al. (2013) found non-musicians to have increased corticospinal inhibition when listening to high-groove compared to low-groove music. While corticospinal excitation is usually associated with increased motor activation, non-musicians exhibited greater pre-pulse electromyographic (EMG) activity during high-groove and not low-groove listening conditions.

The authors suggest this increased pre-pulse EMG activity may be due to non-musicians fighting the urge to move to high-groove music. In turn, when TMS pulses were applied, these voluntary muscle contractions during high-groove music listening may have led to increased corticospinal inhibition compared to low-groove music listening and may be reflective of motor system engagement (Stupacher et al., 2013). Taken together, factors such as innate biological traits, subjective preferences, and musical exposure, rather than musical skills gained from playing an instrument, may have equal or greater effects on how we perceive the groove.

While previous research has focused on the comparison between musician and non-musician groups for the purposes of understanding how music training can enhance brain- and behavior-related mechanisms (Kraus & Chandrasekaran, 2010; Skoe & Kraus, 2010; Slater & Kraus, 2016; Strait & Kraus, 2011), musicality is nuanced in those both with and without expertise (Nave-Blodgett et al., 2021; Zatorre, 2013). Even in musician populations, we see variations in perceptual abilities (Slater et al., 2018), neural responses (Strait et al., 2012), performance artistry, compositional abilities, improvisation skills, and emotional responses to music amongst those who play different instruments and those who pursue different music-based careers (Levitin, 2012). Therefore, it is important to consider how other factors -- not directly related to training -- may influence the way we play, perceive, and interpret music. Some argue that musicians may have a genetic predisposition for excelling at playing and perceiving music (Ebstein et al., 2010; Levitin, 2012; Schellenberg, 2015; Ukkola-Vuoti et al., 2011). They also may be raised in supportive family environments that allow them to pursue music at the highest level (Corrigall et al., 2013; Schellenberg, 2015). It is possible that these biological and environmental benefits may also contribute to heightened musicality in non-musicians. In some instances, musicality may be cultivated due to an availability of resources (Corrigall et al., 2013).

While some of these individuals may never become skilled musicians, they may have had the financial means to be exposed to a variety of music genres by attending concerts and purchasing music for home listening. In other instances, one's musicality may be a predisposed trait (Peretz et al., 2007) that remains somewhat hidden due to a lack of financial or familial support (Schellenberg, 2015) or lack of interest in learning to play music. Instead, some of these untrained individuals may become avid music appreciators and develop similar skills to musicians through hours of listening or other activities such as playing music video games (Pasinski et al., 2016). Furthermore, in both musicians and non-musicians, appreciation for certain types of music may be dictated by one's personality (Colver & El-Alayli, 2015; Kuckelkorn et al., 2021; Luck et al., 2010; McCrae, 2007; Nusbaum et al., 2014) and music preferences (Kowalewski et al., 2020; Madison, 2006; Madison & Schiölde, 2017; Salimpoor et al., 2013; Senn, Bechtold, et al., 2019; Senn, Rose, et al., 2019; Wesolowski & Hofmann, 2016). Therefore, there is a growing need to understand *individual differences* in music perception that are not based on experience with formal music training.

Dance Experience

Up until now, most musical groove studies have focused on *musical* expertise. This may be because the groove has often been studied in the context of music, either describing music of a particular genre, how the music is performed, or the sensation of being "in the pocket" when musicians synchronize with one another. What is often forgotten is that historically, much of music was written for the purposes of dancing. Songs from music genres known for groove rhythms, such as jazz or Afro-Cuban music, were first composed to accompany dance forms such as tap dance (Hill, 2010), swing dance (Madison, 2006), and Latin dance (Crease, 2000). These African-based rhythms have become the basis for many popular Western songs with groove. For example, the repeating rhythmic pattern in The Rolling Stone's hit song "Satisfaction" is a cha-cha-cha (Contreras, 2019), Bo Diddley's "Bo Diddley" uses a 3-2 clave rhythm (Keil & Feld, 1994), and Ray Charles' "What'd I Say" has the central rhythm of a mambo (Contreras, 2019). We also seem to have forgotten the essential connection to dance in classical music. While Bach's gigues and gavottes are highly stylized and hard to dance along to, these compositions follow the structure of their eponymous baroque dances (W. Tecumseh Fitch, 2016).

There is an undeniable connection between musical groove and dance (W. Tecumseh Fitch, 2016; Merker, 2014); yet, there is a surprising dearth of empirical studies investigating the influence of dance experience on musical groove perception (Bernardi et al., 2017), let alone general music perception. Considering how dancers' precise training of movement to music teaches an embodied interpretation of the musical beat (Leman, 2012; Witek et al., 2020), a potentially important factor in feeling the groove (Iyer, 2002), it is advantageous to study how dance can shape the way we hear the groove. Currently, there are few investigations comparing musicians to dancers that may indicate similarities in their perception of musical groove. Dancers and musicians have both shown to have increased cortical thickness in superior temporal brain regions compared to non-experts (Karpati et al., 2017). These regions have been found to be vital to the auditory-motor integration network used during music listening and production (Bangert et al., 2006; Gordon et al., 2018; Zatorre et al., 2007). Additionally, dancers and musicians also share enhancements in sensorimotor integration (Karpati et al., 2016) and appear to outperform those without either expertise in audiovisual beat perception and production tasks (Nguyen, 2017). Furthermore, dancers and musicians both exhibited cortical phase synchrony in beta and gamma frequency bands during passive viewing of dance with music (Poikonen et al., 2018).

These frequency bands have been implicated in musical beat encoding and auditory-motor brain interactions (Fujioka et al., 2009). Together, these studies suggest that training-induced neuroplasticity in sensorimotor regions may be similar in dancers and musicians and may engender heightened perception of the musical beat, a crucial component of musical groove.

While evidence supports similar structural brain enhancements in musicians and dancers, there are several reported differences between the two groups that may indicate deviations in musical groove perception. Dancers and musicians exhibit differences in white matter structure: compared to musicians, dancers have increased diffusivity and reduced fiber coherence in sensorimotor pathways including the corticospinal tract, superior longitudinal fasciculus, and the corpus callosum (Giacosa et al., 2016, 2019). The authors attribute dancers' whole-body training to greater fanning and crossing of fibers connecting different brain regions while music playing may result in focused enhancements of effector-specific pathways that regulate movement in the hands, arms, and trunk (Giacosa et al., 2016, 2019). Additionally, the sensorimotor enhancements in dancers and musicians mentioned earlier may be specific to their training. Karpati et al. (2016) found dancers performed better than musicians on a dance imitation task while musicians were better at melody discrimination. Similarly, Nguyen (2017) found dancers showed preference for the visual modality while musicians showed preference for the auditory modality when completing a beat production task. Because learning dance is more visually-dominant and learning music is more auditorily-dominant, the authors of both studies suggested that dancers and musicians performed better on tasks that catered to the sensory modalities most used in their respective artforms. Moreover, while the cortical phase synchrony mentioned before may suggest similar perception of musical information in dancers and musicians, synchrony was increased in gamma frequencies for dancers and decreased in beta frequencies for musicians intimating possible differences in beat-related auditory processing. Collectively, these results do not provide clarity as to whether dancers possess similar heightened auditory perceptual skills to musicians.

While comparing dancers to musicians may provide some insight into how dance expertise may hone music perception, feeling the groove may not be dependent on possessing heightened auditory processing skill or motor abilities. Instead, the pleasure we derive from listening to musical groove may be dependent on our kinesthetic interaction with the music. For instance, non-dancers felt the most pleasure and arousal when moving spontaneously to high-groove music compared to low-groove music or when listening to music without movement (Bernardi et al., 2017). This may be because moving to music helps us understand the beat and meter through embodiment (Lee et al., 2015; Leman, 2012; Phillips-Silver & Trainor, 2008). Knowing the locations of beats in time can help us synchronize our movements with others (De Bruyn et al., 2009). When we dance in synchrony with a partner or a group of people, decreases in cortisol (Quiroga Murcia et al., 2009) and the release of endorphins and oxytocin may encourage feelings of pleasure and social closeness (Josef et al., 2019; Tarr et al., 2015, 2016).

Additionally, embodied familiarity may influence groove perception. For example, over short periods of dance training, non-dancers enjoyed observing dances of which they previously rehearsed or viewed compared to only listening to the music to which the dances were performed (Kirsch et al., 2015). Having past experiences moving to the music may also facilitate meter awareness. Those without formal dance training, but with experience dancing specific choreography, were better at tapping along to the music's beat than those who did not learn the choreography (Lee et al., 2015). Furthermore, dance familiarity can be embodied through observation. Frequent spectators of dance, compared to novice dance spectators, showed increased corticospinal excitability as they viewed the form of dance with which they were most familiar (Jola et al., 2012). What is unclear, however, is whether these increases in meter perception and motor activation due to repeated dance observation translate to a heightened perception of musical groove. Therefore, there is a great need for investigations that directly study differences in music perception in those with varying degrees of dance experience.

The Present Study

In the present study, we investigated how musical and dance sophistication may shape musical groove perception in adult listeners with a wide range of artistic experiences. The first aim of this investigation was to understand how variations in *musical sophistication* predict musical groove perception. Specifically, we measured how both objective and subjective components of musical sophistication predict musical groove ratings. Musical sophistication is the possession of heightened music skills rather than just the amount of formal training, which is often used to predict performance in studies (Müllensiefen et al., 2013; Zentner & Strauss, 2017). These musical attributes that comprise musical sophistication are also not typically assessed via traditional music aptitude tests, but encompass musical understanding, appreciation, evaluation, and communication alongside skills such as playing an instrument, improvisation, and possessing a sense of rhythm and pitch (Hallam, 2010; Hallam & Prince, 2003; Müllensiefen et al., 2014). Objective components were musical skills measured using The Profile for Music Perception Skills (Law & Zentner, 2012; Zentner & Strauss, 2017) and the Beat and Measure Sensitivity Task (Nave-Blodgett et al., 2021). Subjective components were measured using the Goldsmith Musical Sophistication Index Self-Report Inventory (Müllensiefen et al., 2014). In previous uses of these measures, researchers discovered groups of non-musicians who performed like trained musicians (i.e., musical sleepers), musicians who performed like non-musicians due to lack of consistent practice or who never improve even with ample practice (i.e., sleeping musicians), and those in between who did not fit any specific musical skill category (Law & Zentner, 2012). For our purposes, it is vital to understand these subtleties in musicality across a wide range of listeners because musical groove's likeability and effects on movement seem omnipresent (Janata et al., 2012; Madison, 2006; Madison et al., 2011), and thus potentially independent of skills that are only honed via formal music training (Leow et al., 2014).

In one regression model, we predicted that musical training will be the most reliable predictor of musical groove perception. While we have provided evidence suggesting that both musicians and non-musicians can be susceptible to the feeling of groove (Butterfield, 2010; Frühauf et al., 2013; Hofmann et al., 2017), there is more empirical support for musicians having enhanced perceptions of musical groove compared to non-musicians because of their extensive training of timing movement to music during performance and practice (Ross et al., 2016; Stupacher et al., 2013; Stupacher, Wood, et al., 2017). Other possible subjective predictors of musical groove perception may be measures of active engagement with music and emotional responses to music. Taste and familiarity have been found to be predictors of musical groove perception (Janata et al., 2012; Senn, Bechtold, et al., 2019). Because we are investigating a wide range of listeners that may not have music training, perception of musical groove may be more dependent on individuals' preference for groove genres or their active engagement listening to music and attending live performances.

In a second regression model, we predicted measures of beat sensitivity and measure sensitivity will be the most reliable predictors of musical groove perception. The beat is instrumental to the feeling of the groove because it is the fulcrum to movement, synchronization, and music-making (Burger et al., 2013, 2012; Janata et al., 2012; Madison et al., 2011;

Stupacher, Hove, et al., 2016). It is the underlying pulse to which we spontaneously bob our head or tap our foot (Hove et al., 2019). The music's metrical structure provides an external temporal framework (Iyer, 2002) for body movement to the music (Burger et al., 2018) and to one another (Leman, 2008). Therefore, possessing a heightened sense of beat and/or meter sensitivity may contribute to greater perceived differences between high and low groove music. Other potentially reliable predictors of musical groove perception may be measures of rhythm and accent perception. Previous studies suggest that "groovy" songs with medium degrees of rhythmic complexity and syncopation are the most pleasurable and encourage the most movement (Matthews et al., 2019; Witek et al., 2014). Higher scores on perceptual rhythm and accent measures may indicate heightened perceptions of rhythmic information in music and as a result, may predict greater differences in ratings between high and low groove music.

The second aim of this study is to investigate the impact of *dance sophistication* on musical groove perception. Dance sophistication is the possession of heightened dance enjoyment, knowledge, or skills without undergoing formal dance training (Rose et al., 2020). In a third regression model, we analyzed responses from the Goldsmith Dance Sophistication Index (Rose et al., 2020), a new dance self-report assessment that distinguishes experience in dance participation from experience in dance observation to measure one's overall dance comprehension. This is one of the first investigations studying dance experience and musical groove perception. While there is little published work on how dance appreciation or experience may shape the way we perceive music with groove, we hypothesized dance training to be a strong predictor of musical groove perception in this model. There is some evidence indicating enhanced beat perception in dancers compared to non-dancers (Jin et al., 2019; Nguyen, 2017), a musical skill that may be imperative to the perception of musical groove (Leow et al., 2014).

Additionally, dancers trained in more percussive dance styles such as hip-hop, stepping, or tap have a considerable amount of training synchronizing movement to music from groove-specific genres that may enhance the way they perceive differences between high and low groove music. Other potential predictors of musical groove perception in this model may include measures of the urge to move or social dance. We often have the desire to move to music with groove in social environments where we feel pleasure synchronizing our movements with our peers (Tarr et al., 2014, 2015). Additionally, those with greater degrees of openness to experience may be more moved by music (Colver & El-Alayli, 2015), may possess greater musicality (Corrigall et al., 2013), and may have a greater urge to move to music (Rose et al., 2020). Because we are investigating listeners with varying degrees of dance experience, perception of musical groove may be more dependent on personal traits that make them more open to engaging in dance in social settings.

A final regression analysis uncovered whether objective or subjective elements of music and dance sophistication are more influential in the perception of musical groove. This was an exploratory analysis not proposed in the preregistration submitted to the Open Science Foundation (OSF) prior to data collection or a part of the initial dissertation plan. Here, we used the composite scores from the musical skills tests, the musical sophistication self-report index, and the dance sophistication self-report index to predict musical groove ratings. Though comparisons among these types of measures have not been performed previously, evidence suggests that heightened performance on musical skills tasks (Leow et al., 2014; Nguyen, 2017) and greater musical sophistication may be the most reliable predictors of musical groove perception. These measures of musicality do not target those with musical training and thus, may uncover musicality enhancements in those with dance training or other types of movement experience (e.g., Rock Band game experience) (Jin et al., 2019; Pasinski et al., 2016).

Chapter 2: Method

Ethics Statement

All experimental procedures were approved by the University of Nevada, Las Vegas (UNLV) Institutional Review Board. Participant's data were anonymized and IP addresses were not collected.

Participants

One hundred seventy-one adults completed the study. Most participants were UNLV undergraduates enrolled in a psychology course (*n* = 146). The remaining participants were recruited by word of mouth, email, or by announcements posted on social media platforms (e.g., Facebook, Instagram, Twitter). Twenty-three participants were excluded due to performance on the initial hearing assessment (i.e., answered less than five out of six total trials correctly); eight participants were excluded due to incorrect answers on compliance checks; one participant was excluded due to an excessively noisy environment while completing the study, and 15 participants were excluded due to issues loading the stimuli. The final 124 participants were between the ages of 18-44 years old (*M* = 22.6 years, *SD* = 5.77 years, females = 80) and had no history of learning, neurological, and motor disorders. While musicians and dancers were not actively recruited for the present study, participants reported varying degrees of music and dance experience. See Table 1 for detailed music and dance experience.

Table 1

Participants' Musical and Dance Experience Characteristics

Characteristic	*n*	%	Characteristic (*n*)	*M*	*SD*	Range
No Musical or Dance Experience	45	36%				
No Musical Experience	55	44%				
Musical Experience	38	30%	Age started music lessons (37)	9.7	3.7	4-16
Occasional Musician	47	38%	Years of music lessons (37)	6.5	4.2	1-20
Recreational Musician	13	11%	Age started music ensemble (50)	11.7	2.2	5-16
Serious Amateur Musician	7	5.6%	Years of music ensemble (50)	5.8	4.7	1-30
Professional Musician	2	1.2%	Avg. hours of daily playing (37)	2.7	2.5	0.5-11
No Dance Experience	80	65%				
Dance Experience	14	19%	Age started dance lessons (39)	9.4	6.8	2-35
Occasional Dancer	24	6.5%	Years of dance lessons (39)	8.6	7.6	0.5-27
Recreational Dancer	8	28%	Avg. hours of daily dancing (23)	3.0	2.0	0.25-8
Serious Amateur Dancer	10	8.1%				
Professional Dancer	2	1.6%				
Both Musical and Dance Experience	27	22%	Hours of music listening/week (124)	15.0	14.4	0-70

Note. All values are based on participant self-report. Years musical and dance training, age started musical and dance training, and hours daily playing only include participants with relevant experience. Hours music listening/week include all participants. Those with both music and dance experience are not included in the separate totals for musical and dance experience; however, are included in totals for Musician/Dancer Category (i.e., Occasional, Recreational, Serious Amateur, Professional). Occasional Musician/Dancer = less than weekly practice/participation; Recreational Musician/Dancer = weekly practice or recreational playing/performance; Serious Amateur Musician/Dancer = extensive commitment to practice and/or recreational music activity; Professional Musician/Dancer = paid to perform and/or teach music.

Materials and Procedure

All testing was implemented online using Qualtrics (Qualtrics, Provo, UT) and LimeSurvey (LimeSurvey, Hamburg, Germany). Participants followed an internet link to access the experiment. On the first screen, participants were required to sign a consent form before beginning the study. Then, participants proceeded through the study beginning with the most difficult and attention-taxing measures. The measures are described below in order of administration. Participants were asked to complete the experiment on a computer over headphones in a quiet environment. To ensure that participants could hear the auditory stimuli clearly, they completed a short hearing assessment to test the quality of their earbuds/headphones prior to beginning the experiment. Participants were asked to indicate which tone is the softest by selecting one of three button options labeled “Tone 1”, “Tone 2”, or “Tone 3” (Woods et al., 2017). Any participant who did not correctly answer at least five out of the six trials was excluded from analyses. Total test time was between 60-90 minutes. Participants were offered opportunities to take short breaks after each test and subtest.

Profile for Music Perception Skills

First, participants completed the melody, tempo, accent, rhythm, and embedded rhythm (rhythm-to-melody) subtests of the short version of the Profile for Music Perception Skills (Short-PROMS) (Zentner & Strauss, 2017). Each subtest consists of eight to ten trials with a total testing time of 25 minutes. This music aptitude battery objectively measures perceptual musical skills across multiple modalities in both musically trained and untrained individuals (Law & Zentner, 2012). We selected these subtests because of their robustness against noisy testing environments (Zentner & Strauss, 2017) and their theorized importance to the feeling of musical groove. A salient beat (Burger et al., 2012; Drake et al., 2000; Janata et al., 2012), a danceable tempo (Etani et al., 2018; Stupacher, Hove, et al., 2016), a memorable melody (Danielsen, 2006; Pressing, 2002), and complex rhythms (W. Techumseh Fitch & Rosenfeld, 2007; Matthews et al., 2020; Witek et al., 2017) are all musical components that comprise songs with groove. For each subtest, a trial consisted of a standard auditory stimulus (played twice) followed by one comparison auditory stimulus. The participant determined 1) if the comparison stimulus was the same as the standard stimulus and 2) how confident they were in their answer. The internal reliability of PROMS melody ($\omega = 0.52$), embedded rhythm ($\omega = 0.64$), accent ($\omega = 0.49$), and tempo ($\omega = 0.57$) subtest scores was lower than previously reported by Zentner & Stauss (2017); however, internal reliability of the PROMS rhythm subtest score ($\omega = 0.64$) and PROMS composite score ($\omega = 0.86$) was comparable.

Beat and Meter Sensitivity Task

In the next task, participants completed a shortened version of the Nave-Blodgett et al. (2021) Beat and Meter Sensitivity Task (BMS). The BMS uses naturalistic music stimuli to assess auditory beat and meter sensitivity in individuals with varying levels of musical expertise. Participants listened to brief excerpts of ballroom dance music overlaid with a click track that either matches or mismatches the music at the beat and measure levels (four possible alignment conditions), and then rated how well the click track matched the music using a four-point Likert scale (see Nave-Blodgett et al. (2021) for full methods). In this shortened version, there are several small alterations to the stimuli from the original version used in Nave-Blodgett et al. (2021). First, the fully-mismatching (beat and measure mismatching) metronome condition now consists of two versions per musical excerpt: one click-track that is 15% faster, and one that is 15% slower, in tempo than the paired musical excerpt. In the original study, the fully mismatching condition consisted of only one click-track that was always only 6% faster, which was difficult to detect perceptually and did not balance the beat-level tempo mismatch of the beat mismatching/measure matching metronome condition. Second, the music/click-track pairings are now presented diotically, rather than dichotically, with the music and click track in both ears. Third, the click tracks are now created automatically by a custom script written in Python that places the metronome clicks at pre-specified time locations, eliminating possible error from hand-manipulating the audio waveforms. Fourth, the musical excerpts have been shortened to three full measures of the musical excerpt, down from five, which decreases the length of each trial to no more than eight seconds. Fifth, there are only 30 total trials (five metronome/music pairings for each of the six ballroom dance pieces) versus the 96 in the original study, and only four practice trials versus six in the original. Finally, the version presented in this study was administered using Qualtrics and will be presented entirely online rather than be conducted in-person. This shortened, online BMS version was created for this study by Jessica Nave-Blodgett, Ph.D., the original creator of the BMS. The task in total took about 10 minutes to complete.

Musical Groove Judgment Task

Following the BMS, participants completed the Musical Groove Judgment Task (MGJT). Participants listened to 15-second clips of 10 high-groove (HG) and 10 low-groove (LG) songs and made judgments on what they heard. On a seven-point Likert scale, they answered the following questions: 1) “Is this song groovy?”, 2) “Did you enjoy this song?”, and 3) “Are you familiar with this song?". Previous research has indicated positive associations between musical groove and likeability and musical groove and familiarity (Janata et al., 2012; O'Connell, 2018). In this task, *groovy* was defined as how much a song makes you want to dance. Songs were selected from the Janata et al. (2012) music library based on their mean groove rating: the 10 songs rated highest in groove and the 10 songs rated lowest in groove were chosen for this study (see Table 1 for complete song list). Stimuli were truncated to 15-second segments using Audacity 2.1.2 (Mazzoni, 2016) and normalized to be the same volume. Similar to Janata et al. (2012), song stimuli were segmented based on what is presented in the iTunes song preview, starting at ~45 seconds into the song. This take took about five minutes to complete.

Table 2

Songs Used in the Musical Groove Judgment Task

Song Name	Artist	Groove	Genre	Groove Rating
Superstition	Stevie Wonder	High	Soul	108.7
It's a Wrap	FHI (Funky Hobo #1)	High	Soul	105.9
Flash Light	Parliament	High	Soul	105.1
Lady Marmalade	Patti LaBelle	High	Soul	102.5
Up for the Downstroke	The Clinton Administration	High	Soul	102.4
Mama Cita	Funk Squad	High	Soul	101.6
Music	Lella James	High	Soul	101.1
If I Ain't Got You	Alicia Keys	High	Soul	98.7
Sing, Sing, Sing	Benny Goodman	High	Jazz	97.4
In the Mood	Glenn Miller	High	Jazz	96.9
Space Oddity	David Bowie	Low	Rock	38.7
Ray Dawn Balloon	Trey Anastasio	Low	Rock	38.5
Druid Fluid	Yo-Yo Ma, Mark O'Connor, and Edgar Meyer	Low	Folk	38.1
Flandyke Shore	The Albion Band	Low	Folk	36.5
Citi Na GCumman	William Coulter and Friends	Low	Folk	35.2
Dawn Star	Dean Magraw	Low	Folk	34.8
Fortuna	Kaki King	Low	Folk	32.6
Beauty of the Sea	The Gabe Dixon Band	Low	Rock	32.1
Sweet Thing	Alison Brown	Low	Folk	30.9
Hymn for Jaco	Adrian Legg	Low	Folk	29.3

Note. Groove = groove category (i.e., low or high). Groove rating values are derived from Janata et al. (2012).

Goldsmith Musical Sophistication Index

Upon completion of the MGJT, participants completed the Goldsmith Musical Sophistication Index Self-Report Inventory (GOLD-MSI), a 39-item psychometric instrument used to quantify the amount of musical engagement, skill, and behavior of an individual (Müllensiefen et al., 2013). The questions on this assessment are grouped into five subscales: active engagement, perceptual abilities, musical training, singing abilities, and emotions (see Mullensiefen et al., 2013, 2014 for each subscale's detailed question information). The composite score of these subscales makes up an individual's general musical sophistication score (Müllensiefen et al., 2013). All items, except those assessing musical training, are scored on a seven-point Likert scale with choices that range from *completely disagre*e to *completely agree*. The internal reliability values of the GOLD-MSI subscale (active engagement: a = 0.81, perceptual abilities: a = 0.86, musical training: a = 0.88, singing abilities: a = 0.80, and emotions: a = 0.78) and general musical sophistication scores (a = .89) were good (Gliem & Gliem, 2003) and comparable to what has been published previously (Müllensiefen et al., 2014).

Goldsmith Dance Sophistication Index

After the Gold-MSI, participants completed the Goldsmith Dance Sophistication Index (Gold-DSI), a 26-item standardized instrument used to quantify individual differences in doing dance (i.e., participatory dance experience), watching dance (i.e., observational dance experience), and one's knowledge about dance (Rose et al., 2020). Like the Gold-MSI, the Gold-DSI is designed to measure a wide range of dance skills, behaviors, and engagement in a general population and does not place importance on those who cannot dance (i.e., motor impairments) or those with extensive dance experience (Rose et al., 2020). The Gold-DSI is comprised of two separate inventories: participatory dance experience and observational dance experience. The composite score of four subtests (body awareness, social dancing, urge to dance, and dance training) contribute to the participatory dance experience score while the composite score on six separate questions comprises the observational dance experience score(see Rose et al., 2020 for each subscale's detailed question information). All items, except those assessing dance training, are scored on a seven-point Likert scale with choices that range from *completely disagre*e to *completely agree*. The questions were randomized per participant. The internal reliability values of the GOLD-DSI subscale (body awareness: a = 0.92, social dance: a = 0.92, urge to dance: a = 0.89, dance training: a = 0.94, observational dance experience: a = 0.76) and composite scores (participatory dance experience: a = 0.95) were good (Gliem & Gliem, 2003) and comparable to what has been published previously (Rose et al., 2020).

Demographics

The final task participants completed was a demographics questionnaire (see Appendix A for all items) that asked questions about health history, music experience, dance experience, exercise, and engagement with music listening.

Statistical Design

Four multiple linear regression models were estimated to predict the difference between mean high-groove music ratings and mean low-groove music ratings ($M_{\text{high-groove music}} - M_{\text{low-groove music}}$). This criterion variable is labeled as the *musical groove difference score*. The predictor variables for the first linear regression model (the musical sophistication model) are the total scores of each of the GOLD-MSI subscales (i.e., active engagement, perceptual abilities, emotions, singing abilities, and musical training), totaling five predictors. The predictor variables for the second multiple linear regression model (the dance sophistication model) are the total scores of each of the GOLD-DSI subscales for participatory dance experience (i.e., body awareness, social dancing, urge to dance, and dance training) and the observational dance experience score, totaling five predictors. The predictor variables for the third linear regression model (the musical skills model) are the total scores of each PROMS subtest (i.e., melody, tempo, accent, rhythm, and embedded rhythm), and the total scores on each of the BMS measures (i.e., beat sensitivity and measure sensitivity), totaling seven predictors. The predictor variables for the fourth linear regression model (the composite model) are the composite score of the GOLD-MSI subscales (music sophistication), the composite score of the GOLD-DSI subscales (dance sophistication), and a composite score created from the PROMS-Short and the BMS scores (musical skills), totaling three predictors. Evaluations of Pearson's *r* correlation coefficients between the predictor and criterion variables accompany each multiple regression analysis.

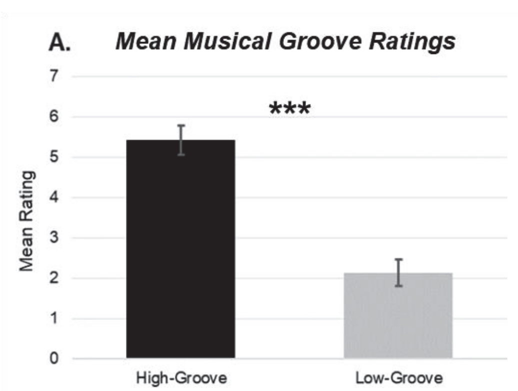
Chapter 3: Results

Relation of Musical Groove, Likeability, and Familiarity

Mean musical groove ratings of songs administered during the Musical Groove Judgment Task (*N* = 20; high-groove = 10, low-groove = 10) were analyzed using a one-way analysis of variance (ANOVA) with a two-tailed alpha level of 0.05 (see Figure 1A). Results reveal statistically significant differences between mean high-groove (*M* = 5.42, *CI* = 5.05, 5.79) and low-groove (*M* = 2.14, *CI* = 1.81, 2.47) ratings, $F_{1,18} = 226.02$, $p < .001$. Correlations between mean musical groove ratings, likeability ratings, and familiarity ratings were conducted (see Figure 2B). There were statistically significant positive relationships between mean musical groove and likeability ratings, $r(18) = 0.79$, $p < .001$; musical groove and familiarity ratings, $r(18) = 0.70$, $p < .001$; and familiarity and likeability ratings, $r(18) = 0.88$, $p < .001$.

Figure 1

Mean Musical Groove Ratings and Correlations for Musical Groove, Likeability, and Familiarity



B. *Correlations for Mean Ratings of Musical Groove, Likeability, and Familiarity by Song*

Variable	1	2	3
1. Musical Groove	--		
2. Likeability	.79***	--	
3. Familiarity	.70***	.88***	--

* p < .05. ** p < .01, *** p < .001

Note. (A) Bar graphs of mean musical groove ratings (*N* = 20; high-groove = 10, low-groove = 10). Error bars indicate 95% confidence intervals. Results reveal statistically significant differences between high-groove (black) and low-groove (grey) mean song ratings $F_{1,18}$ =

226.02, $p < .001$. (B) Relationships between mean musical groove ratings, mean likeability ratings, and mean familiarity ratings ($N = 20$; high-groove = 10, low-groove = 10). Results show statistically significant positive correlations between musical groove and likeability ratings, musical groove and familiarity ratings, and likeability and familiarity ratings.

Relation of Musical Sophistication and Musical Groove Rating Difference

Correlations between musical groove difference scores and GOLD-MSI subtest scores (active engagement, perceptual abilities, musical training, singing abilities, emotion) were conducted (see Table 3). There were statistically significant positive relationships between musical groove rating differences and active engagement, $r(122) = 0.19$, $p = .032$; perceptual abilities, $r(122) = 0.31$, $p < .001$; and emotions $r(122) = 0.31$, $p = .001$. Musical training and singing abilities were not significantly correlated with musical groove rating differences, *ps* > .05.

Table 3

Correlations for Musical Sophistication and Musical Groove Difference Score

Variable	1	2	3	4	5	6
1. Musical Groove Difference Score	--					
2. Active Engagement	.19*	--				
3. Perceptual Abilities	.31***	.38***	--			
4. Musical Training	.02	.37***	.55***	--		
5. Singing Abilities	.12	.39***	.66***	.52***	--	
6. Emotions	.31**	.66***	.53***	.33***	.33***	--

* $p < .05$. ** $p < .01$, *** $p < .001$.

A multiple linear regression analysis was conducted to predict differences between high- and low-groove music ratings from GOLD-MSI subtest scores (see Table 4). The predictor variables entered were active engagement, perceptual abilities, musical training, singing abilities, and emotion. A significant regression equation was found, $F(5, 118) = 4.617$, $p = .001$, $R^2 = .164$. Perceptual abilities were a statistically significant predictor of musical groove rating difference, $b= 0.04$, $SE_b= 0.02$, $p = .005$, 95% CI = 0.01, 0.07; $t = 2.86$, $\beta = 0.38$, such that, for each unit increase in perceptual abilities score, musical groove difference scores increased by 0.38 points. Musical training was also found to be a statistically significant predictor of musical groove rating differences, $b = -0.02$, $SE_b= 0.01$, $p = .048$, 95% CI = -0.04, 0.00; $t = -2.00$ $\beta = -0.21$, such that, for each unit increase in musical training score, musical groove difference scores decreased by 0.21 points. Active engagement, singing abilities, and emotions were not statistically significant predictors of musical groove rating differences, *ps* > .05. Multicollinearity was assessed using the variance inflation factor (VIF). Values for this model were below 2.50 suggesting no presence of multicollinearity (Neter et al., 1996).

Table 4

Multiple Linear Regression Results for Musical Sophistication and Musical Groove Difference Score

Variable	*B*	95% CI for *B*		SE_B	β	*t*	*p*
		LL	*UL*				
Active Engagement	0.01	-0.02	0.03	0.01	0.05	0.46	.647
Perceptual Abilities	0.04	0.01	0.07	0.02	0.38	2.86	**.005****
Musical Training	-0.02	-0.04	0.00	0.01	-0.21	-2.00	**.048***
Singing Abilities	-0.01	-0.04	0.02	0.02	-0.10	-0.84	.017
Emotions	0.03	-0.01	0.08	0.02	0.17	1.40	.080

Note. $F(5, 118) = 4.617$, $p = .001$, $R^2 = .164$. *B* = unstandardized regression coefficients; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; β = standardized regression coefficients.

* $p < .05$. ** $p < .01$.

Relation of Dance Sophistication and Musical Groove Rating Difference

Correlations between musical groove difference scores and GOLD-DSI subtest scores (body awareness, social dancing, urge to dance, dance training, observational dance experience) were conducted (see Table 5). There were statistically significant positive relationships between musical groove rating differences and body awareness, $r(122) = 0.25$, $p = .006$, and social dancing, $r(122) = 0.21$, $p = .021$. Urge to dance, dance training, and observational dance experience were not significantly correlated with musical groove rating differences, *ps* > .05.

Table 5

Correlations for Dance Sophistication and Musical Groove Difference Score

Variable	1	2	3	4	5	6
1. Musical Groove Difference Score	--					
2. Body Awareness	.25**	--				
3. Social Dancing	.21*	.57***	--			
4. Urge to Dance	.15	.48***	.72***	--		
5. Dance Training	.05	.52***	.52***	.55***	--	
6. Observational Dance Experience	.06	.54***	.59***	.65***	.64***	--

* $p < .05$. ** $p < .01$, *** $p < .001$.

A multiple linear regression analysis was conducted to predict differences between high- and low-groove music ratings from GOLD-DSI subtest scores (see Table 6). The predictor variables entered were body awareness, social dancing, urge to dance, dance training, observational dance experience. A significant regression equation was found, $F(5, 118) = 2.299$, $p = .049$, $R^2 = .089$. Body awareness was a statistically significant predictor of musical groove rating difference, $b = 0.03$, $SE_b = 0.02$, $p = .026$, 95% CI = 0.00, 0.06; $t = 2.25$, $\beta = 0.26$, such that for each unit increase in body awareness score, musical groove difference score was predicted to increase by 0.26 points. Social dancing, urge to dance, dance training, and observational dance experience were not statistically significant predictors of musical groove rating differences, *ps* > .05. Multicollinearity was assessed using the variance inflation factor (VIF). Values for this model were below 2.50 suggesting no presence of multicollinearity (Neter et al., 1996).

Table 6

Multiple Linear Regression Results for Dance Sophistication and Musical Groove Difference Score

Variable	*B*	95% CI for *B*		SE_B	β	*t*	*p*
		LL	*UL*				
Body Awareness	0.03	0.00	0.06	0.01	0.26	2.25	**.026***
Social Dancing	0.02	-0.01	0.05	0.02	0.14	1.04	.300
Urge to Dance	0.01	-0.03	0.06	0.02	0.07	0.48	.630
Dance Training	-0.02	-0.06	0.02	0.02	-0.11	-0.90	.368
Observational Dance Experience	-0.02	-0.05	0.02	0.02	-0.13	-0.99	.325

Note. $F(5, 118) = 2.299$, $p = .049$, $R^2 = .089$. *B* = unstandardized regression coefficients; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; β = standardized regression coefficients.
* $p < .05$. ** $p < .01$.

Relation of Musical Skills and Musical Groove Rating Difference

Correlations between musical groove difference scores, BMS measures (beat sensitivity and meter sensitivity), and PROMS subtest scores (melody, rhythm, embedded rhythm, accent, tempo) were conducted (see Table 7). There were statistically significant positive relationships between musical groove rating differences and beat sensitivity, $r(122) = 0.29$, $p = .001$; embedded rhythm, $r(122) = 0.18$, $p = .048$; accent, $r(122) = 0.20$, $p = .025$; and tempo, $r(122) = 0.26$, $p = .003$. Meter sensitivity, melody, and rhythm were not significantly correlated with musical groove rating differences, *ps* > .05.

Table 7

Correlations for Musical Skills and Musical Groove Difference Score

Variable	1	2	3	4	5	6	7	8
1. Musical Groove Difference Score	--							
2. Beat Sensitivity	.29**	--						
3. Meter Sensitivity	.04	.11	--					
4. Melody	.11	.32***	.27**	--				
5. Rhythm	.06	.37***	.37***	.53***	--			
6. Embedded Rhythm	.18*	.33***	.18*	.51***	.59***	--		
7. Accent	.20*	.43***	.26**	.55***	.53***	.56***	--	
8. Tempo	.26**	.50***	.17	.48***	.41***	.49***	.54***	--

* $p < .05$. ** $p < .01$, *** $p < .001$.

A multiple linear regression analysis was conducted to predict differences between high- and low-groove music ratings BMS measures and PROMS subtest scores (see Table 8). The predictor variables entered were beat sensitivity, meter sensitivity, melody, rhythm, embedded rhythm, accent, and tempo. The overall regression was not statistically significant, $F(7, 116) = 2.018$, $p = .058$, $R^2 = .109$. Multicollinearity was assessed using the variance inflation factor (VIF). Values for this model were below 2.00 suggesting no presence of multicollinearity (Neter et al., 1996).

Table 8

Multiple Linear Regression Results for Musical Skills and Musical Groove Difference Score

Variable	*B*	95% CI for *B*		SE_B	β	*t*	*p*
		LL	*UL*				
Beat Sensitivity	0.30	-0.02	0.61	0.16	0.20	1.89	.064
Meter Sensitivity	-0.03	-0.41	0.36	0.19	-0.01	-0.15	.880
Melody	-0.05	-0.18	0.08	0.07	-0.09	-0.74	.463
Rhythm	0.03	-0.12	0.17	0.08	0.04	0.34	.737
Embedded Rhythm	0.02	-0.12	0.17	0.17	0.04	0.31	.756
Accent	0.03	-0.12	0.18	0.17	0.05	0.36	.717
Tempo	0.10	-0.05	0.25	0.08	0.15	1.27	.208

Note. $F(7, 116) = 2.018$, $p = .058$, $R^2 = .109$. *B* = unstandardized regression coefficients; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; β = standardized regression coefficients. * $p < .05$. ** $p < .01$.

Relation of General Musical Sophistication, Participatory Dance Experience, Musical Skills Composite, and Musical Groove Rating Difference

Correlations between musical groove difference scores, GOLD-MSI general musical sophistication, GOLD-DSI participatory dance experience, and musical skills composite scores (i.e., total score of BMS measures and PROMS subtests; see Table 9). There were statistically significant positive relationships between musical groove rating differences and participatory dance experience, $r(122) = 0.21$, $p = .019$, and musical skills composite scores, $r(122) = 0.24$, *p*

= .006. General musical sophistication was not significantly correlated with musical groove rating differences, $p > .05$.

Table 9

Correlations for General Musical Sophistication, Participatory Dance Experience, Musical Skills Composite Score, and Musical Groove Difference Score

Variable	1	2	3	4
1. Musical Groove Difference Score	--			
2. General Musical Sophistication	.14	--		
3. Participatory Dance Experience	.21*	.32***	--	
4. Musical Skills Composite Score	.24**	.54***	.18*	--

* $p < .05$. ** $p < .01$, *** $p < .001$.

A multiple linear regression analysis was conducted to predict differences between high- and low-groove music ratings from GOLD-MSI general musical sophistication, GOLD-DSI participatory dance experience, and musical skills composite scores (see Table 10). The predictor variables entered were general musical sophistication, participatory dance experience, and musical skills composite. A significant regression equation was found, $F(3, 120) = 3.932$, $p = .010$, $R^2 = .090$. Both participatory dance experience, $b = 0.01$, $SE_b = 0.00$, $p = .048$, 95% CI = -0.01, 0.05; $t = 1.99$, $\beta = 0.18$, and musical skills composite, $b = 0.03$, $SE_b = 0.02$, $p = .005$, 95% CI = -0.03, 0.06; $t = 2.29$, $\beta = 0.24$, were statistically significant predictors of musical groove rating difference such that for each unit increase in participatory dance experience and musical skills composite score, musical groove difference score was predicted to increase by 0.18 and 0.24 points, respectively. General musical sophistication was not a statistically significant predictor of musical groove rating differences, $p > .05$. Multicollinearity was assessed using the variance inflation factor (VIF). Values for this model were below 1.60 suggesting no presence of multicollinearity (Neter et al., 1996).

Table 10

Multiple Linear Regression Results for Musical Skills Composite Score, General Musical Sophistication, Participatory Dance Experience, and Musical Groove Difference Score

Variable	*B*	95% CI for *B*		SE_B	β	*t*	*p*
		LL	*UL*				
General Musical Sophistication	-0.00	.004	0.06	0.01	-0.05	-0.45	.653
Participatory Dance Experience	0.01	-0.01	0.05	0.00	0.18	1.99	**.048***
Musical Skills Composite	0.03	-0.03	0.06	0.02	0.24	2.29	**.005****

Note. $F(3, 120) = 3.932$, $p = .010$, $R^2 = .090$. *B* = unstandardized regression coefficients; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; β = standardized regression coefficients.

* $p < .05$. ** $p < .01$.

Chapter 4: Discussion

The present study investigated music and dance characteristics of people that may contribute to musical groove perception. Specifically, this online experiment examined 20 potential predictors across four multiple regression models and assessed how facets of musical sophistication, dance sophistication, and performance on music-based perceptual tasks influence difference ratings between high- and low-groove music. Unlike previous investigations that focused on the acoustic components of music (Senn et al., 2017, 2018; Stupacher, Hove, et al., 2016; Witek et al., 2014) and performance factors (Hurley et al., 2014; Kilchenmann & Senn, 2015; Senn et al., 2016; Witek & Clarke, 2014) that makes the music itself "groovy", this exploratory analysis homes in on the listener's experiences, training, and innate skills that may shape the way they individually perceive musical groove. Overall, we found perceptual abilities, musical training, body awareness, performance on various perceptual music tasks (musical skills composite), and participatory dance experience to be strong predictors of rating differences between high- and low-groove songs.

Musical Groove

In general, our participants agreed on ratings of musical groove, familiarity, and likeability. Songs previously rated as high and low in musical groove by listeners in Janata et al. (2012) were also rated similarly by the listeners in the present study. In fact, our listeners rated high-groove music as being significantly more "groovy" than low-groove music. Like the listeners in Janata et al. (2012), participants also rated high-groove songs as more familiar and more likeable than low-groove songs. Musical groove ratings, familiarity ratings, and likeability ratings all had strong, positive relationships with one another.

Contrary to other findings (Matthews et al., 2019; Ross et al., 2016; Stupacher et al., 2013), our results suggest that formal training in music or dance do not directly influence musical groove perception. We did not find significant correlational relationships between musical groove difference scores and the GOLD-MSI musical training subtest score (i.e., a score comprising measures of regular musical practice, instruments played, years of formal music training, and self-reported views of musical talent; Müllensiefen et al., 2014) or between musical groove difference score and the GOLD-DSI dance training subtest score (i.e., a score comprising measures of dance class weekly attendance, years of formal dance training, and level of dance experience; Rose et al., 2020). If music or dance training did impact musical groove perception, we would have found significant relationships between difference in mean musical groove ratings, music training, and dance training in that greater differences between high- and low-groove songs would relate to higher scores on music and dance training measures. While our correlational findings cannot confirm that the perception of musical groove is universal, they intimate that other factors – either not related to or tangential to formal training – may be more predictive of musical groove perception.

Perceptual Abilities and Musical Training

In our first regression model, the GOLD-MSI's measures of active engagement, perceptual abilities, musical training, singing abilities, and emotions together accounted for 16.4% of the variance in musical groove difference ratings. Of these predictors, perceptual abilities and musical training separately had a strong effect on musical groove difference ratings compared to the other predictors in the model. Active engagement, singing abilities, and emotions did not have any significant effects on the difference between high- and low-groove music ratings. These results align with our initial hypothesis that musical training would be a significant predictor of musical groove difference ratings; however, the weak, non-significant correlational relationship between musical training and musical groove perception was unexpected. Perceptual abilities were also not anticipated to have a direct effect on differences between mean high- and low-groove music ratings.

Perceptual abilities is a GOLD-MSI subtest score comprised of self-reported views of song recognition, tonal perception, and how well one can judge others' musical abilities (Müllensiefen et al., 2014). Out of our two significant predictors, our results suggest that perceptual abilities, compared to musical training, is a stronger predictor of musical groove difference ratings. Unlike musical training, which has a significant negative effect on musical groove difference ratings (when factoring out other predictors), perceptual abilities have a positive effect on differences between high- and low-groove music ratings. These relationships are reflected in correlational measures which show a significant association between musical groove difference score and perceptual abilities but *not* musical training in that greater scores of perceptual abilities relates to greater differences between ratings of high- and low-groove music. Because of this, we believe that the significant effect of music training on music groove difference ratings may be a byproduct of perceptual abilities. Honing perceptual abilities is a facet of musical training. Learning how to play an instrument requires astute attention to musical details such as intonation, tone, dynamics, and clarity. As they gain more expertise, musicians not only become more critical of their own playing but are asked to make judgments about other musicians' performances. The strong correlation found between perceptual abilities and music training in the present study seem to support this notion.

These skills are also reflected in the literature: Müllensiefen et al. (2014) found that both the GOLD-MSI perceptual abilities and music training subscale scores had significantly strong associations with the GOLD-MSI beat perception and melody memory tests. What is unique about our findings is that perpetual abilities had a strong relationship with musical groove difference ratings while musical training did not. While sharpening auditory perception is a component of formal music training, our results support the possibility that possessing heightened perceptual abilities -- not necessarily nurtured through years of playing an instrument or singing -- may influence the way we perceive musical groove.

Body Awareness

In our second regression model, the GOLD-DSI's measures of body awareness, social dancing, urge to dance, dance training, and observational dance experience together accounted for 8.9% of the variance in musical groove difference ratings. Of these predictors, body awareness had a strong effect on musical groove difference ratings compared to the other predictors in the model. Social dancing, urge to dance, dance training, and observational dance experience did not have any significant effects on the difference between high- and low-groove music ratings. These results do not align with our initial hypothesis that dance training would be a reliable predictor of musical groove difference ratings.

Body awareness is a GOLD-DSI subtest score comprised of self-report views on movement control, ease of learning new movements, body awareness, and physical imitation (Rose et al., 2020). Because this was one of the first investigations looking at dance sophistication measures and musical groove perception, there is currently little evidence as to why body awareness would have a direct effect on musical groove difference ratings. These results could be interpreted in a couple ways. First, our significant correlational results between body awareness and musical groove difference score indicate that those who are well-coordinated in movement hear greater differences between high- and low-groove music. These well-coordinated individuals could be dancers: we found significant positive associations between dance training and body awareness; however, dance training does not seem to have a direct effect on musical groove difference ratings. Because we did not find a significant relationship between musical groove difference score and dance training, this suggests that non-dancers who are well-coordinated via experience, such as athletes or video game players, or those who are innately well-coordinated, may also perceive greater differences between high- and low-groove music compared to those who have less coordination. Indeed, previous research from our lab has reported video game players outperforming non-musicians and performing similarly to musicians on the PROMS melody, tuning, tempo, and rhythm subtests (Pasinski et al., 2016). Future research should investigate musical groove perception differences between different groups of well-coordinated individuals with and without music experience (e.g., athletes, dancers, musicians, gamers, innately well-coordinated people) to better understand how coordination could influence the way we perceive the groove.

Second, higher scores on body awareness may not refer to someone who is well-coordinated, but someone who feels comfortable moving one's body. For example, Rose et al. (2020) reported a significant positive association between the GOLD-DSI body awareness subtest score and the Multidimensional Assessment of Interoceptive Awareness scale's (MAIA; Mehling et al., 2012) trusting subtest score. This score measures the experience of one's body as safe and trustworthy (Mehling et al., 2012). The authors posit that the relationship between these two scores implies that the GOLD-DSI body awareness measure signifies the confidence in perceiving one's bodily signals (Rose et al., 2020). Confidence in body movement may be built up through experience. This experience, however, does not need to be formal dance training. In fact, we found a significant positive association between musical groove difference score and social dancing, a subtest not based on questions involving formal dance experience. This suggests that those who enjoy dancing with others and/or have more social dance experience may hear greater differences between high- and low-groove music compared to those with less desire for or experience with social-based dancing. Because songs with groove are often danced to in social settings, those who feel more comfortable dancing socially may have more familiarity with musical groove and as a result, are better at identifying differences between high- and low-groove music.

Musical Skills

In our third regression model, subtest scores from the BMS and PROMS were collectively not a significant model in predicting variance in musical groove difference ratings. These results do not align with our initial hypothesis that beat sensitivity and meter sensitivity would be reliable predictors of musical groove difference ratings. We were surprised by these findings considering the fact that the PROMS subtests used in this model were chosen based on auditory components commonly found in songs rated high in musical groove (Stupacher, Hove, et al., 2016). The non-significance found in this model could be due to potential measurement error. Except for the PROMS rhythm subtest, the reliability of the PROMS subtests in this study were lower than what has been reported by Zentner & Stauss (2017) and were overall low McDonald's omega values (Trizano-Hermosilla & Alvarado, 2016). A bigger sample size would possibly mitigate some of these reliability issues and may result in a significant model.

Additionally, only some of the correlations between musical groove difference score, BMS measures, and PROMS measures were significant, but none were considered strong. Significant positive correlations were only found between musical groove difference score and beat sensitivity, embedded rhythm, accent, and tempo. Some of our findings reflect previous positive associations found between musical groove ratings and syncopation (Senn et al., 2018) and musical groove ratings and beat salience (Stupacher, Hove, et al., 2016). In contrast, the relationship between musical groove difference ratings and tempo differed from what was reported by Senn et al. (2018): they found a weak, negative correlation between musical groove ratings and tempo. These findings, however, are hard to compare to our results because of differences in measurement of both musical groove and acoustic features. First, these studies investigated overall ratings amongst songs with varying groove ratings and not the differences in mean ratings between high- and low-groove music. Second, the acoustic characteristics measured in previous investigations were derived from the stimuli themselves and were not assessments of individuals' musical skills. Finally, our results show greater effect sizes compared to prior work (R^2 range = 0.002 – 0.152; Senn et al., 2018) which may indicate more meaningful relationships between ratings and acoustic characteristics of musical groove.

An interesting finding that did not align with our initial predictions was the non-significant relationship between musical groove difference score and meter sensitivity. Given the theorized importance of meter in movement and groove (W. Tecumseh Fitch, 2016), we expected to find a significant, positive correlation between these two variables. The perception of meter is important in formal dance. For instance, the identifying characteristic of a waltz, compared to other social dances, is that it is danced in a three-beat pattern to music in 3/4 time. Choreographed pieces in formal dance styles, such as ballet or jazz, are often constructed in two-bar phrases. Therefore, having formal dance training, or at least experience learning choreography (Lee et al., 2015) or moving to a rhythm (Chemin et al., 2014; Phillips-Silver & Trainor, 2006), may potentially enhance auditory rhythm perception. Musical groove perception and its ability to stimulate spontaneous dance movement, however, does not seem to be dependent on formal dance training. While those with and without music training are able to perceive meter (Nave-Blodgett et al., 2021), it may not be as important to the feeling of musical groove as the beat. This may explain why we found significant positive relationships between musical groove difference ratings and beat sensitivity but not meter sensitivity.

A big limitation to the current study was the online format. Online administration was chosen due to social-distancing restrictions set during the COVID-19 pandemic. This may have allowed for large variability in testing environments that could have impacted the reliability of measures used in this model. Furthermore, this limited the type of scales we could use to measure objective musical ability to only perceptual tasks. Collecting accurate temporal information or finger tapping data in online tasks is incredibly unreliable due to potential timing lags and lack of necessary equipment in everyday households, respectively. An interesting addition to this work (once labs are able to host in-person studies) would be to incorporate production tasks, such as a beat production test where participants' finger taps along to music are measured for timing accuracy. A task like this would measure both body movement coordination *and* musical beat sensitivity. It is possible that the ability to produce a beat accurately in time to music may be a more reliable predictor of hearing differences between high- and low-groove music than purely perceptual beat sensitivity.

Instead, it may be that possessing heightened perceptual skills on all these music-based tasks synergistically may be more predictive of musical groove difference ratings than each of them alone. In our final, exploratory regression model, GOLD-MSI general musical sophistication, GOLD-DSI participatory dance experience, and a composite of BMS and PROMS musical skills measures together accounted for 9.0% of the variance in musical groove difference ratings. The musical skills composite score had a strong effect on musical groove difference ratings compared to general musical sophistication. These results did partially align with our initial hypothesis that the collective performance on perceptual musical skills tests would be a strong predictor of musical groove difference ratings. Our results also support previous research: Janata et al. (2012) posited that listeners find music with a combination of melodic and rhythm characteristics to be more "groovy" compared to those with only rhythmic attributes (e.g., drum breaks) or a train of isochronous beats.

Participatory Dance Experience

Another significant predictor in our final regression model was participatory dance experience. This GOLD-DSI measure combines body awareness, social dancing, urge to dance, and dance training (Rose et al., 2020). We did not initially hypothesize this measure to be a significant predictor of differences between high- and low-groove song ratings. As previously mentioned, the GOLD-DSI is a new measure and is one of the first psychometric indexes investigating the influence of varying facets of dance sophistication on musical groove perception. Because of this, there is currently little evidence supporting participatory dance experiences' direct effect on musical groove difference ratings.

Previous research has found familiarity for a song or its musical style to have a considerable effect on the experience of musical groove (Senn, Bechtold, et al., 2019). In the present study, individuals who scored higher on participatory dance experience had greater musical groove difference ratings. Participatory dance experience may also be closely linked to familiarity. Those with more experience participating in dancing or dance activities may have had more exposure to music with groove compared to those with less participatory dance experience. Additionally, these individuals may have a more embodied familiarity with dance music. The feeling of groove may not be complete without active participation of the body (Iyer, 2002; Leman, 2008, 2012; Schiavio & Jaegher, 2017). The pleasure experienced when feeling "in the groove" may be attributed to the process of creating movement that synchronizes well with music (Garcia, 2005). Therefore, those who have experience moving to music with high- and low-groove may be better at detecting differences between them.

A question we did not ask in the present study was about participants' prior embodied experience with the song stimuli. Previous research has reported that those who have danced to a particular song are better at synchronizing to the song's beat and find it more enjoyable to listen to compared to songs they have not danced to before (Kirsch et al., 2015; Lee et al., 2015). Future iterations of this research should consider asking questions about participants' embodied familiarity with songs to see if that affects the way musical groove is perceived.

Implications

The clinical implications of this research may include tools for better understanding of perceptual differences in those diagnosed with movement impairments (e.g., Parkinson's disease). There is growing interest in using musical groove as an enjoyable and beat-centric therapeutic tool to aid in shuffling gait, a prominent symptom of Parkinsonism (Krotinger & Loui, 2021; Nombela et al., 2013). Additionally, listening to music with groove may also benefit those diagnosed with developmental disorders, such as Attention Deficit Hyperactivity Disorder (ADHD) who have a harder time moving to the beat compared to typically-developing individuals (Puyjarinet et al., 2017). What is less understood, however, is whether individuals from these clinical populations perceive music similarly to those without these diagnoses. It is possible that the low dopaminergic transmission that cause symptoms of dyskinesia (Galvan & Wichmann, 2008) or inattention (Solanto, 2002) may disrupt or slow timing processes that regulate perception of the beat (Grahn & Brett, 2009). Additionally, results from this investigation may help develop more objective assessments of dance skills that can measure dance ability in a wide array of individuals. For example, Nguyen (2017) conducted a study using motion capture to create a visual bouncing figure to measure beat perception and production; however, there is need to create additional measures that assess skills that are unique to dance.

Conclusion

The present study investigated the influence of musical sophistication, dance sophistication, and musical perceptual abilities on musical groove perception. We found that perceptual abilities, musical training, body awareness, participatory dance experience, and performance on a variety of musical skills tasks are strong predictors of rating differences between high- and low-groove music. Overall, our results indicate that the experience of groove may not be dependent on way the music is written or performed but shaped by listeners' individual experiences and innate abilities.

Appendix A

Auditory Experience Adult Background Questionnaire | UNLV

(All information will be kept confidential)

*Participant#:*______

Background Information

Age:____________________

Sex: ○ Male ○ Female

Handedness: ○ Right ○ Left ○ Ambidextrous

Year in school: ○ Fresh. ○ Soph. ○ Jr. ○ Sr. ○ Non-degree seeking

Are you Spanish/Hispanic/Latino? (*Check one)*

○ No, not Spanish/Hispanic/Latino
○ Yes, Puerto Rican
○ Yes, Mexican, Mexican-American, Chicano
○ Yes, Cuban
○ Yes, other Spanish/Hispanic/Latino: ____________________________________

What is your race? *Check all that apply*

☐ White ☐ Black/African American ☐ American Indian/Alaska Native
☐ Asian Indian ☐ Chinese ☐ Filipino ☐ Japanese
☐ Korean ☐ Vietnamese ☐ Other Asian: __________________
☐ Native Hawaiian ☐ Guamanian/Chamorro ☐ Other Pacific Islander: __________________
☐ Samoan ☐ Some other race: _______________________

Mother's Highest Education Level? ○ No H.S. diploma ○ H.S. diploma ○ Some college ○ 4-year College degree ○ Graduate school degree ○ Technical school

Father's Highest Education Level? ○ No H.S. diploma ○ H.S. diploma ○ Some college ○ 4-year College degree ○ Graduate school degree ○ Technical school

Hearing & Medical History

Have you ever had frequent ear infections (more than three per year)? ○ Yes, at what age(s)? ____________________ ○ No

Have you ever had pressure equalizing tubes in your ears?	O Yes, at what age(s)? ____________________ O No
Do you have a hearing impairment?	O Yes, describe: ________________________ O No
Do you have a vision impairment?	O Yes, if so: Is it corrected via contacts or glasses? O Yes O No Are you currently wearing your corrective lenses? O Yes O No O No
Do you have a cold today?	O Yes O No
Do you have an ear infection, currently?	O Yes O No
Have you been in any unusually noisy environments?	O Yes, describe: ________________________ For how long? ________________________ O No
Have you ever been diagnosed with a neurological/psychological disorder (ADHD, epilepsy, etc.)?	O Yes, please describe: ______________________________________ O No

If you are participating in an EEG study, please answer the following questions. Otherwise, skip to the "Language Information" section.

Do you take any medications regularly?	O Yes, please list: ______________________________________ O No
Have you ever had a serious head injury (concussion, unconsciousness, etc.)?	O Yes, please describe: ______________________________________ O No

Language Information

Country of Your Birth:	______________________________________
Country of Parents' Birth:	Mother:__________________Father: _____
Language… a. learned as child:	______________________________________ ______________________________________

b. age English learned, if not first: ____

Do you speak a language other than Englisl ○ Yes, which ones? ____________________

○ No

Non-English language competence: ○ N/A ○ Beginner ○ Intermediate ○ Advanced/Fluent

Do you consider yourself bilingual? ○ Yes; What do you consider your dominant/main language? ____________________

What percentage of the time do you speak your main language(s) (e.g. 50%, 30%, etc.): ____________________

○ No

Have you lived in any country outside of the United States of America? ○ Yes, where? ____________________
How long? ____________________
○ No

Describe your exposure to music there: ____________________

Describe your exposure to dance there: ____________________

Music Information

Do you sing or play an instrument? ○ Yes ○ No

How would you describe yourself as a musician (please choose ONE):
○ Occasional Musician *(less than weekly practice/participation)*
○ Recreational Musician *(weekly practice or recreational playing/performance)*
○ Serious Amateur Musician *(extensive commitment to practice and/or recreational music activity)*
○ Professional Musician (*paid to perform and/or teach music)*

Type of music practiced (Classical/Jazz/Folk/etc.)? __

__

Instrument(s): ____________________

Have you ever played an instrument in an ensemble (i.e. school band, orchestra, etc.` ○ Yes ○ No

Type of Ensemble: (check all that apply) O School Band O Private Institute Band O Self-Arranged Ensemble
O School Orchestra O Private Institute Orchestra O Other ___________________

Beginning at what age? ________________ No. of years? ______________________________

Have you ever sung in an ensemble? O Yes O No

Type of Ensemble: (check all that apply) O School Choir O School Theater Group
O Self-Arranged Ensemble O Other _

Have you ever taken private music lessons O Yes O No

Beginning at what age? ____________________________________ No. of years? ______________________________

Solo or group lessons? (please describe if group): ____

Are you currently taking private lessons? O Yes, days per week: _____________hours per day:_____________________________
Instrument: ________
O No

How often do you play/sing music on a weekly basis? O 1 day O 2-3 days O 4-5 days O 6-7 days

How many hours per day do you practice music (on average)? ____

How many hours per day do you play music for recreation (on average)? ____

Have you performed or taught music professionally (i.e. for pay)? O Yes; for how many years? _
O No

Dance Information

Do you dance (recreationally, formally, professionally, etc.)? O Yes O No

How would you describe yourself as a dancer? (please choose ONE): O Occasional Dancer *(less than weekly dancing for fun or practice)*
O Recreational Dancer *(weekly practice or recreational dance)*

	O Serious Amateur Dancer *(extensive commitment to practice and recreational dance activity)* O Professional Dancer (*paid to perform and/or teach dance)*
Type(s) of dance practiced:	O Folk O Ballet O Hip-Hop O Middle Eastern O Contra-dance O Contemporary O Jazz O Asian O Ballroom OFlamenco/Latin O Tap O Lyrical O Other(s): ___________________
Have you ever participated in formal dance lessons?	O Yes O No
Beginning at what age? _____	No. of years? _
Are you currently taking dance classes or lessons?	O Yes, hours per week: _____________________ Type of dance: __________________________ O No
How often do you dance on a weekly basis?	O 1 day O 2-3 days O 4-5 days O 6-7 days
How many hours do you practice dance pe day (on average)?	____
How many hours do you dance recreationally per day (on average)?	____
Have you danced professionally (i.e. for pay)?	O Yes; for how many years? _ O No

<u>Other Information</u>

Can you read music?	O Yes O No
Have you ever taken music courses at the university level?	O Yes, which course(s)? ____ O No
Do you have formal training in music theory (classes or self-taught)?	O Yes O No
If so, how many years?	O 0.5 O 1 O 2 O 3 O 4-6 O 7+
Do you have absolute pitch?	O Yes O No O Don't Know
How many hours per week do you listen to music (on average)?	____

What types of music do you listen to?	______________________________
How much music did you listen to growing up (i.e. hours per week)?	______________________________
I have gotten goosebumps/shivers from listening to music before.	○ Yes ○ No
Are any of your family members musicians?	○ Yes, who: ____________________ ○ No
Are any of your family members dancers?	○ Yes, who: ____________________ ○ No
Do you exercise regularly?	○ Yes ○ No
How many days per week do you exercise?	○ 1 day ○ 2-3 days ○ 4-5 days ○ 6-7 days
Hours per day when you exercise:	______________________________
Do you like to listen to music when you exercise?	○ Yes ○ No
If so, what kind(s) of music?	______________________________
During what other activities do you like to sic?	Please list: ____________________ ______________________________

Thank you for your participation!

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Witek, M. A. G., Clarke, E. F., Wallentin, M., Kringelbach, M. L., & Vuust, P. (2014). Syncopation, body-movement and pleasure in groove music. *PLoS ONE*, *9*(4). https://doi.org/10.1371/journal.pone.0094446

Witek, M. A. G., Liu, J., Kuubertzie, J., Yankyera, A. P., Adzei, S., & Vuust, P. (2020). A critical cross-cultural study of sensorimotor and groove responses to syncopation among Ghanian and American university students and staff. *Music Perception*, *37*(4), 278–297.

Witek, M. A. G., Popescu, T., Clarke, E. F., Hansen, M., Konvalinka, I., Kringelbach, M. L., & Vuust, P. (2017). Syncopation affects free body-movement in musical groove. *Experimental Brain Research*, *235*(4), 995–1005. https://doi.org/10.1007/s00221-016-4855-6

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Zatorre, R. J. (2013). Predispositions and plasticity in music and speech learning: Neural correlates and implications. *Science*, *342*(6158), 585–589. https://doi.org/10.1126/science.1238414

Zatorre, R. J. (2015). Musical pleasure and reward: Mechanisms and dysfunction. *Annals of the New York Academy of Sciences*, *1337*(1), 202–211. https://doi.org/10.1111/nyas.12677

Zatorre, R. J., Chen, J. L., & Penhune, V. B. (2007). When the brain plays music: auditory-motor interactions in music perception and production. *Nature Reviews. Neuroscience*, *8*(7), 547–558. https://doi.org/10.1038/nrn2152

Zentner, M., & Strauss, H. (2017). Assessing musical ability quickly and objectively: development and validation of the Short-PROMS and the Mini-PROMS. *Annals of the New York Academy of Sciences*, *1400*(1), 33–45. https://doi.org/10.1111/nyas.13410

Curriculum Vitae

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EDUCATION

2021 *Ph.D.*, Psychological and Brain Sciences, University of Nevada, Las Vegas, NV
Advisor: Joel S. Snyder, Ph.D.
Dissertation: *Exploring the relation between musical and dance sophistication and musical groove perception*

2018 *M.A.*, Psychology, University of Nevada, Las Vegas, NV
Advisor: Joel S. Snyder, Ph.D.
Thesis: *Why musical groove makes us move: an electroencephalographic investigation*

2011 *B.A.*, Psychology, Northwestern University, Evanston, IL

2011 *B.Mus.*, Music Performance, Northwestern University, Evanston, IL
Instrument: Violin

PUBLICATIONS

O'Connell, S. R. (2018). Why musical groove makes us move: an electroencephalographic investigation (Order No. 10974299). Available from Dissertations & Theses at University of Nevada Las Vegas; *ProQuest Dissertations & Theses Global*. (2210151304).

Lenartowicz, A., Simpson, G.V., **O'Connell, S.R.**, & Cohen, M.S. (2015). Measurement of neurophysiological signals of ignoring and attending processes in attention control. *JoVE (Journal of Visualized Experiments),* (101), e52958.

Slater, J., Skoe, E., Strait, D. L., **O'Connell, S.**, Thompson, E. C., & Kraus, N. (2015). Longitudinal evidence of improved speech-in-noise perception with group music training. *Behavioral Brain Research,* 291, 244-252.

Strait, D. L., Slater, J., **O'Connell, S.**, & Kraus, N. (2015). Music training relates to the development of neural mechanisms of selective auditory attention. *Developmental Cognitive Neuroscience*, 12, 94-104.

Slater, J., Strait, D. L., Skoe, E., **O'Connell, S.**, Thompson, E. C., & Kraus, N. (2014). Longitudinal effects of group music instruction on literacy skills in low-income children. *Plos One*, 9(11), e113383.

Strait, D. L., **O'Connell, S.**, Parbery-Clark, A., & Kraus, N. (2014). Musicians' enhanced neural differentiation of speech sounds arises early in life: Developmental evidence from ages three to thirty. *Cerebral Cortex, 24*(9), 2512-2521.

Strait, D. L., Parbery-Clark, A., **O'Connell, S.**, & Kraus, N. (2013). Biological impact of preschool music classes on processing speech in noise. *Developmental Cognitive Neuroscience,* 6, 51-60.

Tierney, A., Strait, D. L., **O'Connell, S.**, & Kraus, N. (2013). Developmental changes in resting gamma power from age three to adulthood. *Clinical Neurophysiology*, *124*(5), 1040-1042.

AWARDS

2019-21 UNLV Foundation Board of Trustees Fellowship, University of Nevada, Las Vegas, NV

2017-21 Summer Doctoral Fellowship, University of Nevada, Las Vegas, NV

2017-19 Patricia Sastaunik Scholarship, University of Nevada, Las Vegas, NV

2017 Lovinger Award, Department of Psychology, University of Nevada, Las Vegas, NV

2015-16 Graduate Recruitment Scholarship, University of Nevada, Las Vegas, NV

PRESENTATIONS

Posters

Lenartowicz, A., Simpson, G.V., **O'Connell, S.R**.*, Noah, S.L.M., Head, A.L., Bilder, R.M., McCracken, J.T., Bookheimer, S.Y., Reid, R., Cohen, M.S. (2015). *New EEG measures reveal infra-slow fluctuations in both attending and ignoring in adults with ADHD that provide high accuracy in discriminating ADHD from control*. Society for Neuroscience. McCormick Place, Chicago, IL.

Strait, D.L., **O'Connell, S.**, Kraus, N. (2012). *Neural discrimination of stop consonants in musician and nonmusician children*. MidWinter Meeting of the Association for Research in Otolaryngology. San Diego, CA.

O'Connell, S.*, Strait, D.L., Parbery-Clark, A., Kraus, N. (2011). *Musical training promotes development of attention abilities: evidence in children and adults.* Music, Science and Medicine: Frontiers in Biomedical Research and Clinical Applications, New York Academy of Sciences, New York, NY.

O'Connell, S.*, Strait, D.L., Parbery-Clark, A., Kraus, N. (2011). *Musical training promotes development of attention abilities: evidence in children and adults.* Chicago Area Undergraduate Research Symposium. Museum of Science and Industry, Chicago, IL.

*presenting author

Talks

Musical Groove Perception: Studies on Motor System Engagement and Arts Sophistication. Bionic Ear Lab, University of Southern California, Los Angeles, March 26th, 2021.

Why Does It Feel So Good to Dance? Movement, Music, and the Brain. Chicago Tap Theatre, Chicago, IL, December 27th, 2020.

Why Musical Groove Makes Us Move: An Electroencephalographic Investigation. Master's Thesis Defense, Department of Psychology, University of Nevada, Las Vegas, July 31, 2018.

Why Musical Groove Makes Us Move: An Electroencephalographic Investigation. Departmental Data Blitz, Department of Psychology, University of Nevada, Las Vegas, April 18, 2018

Why Music Makes Us Dance: An EEG Investigation. Department of Psychology, University of Nevada, Las Vegas, November 15, 2016.

Investigating the Influence of Groove on Motor Excitation and Arousal. Department of Psychology, University of Nevada, Las Vegas, April 20, 2016.

RESEARCH EXPERIENCE

2016-21 Graduate Student Researcher, University of Nevada, Las Vegas, NV
Auditory Cognitive Neuroscience Laboratory
Principal Investigator: Joel S. Snyder, Ph.D.

2013-15 Staff Research Associate II, University of California Los Angeles, CA
Staglin IMHRO Center for Cognitive Neuroscience
Principal Investigators: Mark S. Cohen, Ph.D. & Agatha Lenartowicz, Ph.D.

2013-15	Senior Research Associate, Think Now, Inc., San Francisco, CA Principal Investigator/CSO: Gregory V. Simpson, Ph.D.
2010-13	Research Assistant, Northwestern University, Evanston, IL Auditory Neuroscience Laboratory Principal Investigator: Nina Kraus, Ph.D.
2009	Research Assistant, Northwestern University, Evanston, IL Institute for Policy Research Principal Investigator: Alice Eagly, Ph.D.

TEACHING EXPERIENCE

2018-19	Course Instructor, Department of Psychology, University of Nevada, Las Vegas, NV Course: General Psychology (Undergraduate), 2 sections per semester, approx. 25 students per section, in-person instruction
2016-17	Teaching Assistant, Department of Psychology, University of Nevada, Las Vegas, NV Course: Introduction to Cognitive Neuroscience (Undergraduate), 1 section per semester, approx. 25 students per section
2016	Teaching Assistant, Department of Psychology, University of Nevada, Las Vegas, NV Course: Sensation and Perception (Undergraduate), 1 section, approx. 25 students

ADDITIONAL TRAINING

2017	Certification in Responsible Conduct of Research, Department of Psychology, University of Nevada, Las Vegas, NV
2016	Certification in Non-Invasive Brain Stimulation Method, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA
2016	ERP Boot Camp, Center for Mind and Brain, University of California, Davis, CA

ASSOCIATIONS

2021-	Member, *Association for Research in Otolaryngology (ARO)*
2018-19	Member, *American Psychological Association: Society for Teaching of Psychology*
2017-19	Member, *Association for Psychological Science*
2016-	Member, *Society for Music Cognition and Perception (SMPC)*

SERVICE

2021-	Diversity and Minority Committee Representative, Student, Postdoc, Resident and Fellow chapter of the Association for Research in Otolaryngology (spARO) Steering Committee
2019	Instructor, Rebel STEM Academy, University of Nevada, Las Vegas, NV
2018	Instructor, Dawson Bound Project, Las Vegas, NV
2017	Judge, Beal Bank USA Southern Nevada Regional High School Science & Engineering Fair, Las Vegas, Nevada
2017	Secretary, 500 Women Scientists, Las Vegas, NV
2016-21	Mentor, Outreach Undergraduate Mentoring Program, University of Nevada, Las Vegas, NV

2016 Secretary, Experimental Student Committee, Department of Psychology, University of Nevada, Las Vegas, NV

TECHNICAL SKILLS

Programming Languages: Matlab

Human Neuroimaging:

- EEG (cortical and auditory brainstem responses)
  - Hardware: Biosemi, Neuroscan, Electrical Geodesic, Inc., DuoMag
  - Software: BESA, Net Station, BrainVision Analyzer, ActiView, EEGlab, ERPlab
- TMS: DuoMAG, Magstim

Stimulus Creation and Presentation: Presentation, E-Prime, Audacity

Statistical Analysis: SPSS