JYU DISSERTATIONS 703

Deniz Duman

What Makes Us Groove?

UNIVERSITY OF JYVÄSKYLÄ
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ABSTRACT

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Music captures listeners' attention easily, gives pleasure, makes people dance, and feel connected to other people. In the field of musicology, this combination of musical experiences relates to the concept of groove. Over the last two decades there has been a spike in groove research, revealing both variables that influence listener's groove experiences as well as its applications in social interaction, clinical groups with perception, and motor- and affect-related issues. Despite progress in the field, it is still unclear how listeners' groove experiences are shaped. Recent papers highlight the need for further investigation of variables, mechanisms and neural bases of groove. Thus, the primary motivation of this dissertation is to explore nuances of the concept of groove from various angles by using multiple naturalistic methodical approaches. The current dissertation presents novel findings into the main topics of (i) the concept of groove, (ii) musical features related to groove, (iii) experiences associated with groove, (iv) characteristics and goals of listeners, and (v) neural processing of groove. Notably, these various subjects are presented in a broader context adopting an ecological perspective and introduced through the psychological concept of affordances. In particular, this dissertation proposes an updated comprehensive working definition of groove, and presents it as a multifaceted participatory experience. Importantly, the findings suggested that the concept of groove is closely linked to the function of music listening as regulation of mood and arousal. Moreover, the conducted additional studies (related to reasons for listening to music and personality traits) contributed to development of a psychological model of groove. Finally, part of the thesis investigated an under-researched aspect related to groove, namely how naturalistic groove-related music is processed in the brain. Synthesising these findings, in the discussion section (1) details about personal, complex and multidimensional characteristics of the concept of groove are discussed, (2) in an attempt to explain "why we groove", four types of pleasure associated with groove are presented, and (3) relevance of studying the concept of groove is discussed in both clinical and non-clinical settings and further applications of groove research (such as in the context of education) are proposed.

Keywords: groove, immersion, movement, positive affect, social connection

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Musiiikki vangitsee kuulijoiden huomion helposti, tuottaa mielihyvää, saa ihmiset tanssimaan ja tuntemaan yhteyttä muihin ihmisiin. Musiikkitieteen alalla nämä musiikkielämyksen elementit liittyvät käsitteeseen "groove". Viimeisten kahden vuosikymmenen aikana groove-tutkimuksessa on ollut huomattava kasvu, joka on paljastanut niin kuulijoiden groove-elämyksiin vaikuttavia muuttujia kuin sen sovelluksia sosiaalisessa vuorovaikutuksessa sekä kliinisissä ryhmissä, joilla on havaintoon, motoriikkaan tai tunteisiin liittyviä ongelmia. Vaikka alalla onkin edistytty, on yhä epäselvää, miten kuulijoiden groove-elämykset muotoutuvat. Viimeaikaiset artikkelit korostavat tarvetta edelleen tutkia grooveen vaikuttavia muuttujia, mekanismeja ja sen neurologisia perusteita. Tämän väitöskirjan päätavoite onkin tutkia groove-käsitteen nyansseja eri näkökulmista käyttäen useita luonnollisia metodologisia lähestymistapoja. Tämä väitöskirja esittää uusia löydöksiä seuraavista pääaiheista: (i) grooven käsite, (ii) grooveen liittyvät musiikilliset piirteet, (iii) grooveen liittyvät kokemukset, (iv) kuuntelijoiden ominaisuudet ja tavoitteet sekä (v) grooven neuraalinen prosessointi. Nämä erilaiset aiheet esitetään laajemmassa kontekstissa, joka hyödyntää ekologista näkökulmaa, ja esitellään psykologisen affordanssin käsitteen kautta. Tämä väitöskirja ehdottaa päivitettyä ja kattavaa työskentelymääritelmää groovesta ja esittää sen moniulotteisena osallistavana kokemuksena. Tärkeä havainto on, että grooven käsite liittyy läheisesti musiikin kuuntelun rooliin mielialan ja vireystilan säätelynä. Lisäksi suoritetut lisätutkimukset (liittyen musiikin kuuntelun syihin ja persoonallisuuden piirteisiin) ovat edistäneet groove-psykologisen mallin kehittämistä. Lopuksi väitöskirja käsittelee tähän mennessä vähemmän tutkittua grooven neuraalista prosessointia. Näiden löydösten synteesinä keskusteluosiossa (1) käsitellään groove-käsitteen henkilökohtaisten, monimutkaisten ja moniulotteisten piirteiden yksityiskohtia, (2) selitetään "miksi grooveamme" esittämällä neljä nautinnon tyyppiä, jotka liittyvät grooveen, ja (3) pohditaan groove-käsitteen tutkimisen merkitystä sekä kliinisissä että ei-kliinisissä yhteyksissä ja esitetään groove-tutkimuksen mahdollisia sovelluksia, kuten koulutuskontekstissa.

Avainsanat: groove, uppoutuminen, liike, positiivinen vaikutelma, sosiaalinen yhteys

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I would like to dedicate this thesis to my dear friend Veli, who would have been very proud of my work. Thank you all for being an integral part of my journey.

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THE AUTHOR'S CONTRIBUTIONS

The author had the following main roles in the above-mentioned Publications:

I. Together with her supervisors, the author designed the study. The author collected the data, performed data analysis, wrote the original draft and edited the paper.

II. Together with her supervisors, the author designed the study. The author collected the data together with a co-author of the paper, performed data analysis, wrote the original draft and edited the paper.

III. Together with her supervisors, the author designed the study. The author collected the data, performed data analysis and wrote the original draft and edited the paper.

IV. Together with her supervisors and a master's student the author designed the study. The author performed data analysis and wrote the original draft and edited the paper.

FIGURES

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CONTENTS

1 INTRODUCTION

If you would visit a museum that is showcasing early human cultures (The British Museum in London, for example), there would almost certainly be a few sections relating to our ancestors' musical activities around the globe. Such musical activities are known to have been part of rituals, in helping to transmit knowledge across generations, and in managing social relationships (Trehub et al., 2015). It is known that ancient humans danced and made music, for instance, during dry seasons to beg for rain, or during agriculture and hunting to have enough food to survive. Music and dance are so bound together that our ancestors from Thailand and Nigeria did not even have separate terms for music and dance (Trehub et al., 2015). In fact, to observe the relatedness of dance and music and their significance in our lives, one does not need to travel in time. If we look at babies, we see that they are sensitive to movement patterns to music as early as 7 months of age (Phillips-Silver & Trainor, 2005). This could be because music is so rewarding. It captures our attention easily, gives us pleasure, makes us dance, and makes us feel connected to other people. In the field of musicology, this combination of musical experiences relates to the concept of groove (Duman, Snape et al., 2023).

In the literature, groove is stated to be 'an essential part of popular music' (Zbikowski, 2004). Over the last two decades, there has been a spike in groove research. In a recent preprint, Etani et al. (2023) reviewed the psychological and neuroscientific research on groove between 2006 and 2022. They presented the trending findings in the groove literature under five categories: concept of groove, musical features of groove, responses to groove, characteristics of listeners, and culture and environment. Previous research has also focused on (possible) applications of groove in interpersonal synchronization and social interaction (Witek, 2017), prosocial behaviour (Stupacher et al., 2017), clinical groups with perception, and both motor- (ie. Parkinson's Disease: Pando-Naude et at., 2023; Hove & Keller, 2015; Nombela et al., 2013) and mood- (Witek et al., 2015) related problems.

Despite the progress in the field, it is still unclear how listeners' groove experiences are shaped. Thus, several recent papers call for further investigation

of variables, mechanisms and neural bases of groove (Senn et al., 2023; Stupacher et al., 2022; Etani et al., 2023). For instance, while Senn and colleagues (2023) state that the groove model they presented is incomplete, Etani and colleagues (2023) listed four main gaps for future groove research which are linked with social and musical aspects of groove, mechanisms related with groove, and possible clinical application of groove research.

Similar to the review by Etani et al. (2023), the current dissertation will present novel findings on the topics of (i) the concept of groove, (ii) musical features related to groove, (iii) experiences associated with groove, (iv) characteristics and goals of listeners (in an environment), and (v) neural processing of groove. Notably, these various subjects will be put into a broader context adopting an *ecological perspective* and introduced through the psychological concept of *affordances*. Crucially, several gaps in the groove literature raised by Etani and colleagues (2023) are tackled in this dissertation (such as the relationship between groove and tempo, and other specific examples will be discussed in the following chapters). Finally, in the discussion section, advancing the topic of clinical applications, the relevance of studying the concept of groove will be discussed in non-clinical settings and further applications of groove research (such as in the context of education) will be proposed.

The primary motivation of this dissertation is to explore *granularity* of groove from various angles by using *multiple naturalistic methodical approaches*. With 'granularity', a similar approach as in the emotion literature is taken, which is described as "the ability to make fine-grained, nuanced distinctions between similar emotions" (Smidt & Suvak, 2015, p.48). Combining several experimental and analytical approaches (including qualitative and music information retrieval data, dimensionality reduction and correlational methods, electroencephalogram recordings), the goal is to help us better understand the variables that influence listeners' groove experiences and facilitate advancement not only in the groove literature but also its application to fields outside academia. For this purpose, four interrelated articles were compiled. These articles focused specifically on the following research questions:

1. What makes a song groove?
2. What are the groove-related songs that people listen to and what are the primary reasons that people listen to such songs?
3. What is the role of personality traits in people's groove experiences?
4. How is groove music processed in the brain?

Research findings of these four articles are explained within the ecological theory and the concept of affordances. The framework of the thesis is as follows. Chapter 2 describes (musical) affordances, and provides a review of groove and related literature. Chapter 3 presents the aims and overview of the thesis. Chapter 4 explains the methodological details of the studies included in the thesis. Chapter 5 includes summaries of the four original articles upon which the thesis is based. Finally, Chapter 6 offers a general discussion and concluding remarks.

2 BACKGROUND

Combining different theoretical approaches is described as the key to understanding the phenomenon of groove (Etani et al., 2023). Previously, the concept of groove has been investigated using several theories such as dynamic attending (Large & Jones, 1999), neural resonance (Large & Synder, 2009), predictive coding (Vuust & Witek, 2014), theories of expectations (Meyer, 1956; Huron, 2006), embodied cognition (Shapiro, 2019; Leman & Mae, 2014) and ecological theory (Gibson, 1979; Clarke, 2005) in works by Witek (2013), Stupacher (2017) and Matthews (2021). Research findings included in this dissertation overlap mostly with the *ecological theory* and the concept of *affordances* in particular. Therefore, next, an overview of ecological theory and affordances is provided.

2.1 Ecological Theory and Affordances

Ecological theory was proposed by James Jarome Gibson and Eleanor Jack Gibson as an alternative to cognitivist and behaviourist approaches to perception and cognition (Lobo et al., 2018). Contrasting with conventional theories, the ecological approach re-evaluates the power of stimulus and considers the perceiver as an *active* entity. In other words, ecological theory highlights the continuous dialogue between action and perception. Thus, an *interaction* between the organism and the environment is emphasized for perception and action.

With the ecological perspective, around the 1920s J. J. Gibson pioneered the term *affordances*, which refers to the *possibilities that the environment offers to the perceiver* in the field of psychology. A classic, day-to-day example of affordances is a seat that by its physical qualities such as flatness, rigidness, horizontalness and being knee-high, invites people to sit upon. Affordances are highlighted as being relative to the *entity* (and its capabilities) who is engaging with the environment. For instance, for an infant a seat does not offer the same possible interactions as for an adult (Gibson, 1977). Action possibilities of the environment

have been further linked with *needs, motivations* and *intentions* of the entity. As Reed (1993, p. 68) describes, motivation and intentions are "spread out across mind, body, information, ecological context, and social setting", which offers an explanation as to why the same environment might offer different affordances to different people, even at different points in time (Reed & Jones, 2019; Withagen et al., 2012). For instance, for a tired person who seeks rest, any surface with seat-like affordances might be perceived as relevant to interact with and to be sat upon; whereas for another person who went out for a walk, the same surface might not be perceived with seat-like qualities. Consequently, the actions of these two people towards the same environment differ as a result of their needs and motivations.

The concept of affordances has been widely considered including in industrial, architectural and technological design of artifacts and the environment. Donald Norman (1988), for example, describes the power of affordances in design; a good design being able to reveal to an inexperienced user how to use an object without any instruction (such as how a drawer handle naturally engages the subject with a pulling behaviour).

2.2 Musical Affordances

In the last two decades, the field of musicology paid increased attention to affordances of soundscapes and music (Clarke, 2005; Clarke, Williams, & Reynolds, 2018; Krueger, 2011, 2014; Menin & Schiavio, 2012; Windsor & De Bézenac, 2012; Huron & Berec, 2009). Clarke and colleagues (2018) suggest that one of the functions of art is to provide better interaction possibilities for people with their environments. They further discuss that, in our dynamically changing environment, dynamically changing organisms have the potential to perceive different things from the same music. As a result, a range of possible actions are afforded by music such as "dancing, worship, co-ordinated working, persuasion, emotional catharsis, marching, foot-tapping, and a myriad of other activities of a perfectly tangible kind" (Clarke, 2005, p.38). Similarly, Krueger (2011) describes music as a "nested acoustic environment" that affords possibilities (such as emotion regulation, social coordination and identity construction) which depends on *qualities of music* and *interactional nature*.

Perception of music and its affordances shape the actions of the listener depending on their *particular situation*, as Krueger states (2014, p.6): "the listener offloads certain regulative functions onto the music; instead of attending to this time-keeping, action-monitoring information herself, she allows the music to tell her both when and how to act". Thus, certain *characteristics of music* (such as musical textures and sonic patterns) afford physical and affective entrainment, and consequently shape our musical experiences. For instance, while "texturally simple" lullabies provide babies with a secure and emotionally warm environment, guitar-based loud rock music might have different affordances for the baby, but could work to draw a crowd's attention and coordinate their actions

(such as standing up and cheering along) during an athletic event (Krueger, 2011). In another scenario, especially during adolescence, music might function as a tool for expressing emotions, understanding and forming social identities (Saarikallio, Randall, & Baltazar, 2020).

Moreover, DeNora states that "[music] meditates tensions between endogenous (bodily) and exogenous (environmental) processes" (2000, p.79). In this regard, the questions "how does music mediate this tension between the body and the environment?" and "what are the variables influencing musical affordances?" naturally arise. One possible explanation to these questions could be reached from the point by Windsor and De Bézenac (2012); the listener actively interprets and participates in musical stimuli by responding with appropriate behaviour which "result from musicians, instruments, environments and listeners" (p.103). Therefore, an *interactional process* among musicians, the instruments they use, and the *environment* they are in together with the listeners can be considered as key elements for the concept of musical affordances.

2.3 Overview of the Groove Literature

As a word, groove might be a familiar term to many people. However, the exact definition of it has been described as koan-like[1] (Zbikowski, 2004) or challenging to grasp (Hosken, 2020). This could be because groove has been used in various fields throughout history (such as in mining, referring to a canal in wood, metal and vinyl, and different branches of musicology). In fact, according to Roholt (2014), the use of the term groove in the field of music is rather *borrowed* and *metaphorical*. This might be the other reason for groove to be a koan-like concept. In a similar vein, if one reads dictionary examples of groove, various early uses of the term in daily life will be encountered; referring to having a good time, a state of being, performance style, rhythm, general preference, cool or hip (in slang), going back to one's previous state, being immersed or being successful (details of these examples can be found in Duman, Snape et al., 2023). Later on, after the nineteenth century, groove gained popularity in the field of music. While in the 1920s "in the groove" referred to a "good performance" (Back in the Groove, n.d.), by the 1940s it was denoting more a musical style and related aesthetic aspects (Kernfeld, 2002). By the 1970s, groove was mostly linked with funk and soul musical styles (Hale, 2014) as well as the slang words cool or hip (Hein, 2011; Runyan et al., 2013).

Groove also has various connotations across different branches of musicology. From a music-historical point of view, it is connected mostly with the "Black Atlantic" music of the mid-twentieth century (Attas, 2011) such as latin, reggae and jazz (Davies et al., 2012; Pressing, 2002; Frühauf et al., 2013). On

[1] Koan is a term in Buddist philosophy referring to a paradoxical question with no solution. In the context of groove, Zbikowski (2004) explains groove to be a koan-like concept, as something to be known only while experiencing it.

the other hand, an ethnomusicologist has described groove as participatory discrepancies: "[Participatory discrepancies] exist. Between players. Between the beginnings of their notes. In the moment when each of us chooses to snap fingers, or nod a head, or in the instant when many decide to get up and dance because the music is so contagious." (Keil, 1995, p.2). Here, while *participation* refers to an experience, *discrepant* denotes a musical aspect. More recently, a (music) philosopher described groove similarly; with its *musical* and *felt* dimensions (Roholt, 2014). The concept of groove has come under increasing examination from neuroscientific and psychological approaches in musicology. Since the current work contributes directly to these scientific disciplines, next, previous literature findings related to neuroscientific and psychological approaches to groove music are summarised. (For a detailed overview of groove definitions in different fields, please see Duman, Snape et al., 2023.)

2.3.1 Groove in Neuroscience

Neuroscientific approaches to groove research are increasing (for an overview, also see: Vuust et al., 2022 and Etani et al., 2023). In a Transcranial Magnetic Stimulation (TMS) study, Stupacher et al. (2013) reported that music associated with high groove experience activated the motor cortex more (compared with low groove music) even in the absence of overt movements. Similarly, in a functional magnetic resonance imaging (fMRI) experiment, Matthews et al. (2020) measured brain activity to high vs low groove stimuli and reported stronger activation in motor- and reward-related areas (putamen, supplementary motor area, nucleus accumbens, caudate and orbitofrontal cortex) in addition to prefrontal and parietal cortexes associated with the groove experience. Using functional near-infrared spectroscopy (fNIRS), another study (Fukuie et al., 2022) investigated the role of (dorsolateral) prefrontal cortex (DLPFC) on inhibition of executive functions associated with the experience of groove. Participants completed a Stroop task before and after listening to a metronome or groove-related rhythms. While the general findings showed no difference between conditions, sub-group-level analysis revealed that familiarity to groove rhythms were associated with enhanced DLPFC activity and thus linked with higher inhibition of execution of movement.

Using electroencephalogram (EEG), Cameron et al. (2019) measured neural entrainment to mechanical rhythms (generated via MIDI) versus rhythms performed by humans and reported stronger neural entrainment to rhythms played by humans. This finding was interpreted as demonstrating the importance of microtiming variations for the experience of groove. However, in another, recent EEG and electromyography (EMG) study Nijhuis et al. (2022) examined cortico-muscular coherence (CMC, measured with beta power) during isometric contraction and reported no effect of naturalistic groove music on CMC. This finding is also contradictory to previous findings on sensory-motor processing and beta/mu oscillations (Ross et al., 2022; Engel & Fries, 2010; Khanna & Carmena, 2015; Mazaheri et al., 2009; Pfurtscheller, 1981). These findings demonstrate that more neuroscientific groove research is needed.

2.3.2 Groove in Music Psychology

In the field of music psychology, while one can argue that there are several ways in which groove is described in the literature, such descriptions can still be grouped as referring to aspects related to (1) music and (2) experience. Previous literature examples referring to groove with its musical aspect are: "primordial aspect of music" (Madison, 2001), performed through "mutual tuning-in" (Doffman, 2009) and musicians playing together (Zbikowski, 2004). On the other hand, some of the literature examples denoting groove with its experiential aspect are: "state of listening" (Witek, 2009), "sensation of movement" (Davies et al., 2012), "experience of music" which makes people dance (Madison et al., 2011; Madison, 2006; Stupacher et al., 2013). For an overview of how groove is considered as a musical and experiential concept, see also Etani et al. (2023).

Overall, these literature examples characterise groove with respect to its historical, cultural, as well as musical and psychological aspects, highlighting its complexity. In fact, several musicologists stated that groove is a complex, multifaceted phenomenon. Pfleiderer (2010) describes groove with structural-cognitive, movement, emotional and social dimensions. Danielsen and Camara (2018) highlight three aspects to groove: pattern and performance, pleasure and wanting to move, and state of being. Following a listening task, Hosken (2020) grouped participants' groove descriptions into four themes: movement/energy, tension/relaxation, expectation/surprise and technical language. Senn and colleagues consider (2019; 2023) a model of groove including the following factors: personal background, concrete listening situation, musical properties and the experienced outcome (relating to pleasure and movement).

Nonetheless, in the last couple of decades, groove has gained an operationalised definition as a "pleasurable desire to move to music" (Madison, 2006; Janata et al., 2012). This operationalisation made the investigation of this complex concept much simpler and has led to a surge of interest in the topic. Since then, several factors related to groove have been reported in the literature.

2.3.3 A Groove Model and Factors Related to Groove

In this subchapter, factors associated with groove are summarised (for a broader review, see Etani et al., 2023). In so doing, the main concepts presented in the groove model by Senn and colleagues (2019; 2023), namely personal background, concrete listening situation, musical properties, and the groove experiences (please note that "groove experiences" is a modified title in this work) are employed.

In the groove model (Senn et al., 2023), *urge to move* and *entrained body movement* are situated in the centre and as the outcome (referred to as *groove experiences*). Similarly, several researchers associate groove with the experience of movement (Janata et al., 2012; Stupacher et al., 2013; Ross et al., 2016; González-Sánchez et al., 2018, 2020). Second, *pleasure* is considered as a key factor for experiencing groove (Madison, 2006; Kawase & Eguchi, 2010; Janata et al., 2012; Witek et al., 2014; Matthews et al., 2020). In fact, the Experience of Groove

Questionnaire has two main dimensions, urge to move and pleasure (Senn et al., 2020). Additionally, groove is often described with the experiences of *immersion* or *flow* (Janata et al., 2012; Stupacher, 2019; Câmara & Danielsen, 2018; Duman, Snape et al., 2023). Groove is also linked with a *social aspect* (Witek, 2017; Dotov et al., 2021; Duman, Snape et al., 2023). These experiences of groove are influenced by personal background, musical properties and the concrete listening situation.

Second, in the *personal background* section of the groove model (Senn et al., 2023), there are variables like cultural context, taste, familiarity, affinity towards dance and hedonic tendencies. Empirical evidence for some of these variables can be found in the literature. *Familiarity* with music and musical styles (Fitch, 2016; Senn et al., 2018), *musical expertise* (Senn et al., 2019; Witek et al., 2017) as well as *cultural* details (Witek et al., 2020; Etani et al., 2018) are related with groove experience.

Third, the groove model (Senn et al., 2023) covers *musical properties*. The groove literature has several empirical findings related to this category. For instance, some *genres*, such as pop and funk, are associated with groove more than other genres, such as rock (Senn et al., 2019). Yet, another study argues that groove can be experienced through various styles, including classical, and it is not only restricted to popular music (Frühauf et al., 2013). Several other musical features such as *tempo* (Etani et al., 2018), *frequency ranges* (Stupacher et al., 2016; Hove, Martinez, & Stupacher, 2020; Wesolowski & Hofmann, 2016), *pulse and meter* (Fitch, 2016), *event density* (Madison et al., 2011; Senn et al., 2018), *rhythm*, especially *syncopation* (Witek et al., 2014, 2017) and *harmony* (Matthews et al., 2019) are reported to influence the experience of groove. For *microtiming* on the other hand, the evidence is mixed (Keil, 1995; Frühauf et al., 2013; Senn et al., 2016; Butterfield, 2010).

Finally, contextual details like live/recorded, company/alone, home/club, weekday/weekend and mood are listed for the *concrete listening situation* section in the groove model (Senn et al., 2023). Up to date, empirical contributions in the groove literature regarding contextual details are scarce (Stupacher et al., 2022; Etani et al., 2023). Nevertheless, there are some works on this topic too. Witek (2017) describes a club atmosphere and how such a musical experience among other people can be linked with bonding and groove experiences. In another study, Dotov and colleagues (2021) reported that existence of social cues influences the experience of groove.

2.4 Linking the Concepts of Affordances and Groove

Above, the main variables associated with groove were reviewed using the groove model by Senn et al. (2023). The goal of this subchapter is to demonstrate how the concept of affordances can be applied to the concept of groove using these groove-related variables. Previously, Witek (2013) has explained her groove findings using the concept of affordances. One of the goals of the current

work is to develop this approach and contribute to this line of research that considers groove from an ecological viewpoint. In so doing, the key elements of affordances are combined with the groove model proposed by Senn et al. (2023). Figure 1 outlines certain factors, how *interaction* between a *listener* with her *environment* results in certain *action possibilities* in the context of groove.

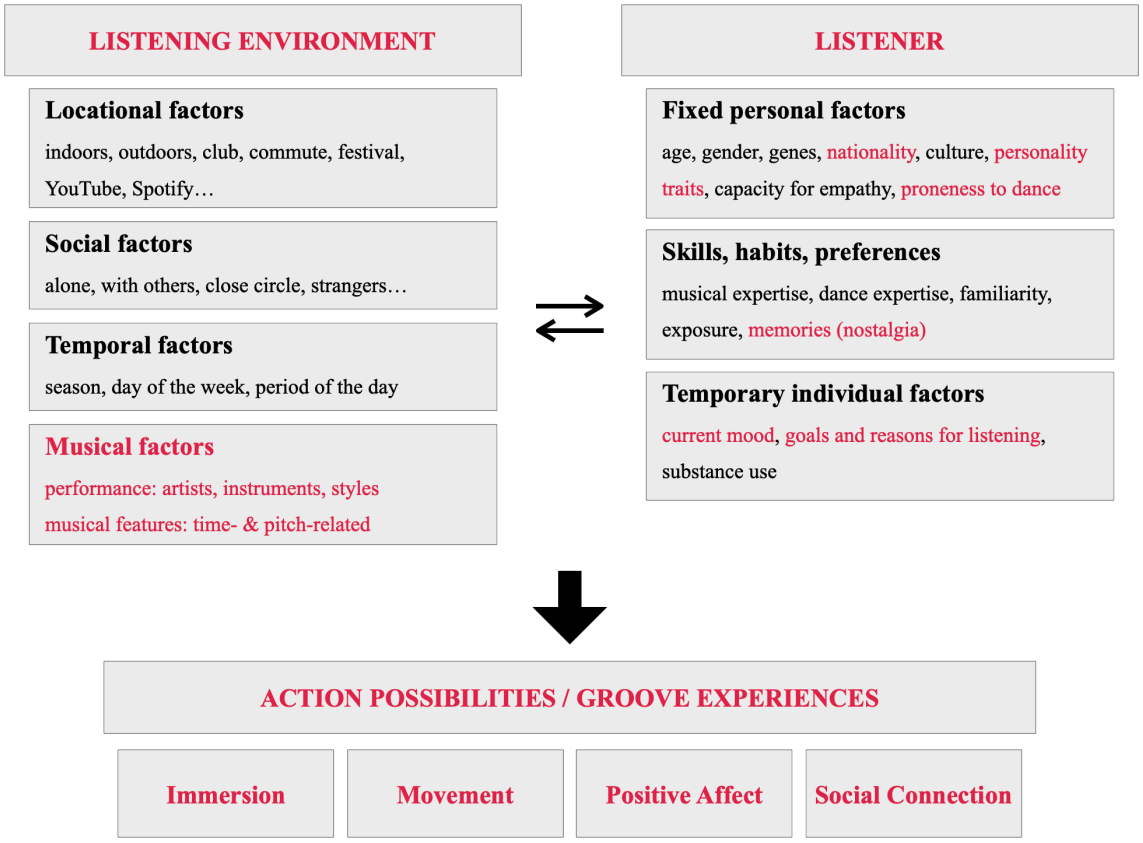

FIGURE 1 Application of the concept of affordances to the concept of groove. The listener (as the perceiver) interacts with the listening environment (horizontal bidirectional arrows). This interaction then leads (bold downward arrow) to certain action possibilities. Four action possibilities are shown for the experience of groove. Finally, the red-coloured text in the figure highlights the variables which this thesis contributes to.

The *context of music listening* has been shown to be a crucial determinant of people's musical preferences and actions (Juslin & Laukka, 2004). While listening, whether we are alone inside our house or outside at a festival with close friends influences the ways in which we perceive and interact with music. Research has also shown that people choose to listen to different music depending on the temporal changes (such as period of a year or day) (Heggli, Stupacher, & Vuust, 2021). Seasons, as well as the day of the week and the time of the day seems to have an influence on the music we listen to (Park et al., 2019). These contextual factors relate to locational, social and temporal aspects of a listening situation. Moreover, the music played in a given situation can be considered as part of the atmosphere that a listener is in (referring to the *musical factors* in Figure 1). (This

can be seen as one of the main differences with Senn's groove model (Senn et al., 2023). While musical properties are stated as a separate factor, the current work considers the musical aspect as part of the environment that the perceiver can interact with.) While there is no research on how this temporal aspect contributes to people's groove experiences, the literature reveals some evidence for social (Dotov et al., 2021) and locational aspects (Witek, 2013) related with the experience of groove. The musical aspect of groove is rather frequently studied (as it was reviewed above).

In terms of the *listener*, one might outline three main factors influencing listener's groove experiences. First, *fixed personal factors* include permanent variables like age (Cameron, et al., 2022) and country of origin or culture (Etani et al., 2018; Witek et al., 2020) whereas the second main factor, *skills, habits, preferences*, relates mostly to the prior experiences of the listener such as familiarity, musical (Senn, Bechtold et al., 2019) and dance expertise (Cameron et al., 2022). Finally, one can talk about *temporary individual factors* which refers to more momentary and dynamic variables like current mood, goals and reasons for listening (Duman, Snape et al., 2023).

Overall, the interaction of the listener with her environment affords her some *possible musical (groove) experiences*. These experiences are listed according to the recent findings by Duman, Snape and colleagues (2023) namely as immersion, movement, positive affect, and social connection. The other main difference with Senn's model (Senn et al., 2023) and the current dissertation is the inclusion of immersive and social aspects as part of the experience of groove.

At first glance, the proposed groove model might seem to be applicable for one's musical experiences in general. In order to highlight groove-specificity of the model, let us take an example: the concept of flow (a similar musical phenomenon to groove). According to flow theory by Csikszentmihalyi (1988), there has to be an interplay between challenge of a task (i.e., playing a piece of music) and skills (i.e., playing violin) which give rise to changes in anxiety and boredom. If one was to create a similar model for experience of flow based on the flow theory and the concept of affordances, centring the factors affecting the key components of flow (skills, challenge, anxiety and boredom) in the model would be essential. Specifically, considering musical training (for skills), playing alone or in a group, during improvisation (for challenge) or other measures for testing proneness to anxiety and personality traits (for anxiety/boredom) might be needed for creating such a flow model (along with other items relates to the environment and listener aspects which are presented in the groove model). In other words, there are certain similarities in our general musical experiences with the presented groove model along with differences. The logic behind creating the groove model was to focus on participants' responses in Duman, Snape and colleagues' 2023 paper and the previous work (especially the groove model by Senn and colleagues, 2023). Thus, together with the interaction of listener and the environment, the action possibilities (or groove experiences, namely immersion, movement, positive affect, and social connection) can be considered as the key groove-specific items in this model.

2.5 Overview of Other Related Literature

Along with the concept of affordances, above, the importance of details regarding the perceiver (such as their individual characteristics, including personality traits, goals and motivations etc) and the environment (including the musical features as part of the environment) were highlighted. However, the expanding groove literature has not yet investigated all of these potential variables pertaining to the experience of groove. Therefore, the goal of this section is to provide an overview of related research findings (outside of the groove literature; such as music-induced movements and everyday music listening). These variables are gathered under the subtitles of "reasons for listening and audio characteristics" and "personality traits", as these topics are among the main contributions of the articles presented in this thesis.

2.5.1 Reasons for Listening and Audio Characteristics

Music has various functions in human life. People use music to relax, dance, enhance their mood, facilitate relationships, feel connected, fill the background, improve self-awareness, entertain or distract themselves. People also listen to music throughout different phases of their daily life such as right after they wake up, during their commute, while doing housework/exercise, in a party with friends or before going to bed. Previous literature has demonstrated that musical preferences and the audio qualities of the preferred music varies depending on the context and reasons for listening (North & Hargreaves, 1996; Schäfer et al., 2013; Groarke & Hogan, 2016). Systematising people's reasons for listening, Schäfer and colleagues (2013) proposed that music has three main functions in people's lives: "regulation of mood and arousal", "achievement of self-awareness", and "expression of social relatedness".

Literature has also shown that audio characteristics of the music change according to the time of the day, as a function of engaged tasks or current mood (Heggli et al., 2021; Park et al., 2019). For instance, while in the morning louder, positive and energetic songs are preferred, night song are characterised with slower tempo and reduced loudness (Heggli et al., 2021). Another study focused on sleep music and characterised them with instrumental, soft and slow audio features compared with music in general (Scarratt et al., 2023). These exemplify how contextual factors relate to reasons for music listening, musical preferences and thus audio characteristics of preferred music. While in the groove literature audio features associated with experience of groove have been investigated in several studies, there is no research on the role of reasons for listening to music associated with groove music (and its audio characteristics), creating a gap in the literature.

2.5.2 Personality Traits

Previous literature has investigated links between personality traits and musical activities. For instance, research showed links between Openness and genre preferences (Brown, 2012) as well as Extraversion and preference for up-beat music (Zweigenhaft, 2008). Other research has reported that participants who are high in Neuroticism are more likely to listen to music for the purpose of regulating their emotions (Chamorro-Premuzic & Furnham, 2007). In terms of musical emotions, people who are open to experiences were reported to have a tendency to experience music-induced chills (McCrae, 2007).

Music-induced movements are extensively investigated in terms of their relation with personality traits (see for example Burger 2013; Carlson 2018). In a motion capture study, Luck and colleagues (2010) showed that participants' movements were linked with their personality traits. In particular, Extraversion and Neuroticism were reported to be the most relevant traits for music-induced movements. For instance, while Extraversion was associated positively with global (large-scale) movement, Neuroticism was negatively related to this type of movement (Luck et al., 2010). In another motion capture study, Burger and colleagues (2013) suggested Extraversion as a mediator of low-frequency audio features and head motion. Carlson and colleagues (2016) found Conscientiousness to be linked with following changes in tempo. Wakabayashi and colleagues (2006), meanwhile, reported Agreeableness to be associated with speed of entrainment to music. Moreover, building on the previous findings on music-induced movements and individual differences, Agrawal et al. (2022) suggested a method that can decode individual differences (including gender, musical preferences and personality traits) from dancers' movements with high accuracy.

Despite extensive evidence for connections between personality traits and musical activities (music-induced movements in particular), only one study (Senn et al., 2016) appears to have investigated the role of personality traits on experience of groove, and even then, there appeared to be no reliable connection. Considering the literature reviewed above, one could expect an influence of personality traits on groove, creating a gap in the groove literature.

2.6 Main Gaps in the Groove Literature

Despite the fact that the groove literature is expanding rapidly, the need for further research is growing as well. This dissertation contributes to the following three main gaps in the groove literature:

1. **Groove as a concept:** Above, groove is described as a complex and multidimensional phenomenon. Yet, some of the previous literature findings are overlooked and the concept of groove has been researched often overly simplified with only its pleasure and movement related aspects being

considered. This situation not only causes implementation of dissimilar definitions in the empirical research, but also distorts the interpretation of results according to the adopted definition. Overall, there might be missed opportunities to expand the groove literature. These arguments are further **addressed in Article 1** (Duman, Snape et al., 2023).

2. **The groove model:** As reviewed above, the groove model by Senn and colleagues (2023) presents a range of variables influencing the experience of groove. Yet, it has been stated that the model is incomplete (Senn et al., 2023; Etani et al., 2023). Contributing to this model, the current dissertation targets three variables related with groove:
    2.1. **Musical features:** More research is needed associating musical features with experience of groove (Etani et al., 2023). This need is further **explained in Article 2** (Duman et al., 2022).
    2.2. **Reasons for listening**: While there is a body of research investigating reasons of general music listening (such as Schäfer et al., 2013), reasons and motivations of listeners in the context of groove appears never to have been studied. This gap is **elaborated in Article 2** (Duman et al., 2022).
    2.3. **Personality traits:** While the music-induced movement literature demonstrates strong links with individual differences (such as Luck et al., 2010), there is a lack of knowledge on the role of personality traits in listeners' groove experiences. This lack is **described further in Article 3** (Duman et al., 2023a).
3. **Neural processing of groove:** As reviewed above, research findings on neural correlates of groove experience are contradictory. More research is required on neuroscientific approaches to processing of groove (Etani et al., 2023; Stupacher et al., 2022). Reasons for this gap are **explained further in Article 4** (Duman et al., 2023b).

3 AIMS AND OVERVIEW

In light of the gaps in the groove literature noted above, the aim in this thesis was to bring granularity to our understanding of "what makes us groove?" by employing a range of methodological approaches (including analysis of qualitative and music information retrieval data, dimensionality reduction and correlational methods, electroencephalogram recordings). Overall, an ecological approach (implementation of the concept of affordance to the concept of groove) was adopted. The thesis facilitated (a) reconsideration of groove as a multifaceted concept, (b) novel contributions to the psychological model of groove experience, and (c) investigation of how naturalistic groove music is processed in the brain. For this, two main empirical studies were conducted, which were reported in four articles. In Figure 2, an overview of the topics of the articles included in the dissertation are presented.

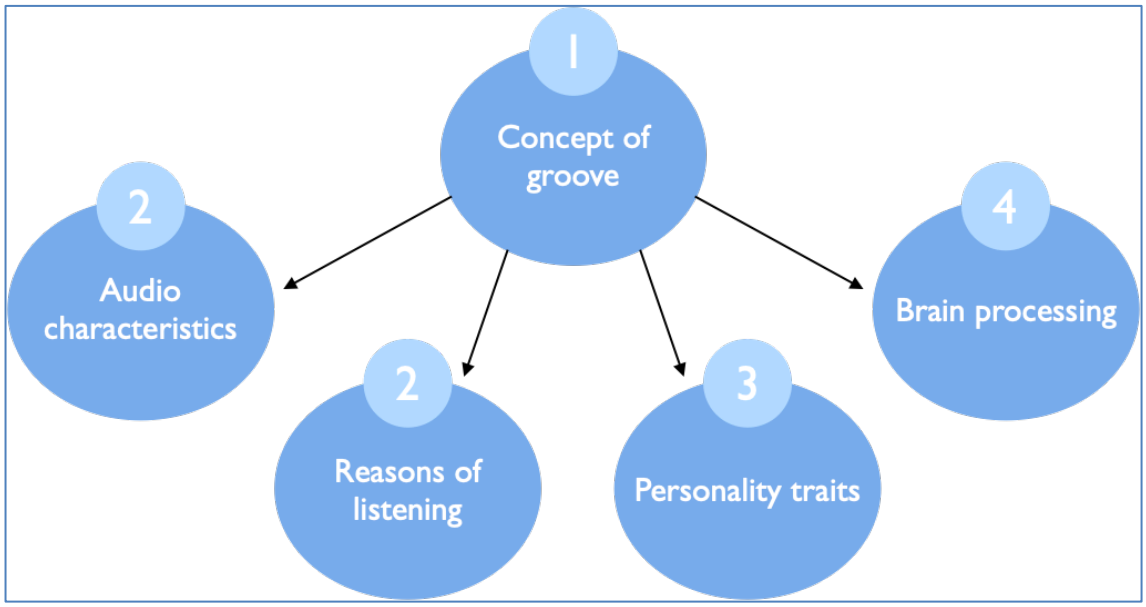

FIGURE 2 Overview of the topics of the articles included in the dissertation (separate articles are presented with numbers).

Article 1 focused on the concept of groove and understanding *what it signifies in people's minds*. This paper depicted "how listeners perceive groove conceptually", which provided a basis for general action possibilities associated with the experience of groove.

Article 2 investigated the audio characteristics and reasons of listening to music associated with dance. This paper identified the songs people reported moving to (with associated reasons of listening), providing information about the audio features of the songs people dance to and why they are being listened to.

Article 3 examined the relationship between personality traits and the experience of groove. This paper informed about inter-individual variation in listener's groove experiences.

Article 4 explored how naturalistic groove music is processed in the brain compared with low groove music.

While *Article 1* contributes to the understanding of groove as a concept, *Articles 2* and *3* contribute to the experience of groove model. Finally, *Article 4* focuses on understanding neural processing of groove-related music. Overall, this dissertation advances our knowledge concerning the factors which shape listeners' groove experiences.

4 METHODOLOGIES

Multiple methodological approaches were pursued in this thesis. In this chapter, the goal is to give a brief overview of the data collection and analysis methods. The empirical evidence this thesis was based on was collected in two studies. Details of these studies are described below.

4.1 Study 1: An Online Survey

Study 1 relates to Articles 1, 2 and 3.

4.1.1 Materials

An online study was composed of five main parts, which formed the materials: (1) demographics, (2) questionnaires, (3) online listening task, (4) naming a dance song, (5) groove definition. While the fifth part (groove definition) was used for Article 1, Article 2 was based on the fourth part (naming a dance song) and the questionnaire of general reasons of listening. Data from personality traits questionnaire and online listening task formed the empirical evidence for the Article 3.

1. **Demographics.** Participants gave information about their age, gender, country of origin, musical training, dance training, and dance ease.
2. **Questionnaires.** Three questionnaires measured participants' personality traits (measured with Ten Item Personality Index: TIPI by Gosling et al., 2003), musical preferences (measured with Short Test of Music Preferences: STOMP by Rentfrow & Gosling, 2003) and general reasons of listening (RL *general*, measured with 21-itemed reasons of listening questionnaire by Duman et al., 2022).
3. **Online Listening Task.** Participants were presented with thirty 25-second-long audio clips from commercial songs, with varying degrees of groove, in a random order. For each clip, participants were asked to rate several groove-

related items: *wanting to move*, *liking*, *familiarity*, *desire to sing along*, *experience of nostalgia*, and *perceived beat clarity* on 5-point likert scale. Additionally, participants selected "which parts of your body you would like to move along" with the music from an 11-itemed predetermined list.

Stimuli. In order to determine the final list of thirty songs, the author and the main supervisor first created a 16+ hours long playlist with candidate songs. Second, together with the author and the main supervisor, two other listeners rated grooviness of each song. In the third step, the author and the main supervisor went through the groove ratings of the songs in the initial list. In doing so, the criteria were that there would be low, mid, and high levels of groove across five genres (pop, EDM, funk, rock, alternative) with tempi within the range 100-140 bpm. The final list of the songs can be found in Table 1.

4. **Naming a Dance Song.** Next, participants were asked to "name a song which makes you want to move and select all the reasons why you listen to this song". These reasons associated with the songs will be referred to as dance-related reasons of listening (RL *dance*).
5. **Groove Definition.** Finally, participants were asked to rate their familiarity with the term groove (on a 7-point likert scale) and give a free-text answer in response to the inquiry "what makes a song groove in your opinion".

Table 1 Stimuli with wanting to move ratings (descending order)

Order	Artist	Song	Wanting to Move Rating
1	Queen	We Will Rock You	4,29
2	Bruno Mars	Uptown Funk	4,11
3	Daft Punk	Get Lucky	4,05
4	Earth, Wind & Fire	September	4,03
5	LaBelle	Lady Marmalade	3,79
6	KISS	I was Made for Loving You	3,71
7	Frank Sinatra	Fly Me to the Moon	3,70
8	War	Galaxy	3,69
9	Santana	Smooth	3,66
10	The Fratellis	Chelsea Dagger	3,59
11	DNCE	Cake by the Ocean	3,56
12	Bob Marley	Is This Love	3,52
13	Buena Vista Social Club	El Cuarto de Tula	3,51
14	Justin Timberlake	Can't Stop the Feeling	3,45
15	Avicii	Waiting for Love	3,44
16	Florence the Machine + Calvin Harris	Say My Name	3,44
17	Lyn Collins	Think About It	3,37
18	Vulfpeck	Dean Town	3,30
19	Imagine Dragons	Believer	3,29
20	Incredible Bongo Band	Bongo Rock	3,25
21	Parliament	Flashlight	3,19
22	Bruno Mars	Liquor Store Blues	3,10
23	Iron Maiden	Run to the Hills	3,05
24	Gotye	Somebody that I used to know	3,00
25	Beyonce	Halo	2,99
26	Stevie Wonder	I Just Called to Say I Love You	2,96
27	Lorde	Perfect Places	2,57
28	Kaleida	Think	2,57
29	Gwen Stefani	Cool	2,49
30	No Doubt	Simple Kind of Life	2,38

4.1.2 Participants

One hundred and five participants took part in the online survey. Participants (61 women, 41 men, 3 other) aged 16 to 54 (M=27.07, SD=6.46) and originated from 19 countries, mostly from Finland (N=65) and Turkey (N=23).

4.1.3 Procedure

The online survey was conducted during the spring of 2020. Webropol.com was used as a platform and the survey was distributed via personal social media and University of Jyväskylä email lists. While participation was voluntary, and the data processing were kept anonymous, upon completion, participants were given a chance to win a 50 € voucher. The survey began by informing participants about the content of the study and they were asked to give their consent to participate. The study followed the general ethical guidelines of the University of Jyväskylä thus, no further ethics approval was required.

4.1.4 Additional Data Collection

This section describes the additional methodological details for Article 2. Supplementary data was collected for the purpose of increasing the sample size for more meaningful results. For the additional data, participants responded to the inquiry "give 3 different song examples which 'make you want to move'". While demographics were gathered, no RL data were collected. Participants also stated that they did not take part in the previous data collection. Sixty-eight participants (39 women, 28 men, 1 other) aged 14 to 53 (M = 29.34, SD = 7.88), originating from 21 countries took part in the additional study. The same procedure described in 4.1.3 was also followed in this additional data collection.

4.2 Study 2: An EEG Experiment

Data from Study 2 formed the empirical evidence for Article 4. Moreover, data from Study 1 were used for stimuli selection of Study 2 and thus informed Article 4.

4.2.1 Procedure

In order to investigate neural processing of music with differing levels of groove, a pilot EEG investigation was conducted in the EEG lab of the Department of Music, Art and Culture Studies, University of Jyväskylä, Finland. First, participants were given brief information about the content of the experiment, their rights, and informed consent papers were collected. Second, while EEG data was collected, participants completed a passive listening task and were asked to "listen to the presented stimuli and try not to move". Finally, participants

listened to the stimuli again and this time ratings for the items *enjoyment*, *wanting to move* and *familiarity* of each stimuli were collected.

4.2.2 Participants

Eight participants (2 women, 6 men) with an average age of 25.38 (*SD*=1.3) participated in the study.

4.2.3 Stimuli

For stimuli selection, the groove ratings from Experiment 1 were revisited and three stimuli from each low, mid and high groove categories were selected according to the initial groove ratings. As a result, 9 stimuli (presented in Table 2) were used in Study 2.

Table 2 Stimuli with initial wanting to move ratings

Order	Artist	Song	Wanting to Move Rating
1	Bruno Mars	Uptown Funk	4,11
2	Daft Punk	Get Lucky	4,05
3	Earth, Wind & Fire	September	4,03
4	Florence the Machine + Calvin Harris	Say My Name	3,44
5	Lyn Collins	Think About It	3,37
6	Gotye	Somebody that I used to know	3,00
7	Stevie Wonder	I Just Called to Say I Love You	2,96
8	Kaleida	Think	2,57
9	Gwen Stefani	Cool	2,49

5 SUMMARIES OF THE ARTICLES

This chapter summarises the four articles included in this dissertation.

5.1 Article 1: Groove as a Multidimensional Participatory Experience

5.1.1 Background & Aim

Groove is described as being a complex, koan-like concept (Zbikowski, 2004) in music. It has been regarded as an historical, cultural, musical, and psychological phenomenon. Two decades ago, this ambiguity – or, one might say, multidimensionality – has been operationalized in the field of music psychology as a *pleasurable desire to move to music* (Madison 2006; Janata et al., 2012). While this operationalized definition has led to a spike in the groove literature, some shortcomings have emerged as well. For example, some of the research findings are left overlooked, dissimilar definitions of groove have been used across different studies, and there might be some potential missed opportunities for the future of groove research.

These points created the need for reconsideration of the definition of groove used in the field of music psychology. Thus, the main motivation for Article 1 was to reach a more nuanced and comprehensive representation of groove in light of previous literature.

5.1.2 Methods

In an online survey, participants were asked to provide free-text groove descriptions. Using a semiotic approach, our aim was to investigate themes which the concept of groove signifies in participants' minds. That is why adopting a free-text groove description was considered an optimal method to arrive at a broader picture of the concept. Based on the reviewed literature, our principal prediction

was that participants' definitions of groove would cover a variety of concepts, including the pleasure- and movement-inducing aspects.

In order to achieve a nuanced reporting of groove definitions, an abductive thematic analysis method was preferred (Timmermans & Tavory, 2012). Abduction combines both data- and theory-driven approaches (called induction and deduction subsequently) which allowed authors to consider participants' possible novel responses as well as previous literature findings simultaneously.

5.1.3 Results

As a result, two main findings were observed. First, in line with previous literature, in which groove has been described as a multifaceted phenomenon, participants not only described groove as a musical concept, but also referred to it often as an experience. Second, using this separation, we defined two main categories of groove related to *musical* and *experiential aspects*. This distinction is also supported by previous literature (e.g., Roholt, 2014).

Figure 3 summarises the key findings, demonstrating main and sub categories which were identified in the analysis. While the *performance* subcategory can be considered as *how* the music is being produced, the *musical features* subcategory refers more to *what* is being played. Using their *instruments*, *artists* perform music in specific *styles* which give rise to certain *time- and pitch-related musical features*. For the musical aspect, some of the key details can be listed as: performance ability of the artists, various instruments' playing in harmony (especially the bass and drums), several musical styles (especially funk, jazz and metal) as well as rhythm and low frequency ranges. Details of the musical aspect then shapes listeners' general *musical preferences* and lead them to choose specific music depending on their *musical taste* and *current mood*. Individual-related factors, then, play a mediating role between musical and experiential aspects of groove. As a consequence, music induces certain psycho-physical states which are described as *participatory experiences*; namely *immersion*, *desire to move*, *positive affect* and *social connection*. These themes were often described as if the listener wants to participate or be involved in the music physically or psychologically. This tendency for participation was explained in the article within the predictive coding and participatory discrepancies frameworks (see, for instance, Vuust & Vitek, 2014; Keil, 1987). Implications and further suggestions regarding these findings are presented in the discussion chapter.

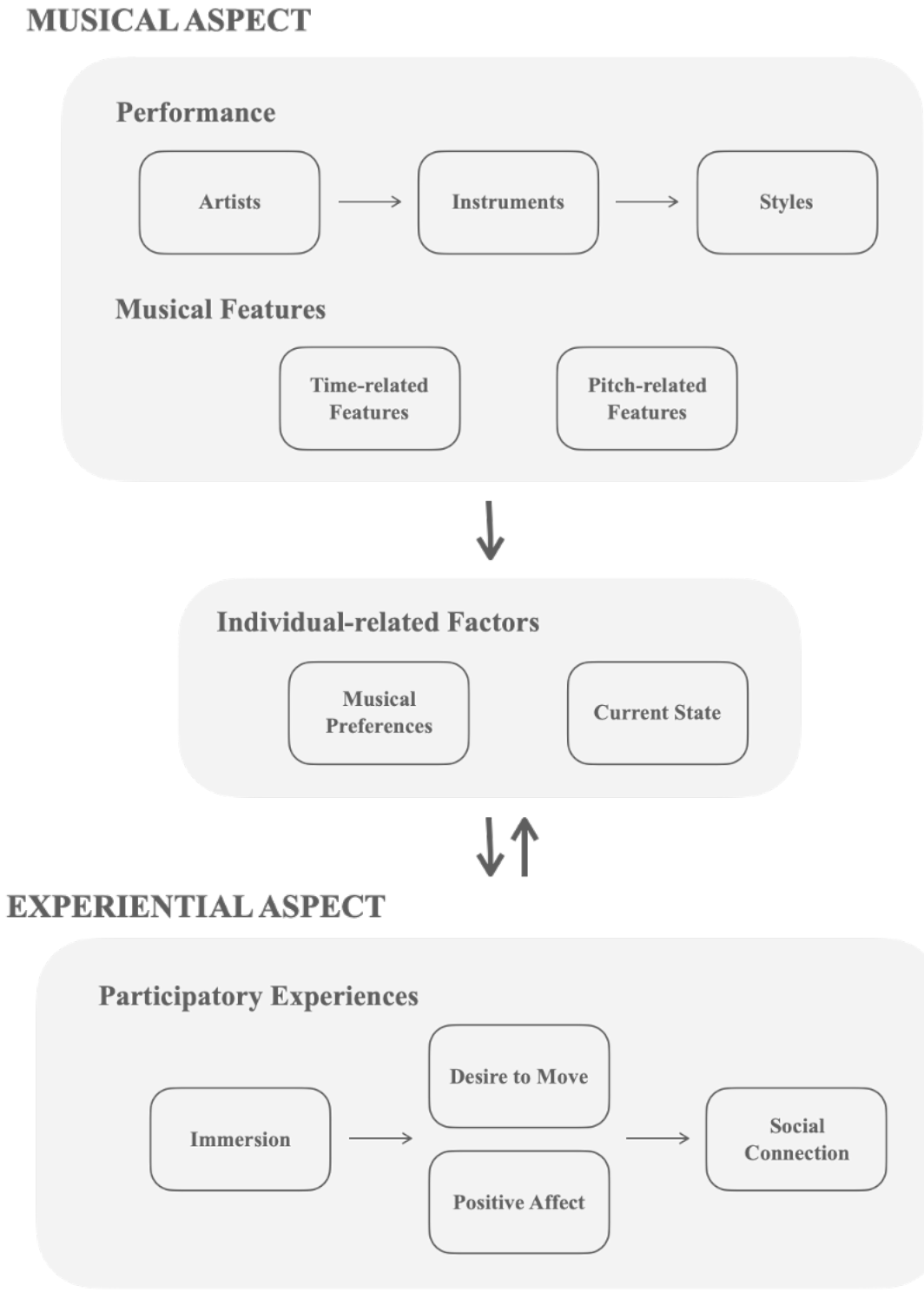

FIGURE 3 An overview of the main themes of participants' groove descriptions, demonstrating how the musical aspect of groove leads to the experiential aspect, moderated by individual-related factors.

5.2 Article 2: Music we move to: Spotify audio features and reasons for listening

5.2.1 Background & Aim

As explained above, motivations and intentions are regarded as crucial factors which influence affordances, or the ways in which a perceiver interacts with her environment. While previous literature has shown that certain musical features are associated with the experience of groove (e.g., Stupacher et al., 2016), there remains a gap in our understanding of why people prefer certain music for dancing, and whether there is a link between the characteristics of music and the reasons of listening (RL) to them.

In Article 2, we aimed to (1) determine audio features of music people report moving to, (2) examine motivations of people for choosing specific dance songs, and (3) associate audio features and motivations of listening to particular music that people move to.

5.2.2 Methods

In an online study, participants named songs they move their body to (referred to as "dance music") and reported RL for the songs they named. First, audio features of the dance music were extracted using the Spotify API and the obtained Spotify audio features were compared with features of a baseline dataset (referred as "general music"). Second, a cluster analysis was performed to determine whether all the dance songs shared similar characteristics, or whether it would be possible to identify subgroups of dance music. Third, factor analyses were performed on participants' ratings of RL *general* ad RL *dance*. Fourth, to compare RL *dance* and *general*, frequency distributions for RL *dance* and *general* ratings were plotted. Finally, to examine the relation between the audio features of the dance music and associated RL, a heatmap was produced revealing how RL *dance* items were rated for each subgroup of dance music.

5.2.3 Results

Article 2 has four main results. First, compared with the baseline, dance music was associated with higher levels of energy, danceability, valence, loudness, and lower levels of acousticness, instrumentalness and speechiness Spotify audio features. Additionally, dance songs were more likely than general music to have a tempo close to 120 bpm. Second, the songs that participants reported moving to varied in terms of genre and year of production. Further, a cluster analysis revealed five subgroups of dance music each associated with different combinations of Spotify audio features. These subgroups were named – according to the most prominent audio features for that subgroup – as *happy-energy*, *sad-energy*, *sad-instrumental*, *fast-lyrical*, and *soft-acoustic* (shown in Figure 4).

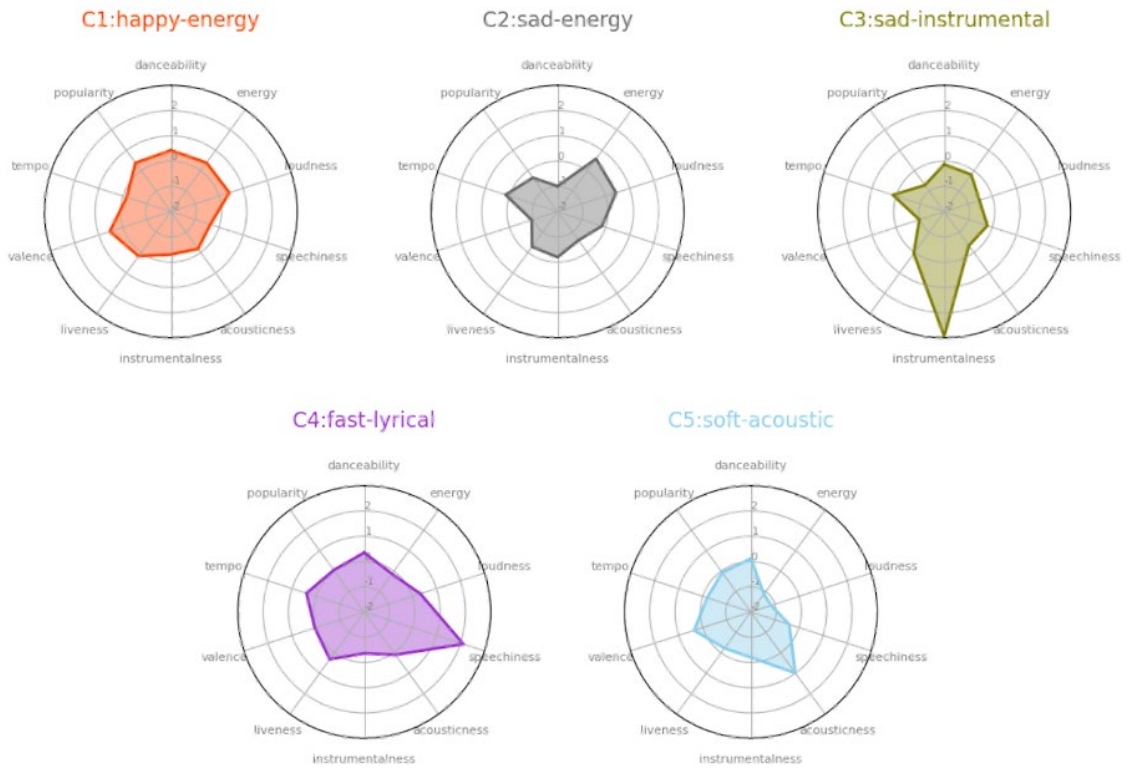

FIGURE 4 Subgroups of dance music.

Third, plots of frequency distributions for RL *dance* and *general* ratings demonstrated that "For pleasure / entertainment" and "To improve my mood / raise energy" were the highest rated items for both RL *dance* and *general*. For the RL *dance* ratings, "To dance / move along" and "To sing / play along" were the next highest-rated items. Finally, in terms of linking audio characteristics with RL *dance*, some variation in terms of ratings of RL *dance* items and subgroups of dance music were identified (shown in Figure 5). This might indicate that certain types of dance songs might be more suitable for certain RL. Implications and further suggestions of these findings are presented in the discussion chapter.

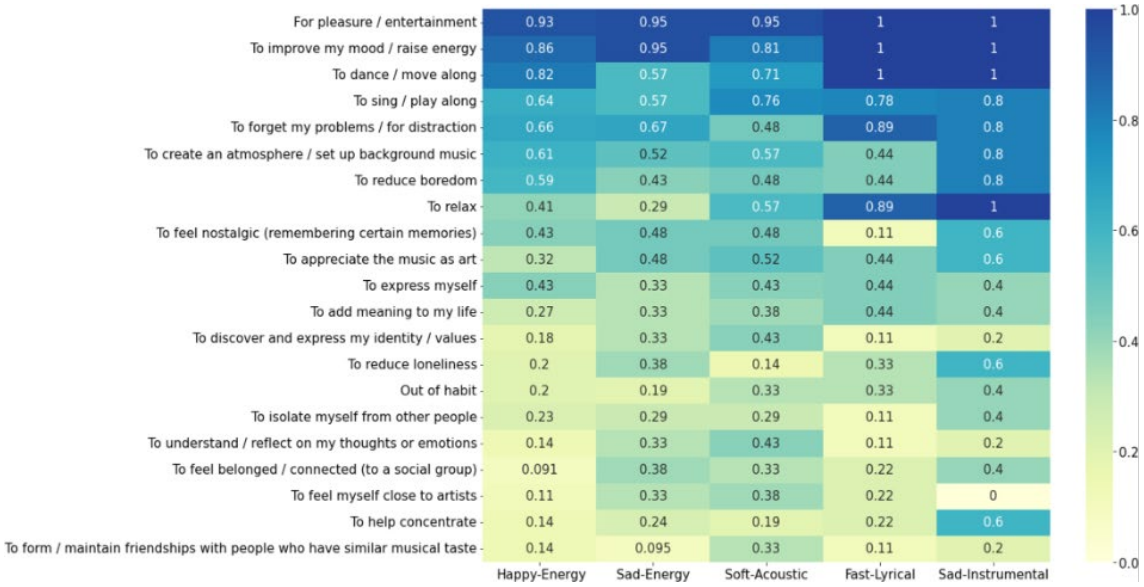

FIGURE 5 Linking subgroups of dance music and reasons for listening.

5.3 Article 3: Correlations Between Personality Traits and Experience of Groove

5.3.1 Background & Aim

Previous literature has shown the effects of various intra- and extra-musical factors on listeners' groove experiences. While in the experience of groove model Senn and colleagues (2019; 2023) situate groove as being influenced by several variables, the role that personality traits play in experience of groove seems to be inconclusive. Previously, using the NEO Five Factor Inventory (McCrae & Costa, 1987), a study by Senn and colleagues (2016) found no link between personality traits and self-reports of groove experience. However, as reviewed earlier, personality has been reported as one of the key factors predicting music-induced movements (see, for example, Burger, 2013; Luck et al., 2014).

Despite the previous null reports, substantial findings from the music-induced movement literature motivated us to investigate the role of personality traits on people's groove experiences. Aligned with the previous literature, we hypothesised that participants' groove ratings would correlate positively with Extraversion and negatively with Neuroticism.

5.3.2 Methods

In the online survey, participants first responded to the Ten Item Personality Inventory (TIPI). They subsequently completed a listening task in which they rated six groove-related items for each of 30 short musical clips which differed in their level of groove. For the analysis, a number of Pearson correlations were

calculated between the groove-related items. In addition, Pearson correlation analyses were performed to investigate the relation between ratings of groove-related items and each personality dimension.

5.3.3 Results

First, in line with previous literature, groove-related items were highly correlated (Madison et al., 2011; Janata et al., 2012; Senn et al., 2018). Moreover, in a significant contribution to the literature, a link between nostalgia and wanting sing along and other groove-related items was demonstrated for the first time. Correlation values are shown in Figure 6.

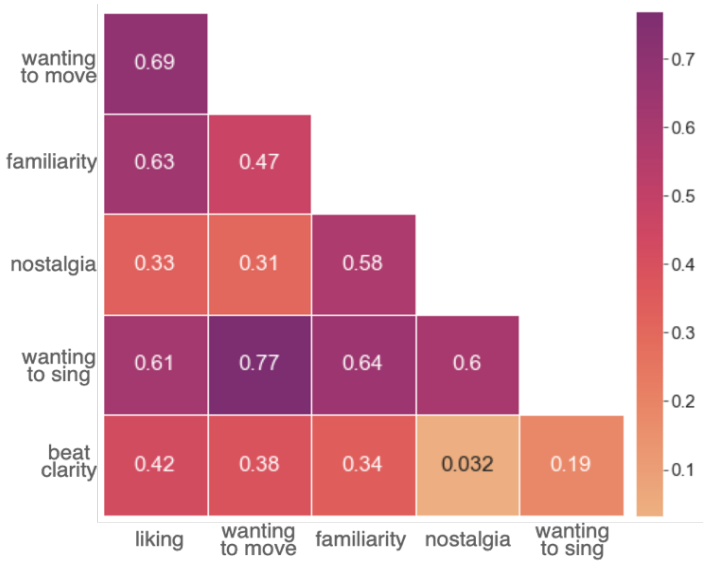

FIGURE 6 Correlation matrix of groove-related items.

Second, results revealed that Extraversion and Conscientiousness in particular related positively to certain groove items. Specifically, while Extraversion was connected with dance ease, wanting to move and sing along, Conscientiousness correlated with liking and participants' general tendency to dance. In other words, people with higher Extraversion scores are more likely to move to music and sing along, whereas people with higher Conscientiousness score are more likely to report enjoying the music and moving along. While these findings are aligned with the literature (Carlson et al., 2016; 2017), since the hypothesis was not fully supported, we propose for further research on the topic. Other implications of these findings are offered in the discussion chapter.

5.4 Article 4: Investigation of Mu Oscillations to Naturalistic Groove Music

5.4.1 Background & Aim

With the increased interest in understanding groove as a musical experience, some researchers have focused on the neural basis of the experience of groove. For instance, in a TMS study, Stupacher and colleagues (2013) reported increased motor cortex activity in response to high (as compared to low) groove music. In an fMRI study, Matthews and colleagues (2020) found that medium-complex rhythms led to higher ratings of groove, and were associated with increased activity in brain areas related to reward, motor activity, and beat perception. However, in an EEG study that utilised naturalistic stimuli, Nijhuis and colleagues (2022) reported no effect of groove on cortico-muscular coherence (quantified with beta oscillations) during isometric contraction.

These findings reveal a gap in the literature concerning the neural correlates of processing groove-based music in the brain. While the first motivation of this study was to target this gap, a second motivation was to use naturalistic stimuli. The reason for preferring more naturalistic music was to achieve greater ecological validity, using actual commercial music of the kind that people listen to in their everyday lives.

However, investigating the processing of complex stimuli (like commercial music) is challenging from the research perspective, when analysing and interpreting the data. In the present study, this challenge was attempted by choosing a methodological approach based on previous EEG studies which focused on motor cortex activity indexed by beta and mu oscillations (e.g., Ross et al., 2022; Pfurtscheller, 1981; Mazaheri et al., 2009).

5.4.2 Methods

A pilot EEG study was conducted while participants (N=8) were instructed to sit still and listen to presented sound stimuli. Nine stimuli with 3 levels of groove (high, mid, low) were chosen according to participants' groove ratings from the previous online study (Study 1). After the study, participants were asked to provide subjective ratings for the items wanting to move, enjoyment and familiarity.

After the pre-processing, a spectral analysis was performed on the data in order to compare the mu oscillations to stimuli with different levels of groove. Following the findings of Ross et al. (2022), we hypothesized that stimuli associated with high-groove would result in stronger mu oscillations, indicating a greater motor suppression of movement in the passive listening task (compared with low-groove stimuli).

5.4.3 Results

Contrary to the hypothesis, both the average and individual level spectral analyses yielded no change in mu power for stimuli characterised by different levels of groove and the experience of groove. In Figure 7, individual spectral decompositions from eight participants are presented. Despite this finding being in alignment with the study by Nijhuis and colleagues (2022), instead of reaching a similar conclusion, we reconsidered the details of the study, and made a number of recommendation for further research that might shed further light on this topic: (1) more data might be necessary to observe the neural correlates of different groove stimuli, (2) a different set of stimuli should be used, (3) instantaneous measures of overt movement of the participants would help us to control for potential confound of movement, (4) alternative analysis could be considered, and (5) different design approaches might be beneficial (such as adding a localisation task and carrying out a localisation analysis). Despite the null results, this study offered promising findings and directions for future research. Further implications of the study are presented in the discussion chapter.

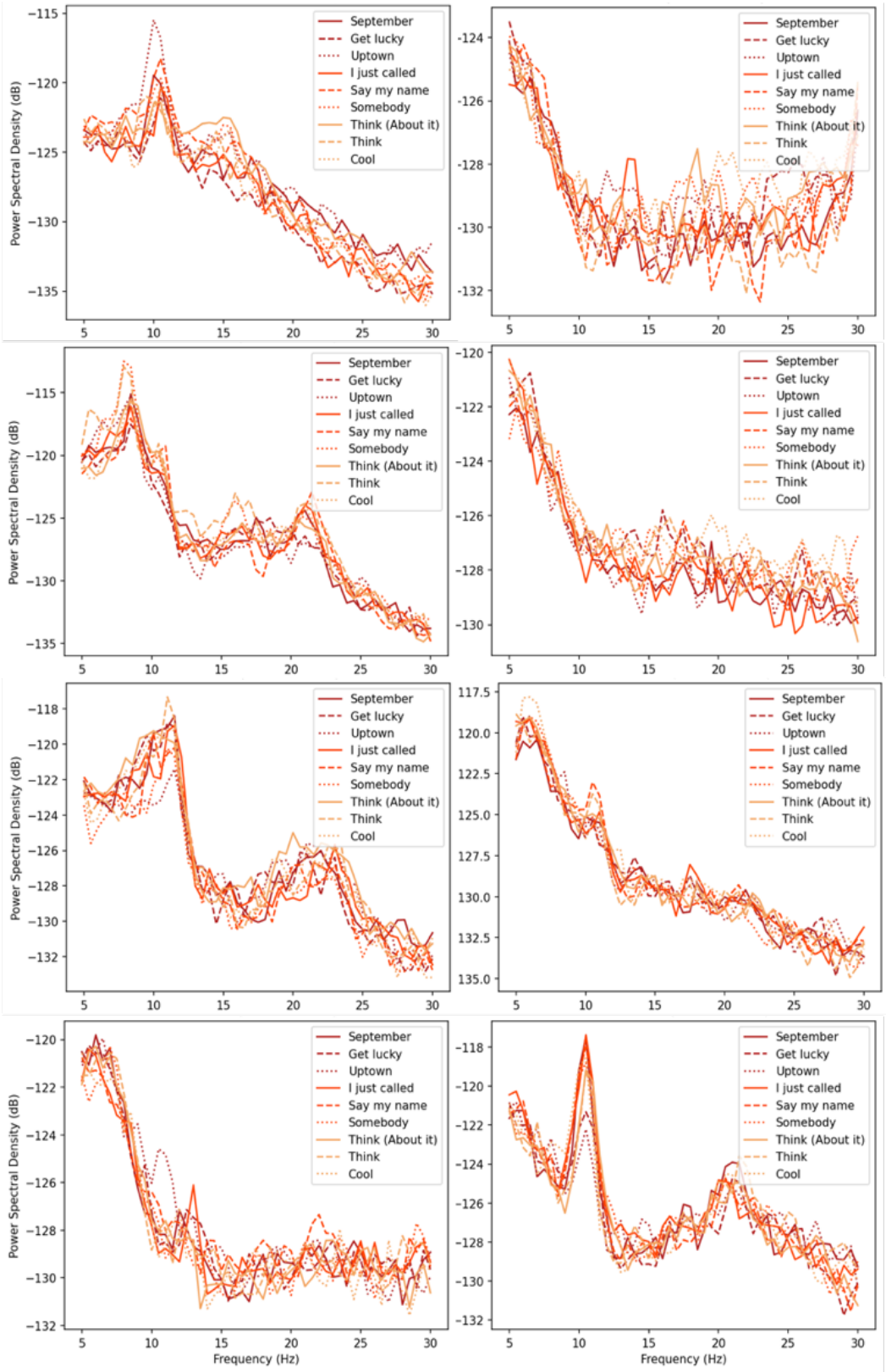

FIGURE 7 Participant level power spectral density illustrations of the stimuli.

6 CONCLUSIONS AND GENERAL DISCUSSION

To summarise the main research findings, in developing previous literature, this dissertation proposes an updated, comprehensive working definition of groove, introducing it as a multifaceted participatory experience (Duman, Snape et al., 2023). Importantly, the concept of groove was found to be closely linked to function of music listening "regulation of mood and arousal" (Duman et al., 2022). Moreover, additional studies (related to musical features, reasons for listening to music and personality traits) contributed to development of a musicological model of groove (Duman et al., 2022; Duman et al., 2023a). Finally, the thesis investigated an under-researched aspect related to groove, namely how naturalistic groove-related music is processed in the brain (Duman et al., 2023b).

Synthesising the main findings of the articles presented above, next, the author will discuss (1) defining the concept of groove, (2) groove as a personal experience, (3) groove as a complex and multidimensional phenomenon, (4) granularity of the concept, and (5) why people groove, in other words, why the concept of groove is important. Finally, limitations and future directions will be presented.

6.1 Redefining the Concept of Groove

As reviewed earlier, groove has historical, ethnological, musical and psychological connotations. In Article 1, we investigated the representations of groove as a concept, how it is characterized in people's minds. By compiling the main themes in participants' groove descriptions, a more comprehensive groove definition was formed that could be used in the field of music psychology. Consequently, groove was described as "a participatory experience (related to immersion, movement, positive affect, and social connection) resulting from subtle interaction of specific music- (such as time- and pitch-related features), performance-, and/or individual-related factors."

Several aspects of this definition should be elaborated upon. First, in line with previous literature (e.g., Roholt, 2014), this definition highlights two aspects of groove: groove as an experiential phenomenon and groove as a musical phenomenon. Second, several key factors associated with groove are included in the definition, highlighting its complexity and multidimensionality (emerging from the interaction of several factors). Third, from a music psychological point of view, groove is primarily defined as a *participatory experience*. This participation was observed several times in the way participants explained it as something that *compels* them, as an *urge to be involved in*, makes them *become one*, experience *unity*, *joining* or *filling in*. This participatory quality of groove has been discussed in previous research as well (see, for example, Keil 1987, 1995; Witek, 2017; Levitin et al., 2018). For instance, Kawase and Eguchi (2010) investigated free groove description of participants followed by a listening and rating task. The experience of groove was most closely related with the item "you feel a sense of unity". (Unity here was highlighted as denoting *cohesion* in particular.) Fourth, by combining participants' groove descriptions with previous groove findings in the literature, experiences of 'immersion' and 'social connection' are added as part of the experiential aspect of groove (in addition to previously acknowledged dimensions of 'pleasure' and 'movement'). While there is limited research on social implications of groove (such as Dotov et al., 2021; Witek, 2017), the immersive (or flow-related) aspect of groove has been rather neglected. For instance, there is no mention of the experiences of flow or immersion in the review paper by Etani and colleagues (2023), despite previous such links being made (see Janata et al., 2021; Stupacher, 2019; Camara & Danielsen, 2018). For example, in Janata and colleagues' research (2012), participants associated the word "flow" with groove more than with the word "enjoy".

Putting together all the evidence of how participants described groove (as depicted in Duman, Snape et al., 2023) and the previous literature findings, there is no doubt that considering the current proposed definition (and the variables mentioned above) will provide a more nuanced representation to the concept of groove in general and would improve future experimental designs, quality and the impact of research outcomes.

6.2 Groove as a Personal Experience

After examining the four articles compiled in this dissertation, a common theme, consideration of groove as a *personal* experience, arises. First, in Article 1 participants provided various groove definitions. Although several themes reoccurred in the descriptions, participants gave their own combination of variables associated with groove. For instance, several people referred to its movement-inducing aspect, whereas some others emphasized that the lyrics help them to connect with the music. This highlights how the concept of groove is represented diversely associated with their own musical experiences. Second, in Article 2, participants were asked to name songs which make them want to move.

While there were a few repeated song examples, the list consisted of various songs in terms of genre, year of production and musical features. This would mean that songs that people choose to listen to (associated with groove) depend on personal factors rather than a single song being considered as "the grooviest". Third, Article 3 directly relates to individual differences. It emphasises how certain personality traits can be linked with experience of groove. In other words, instead of suggesting a fixed groove experience to all, the influence of personality traits on individual's groove experiences were shown. Finally, in Article 4, variance across participants' EEG signal to music with various levels of groove was observed. This variance could be due to common variance in brain processing across individuals (as discussed for instance in Croce et al., 2020) or alternatively contributing to the argument that groove is a personal, dynamic experience.

Together with these points, considering groove as a personal experience gains importance especially while approaching the concept of groove in general. For instance, Etani and colleagues (2023, p.36) provide a list of musical features associated with groove, under the title "music that elicit groove". This expression gives the impression that 'with an optimum combination of the listed musical features, a groove experience can be guaranteed'. However, to the best of our knowledge, thus far, no music has been reported to induce the experience of groove in everybody. This could be because groove is a personal experience and results from the momentary interaction of the listener with music. Therefore, considering groove as an individually-variant experience would facilitate more reliable future experimental designs.

6.3 Groove as a Complex, Multidimensional Phenomenon

Synthesising the research findings of the articles compiled in this dissertation, groove should be highlighted as a complex, multidimensional phenomenon. Particularly, in this section, the goal is to elaborate on this (previously mentioned) complexity and describing this multidimensionality through the groove model; using the contributions of the four articles.

In the previous section, groove is emphasised as an individual experience. The individual experience of groove is complex, shaped by several variables (summarised in Chapter 2, via the concept of affordances and the groove model). First, in Article 1, this process is described as resulting through the interaction of different counterparts: "(a) the artists who are performing the music, (b) the musical elements that emerge during the performance, (c) its listeners and the artists, (d) the listeners as individuals, and (e) the listeners within a group" (Duman, Snape et al., 2023, p.19).

Second, centring around the musical features of dance music, Article 2 demonstrated the interaction between reasons of listening to certain dance music and musical features. In particular, depending on their current state and motivation of listening, people might have different preference of music. This is in line

with the ecological approach (and concept of affordances) and how the musical environment and the goals are interacting. Following the ecological view, adding the reasons of listening into the picture, Article 2 advances previous literature findings of the relationship between musical features and groove experience. For example, while previously no link between loudness and the experience of groove was conveyed (Stupacher et al., 2016), in Article 2, Duman and colleagues (2022) reported five subgroups of dance music (emerging as a combination of various Spotify audio features), one of these subgroups (soft-acoustic) to be primarily linked with loudness. In a similar vein, reviewing the literature on groove, Etani and colleagues (2023) reported that the relationship between tempo and groove is unclear. Whilst some research suggests faster tempo (Kawase & Eguchi, 2010; Janata et al., 2012), some others propose slower (Senn et al., 2018) or no influence of tempo (Madison, 2006; Madison et al., 2018) on the experience of groove. One other study proposed an optimum tempo for groove (Etani et al., 2018). While Article 2 demonstrated that dance songs are more likely to be close to 120 bpm compared with music in general, the five subgroups of dance music also varied in terms of their tempo. In other words, it is expected that tempo of a preferred song varies depending on the current mood and the motivation of a listener. Additionally, this interpretation is supported with the findings in Article 1. In their groove descriptions, several participants indicated that in order for a song to groove, it should match their current mood. Some other participants responded directly with regards to tempo: while some reported preference for slow, some others related faster songs more with groove. Together, these examples demonstrate the complexity and multidimensionality of the personal groove experience and can give an explanation to the proposed lack of clarity in the relationship between tempo and groove. This nuance can be noted thanks to the ecological approach and considering several interacting variables together in the groove model in the endeavour of detangling the experience of groove.

Third, with Article 3, the influence of personality traits on the experience of groove was shown. This finding develops the groove model (Senn et al., 2023), demonstrates that individual-related factors should be considered while measuring the experience of groove. Finally, the null findings of Article 4 might be considered in conceptualising groove as a complex phenomenon as well. During the design of the experiment, researchers were aware that it was not a simple task to set an EEG experiment that would measure brain dynamics of processing music associated with various levels of groove. Yet, with Article 4, the goal was to test the limits with a rather straightforward EEG-listening task for the experience of groove. Therefore, the obtained null results are reported along with several limitations (including reconsideration of stimuli choice, experimental and analysis methods). It can be presumed that future research that is aiming at understanding neural correlates of the experience of groove might well achieve null or non-significant results if the complexity of the concept is disregarded. Therefore, careful experimental designs considering multidimensionality would be crucial for future groove-brain research.

Together, these four articles demonstrate the importance of studying groove with its various facets. For future research, instead of looking for "recipes to groove", groove could be considered as a dynamic concept, one that arises from the interaction of various factors included in the groove model.

6.4 Granularity of the Concept of Groove

One of the main aims of the current dissertation was to investigate nuances of the concept of groove. Novel findings presented in this work contributed to the granularity of the concept of groove. By granularity, various details related with groove are mentioned. First, as reviewed in the previous section, several novel factors (such as relationships between experience of groove with current mood, lyrics, Spotify audio features, reasons of listening and personality traits) were reported.

Contributing to the granularity of the concept of groove, second and importantly, in Article 1 the experience of immersion was suggested as the prerequisite for experiencing groove. Expanding on the discussion initiated in Article 1, the experience of groove can be considered as an *altered state of consciousness*, like deep meditation or orgasm. As Câmara and Danielsen (2018, p.2) stated, groove is an immersive and ungraspable experience: "Groove happens in the here-and-now of performance, meaning that groove is, in a sense, ungraspable as such – the very moment one tries to come to terms with a groove experience, one is no longer in the groove." In line with that argument, Feld (1988) similarly describes the 'difficult to pinpoint' and absorbing qualities of groove as "unspecifiable but ordered sense of something that is sustained in a distinctive, regular and attractive way, working to draw a listener in" (Feld, 1988, p.76). In another work, Wycisk and colleagues (2022) described immersion and other related terms as "being involved" (immersion), "extreme involvement" (absorption) and "being there" (presence).

Because of the nature of such altered states, there are challenges in measuring them. As explicated in section 6.1, immersion has been mainly neglected by previous literature. This might be because of the challenge in quantifying such altered states. In other words, despite previous literature having discussed the links between flow or immersive experiences with groove, measuring immersion might not be as straightforward as quantifying affect or induced movements. Moreover, in their review, Etani and colleagues (2023) argue that pleasure and movement are the main characteristics of groove. While acknowledging these two as the most *apparent* features of groove, in Duman, Snape et al. (2023), we proposed an immersive state to be the prerequisite to these most obvious qualities. While further arguments can be found in Article 1, in this dissertation one other example is depicted: "Basically, the urge to move the body to rhythms with moderate levels of syncopation (feeling the groove) arises as it compels us to reduce the weighted prediction error by attenuating the precision of sensory information." (Etani et al., 2023, p.13). Here, the key word "compulsion" can be

interpreted as hinting at an immersive state for how the sensory information is being processed – automatically – and results in the urge to move. In line with our argument, Levitin and colleagues describe compulsion (similar to immersion) as the key to groove: "when the music compels you to move along with it. This compulsion is the essence of groove" (2018, p.63).

Third, contributing to fine granularity of groove, in Article 1, a social aspect as a secondary quality to the experience of groove was introduced. The social aspect was described by participants as feeling an affinity towards artists and other people who are sharing the same musical (groove) experience. While there are only a few works regarding the social links of groove (Dotov et al., 2021; Witek, 2017), the links between social aspect and musical activities are well established (see, for instance, Savage et al., 2020).

Furthermore, giving importance to the nuances of the concept of groove would facilitate precision in future research and lead to further advancement in the field. In fact, groove researchers have recently paid attention to nuances of the concept. In a recent preprint, Pando-Naude and colleagues (2023) abbreviated the pleasure and movement facades of groove as PLUMM (pleasurable urge to move to music) instead of referring to it simply as "groove". Similar to this, by uncovering several aspects of groove and gaining precision, future research can choose which aspects of groove should be further investigated.

6.5 Why Do We Groove? Why is the Concept of Groove Important?

After highlighting groove as a personal, multifaceted and complex phenomenon, one might ask what the benefits are of studying such a personal and complicated topic? To answer this, one might observe the functions of musical activities of our ancestors. Traditional rhythmic engagement with music shares similarities with what we *nowadays* understand within the concept of groove. The documentary series Rhythms of Earth – "Dance and Human History" by Alan Lomax and Forrestine Paulay (1974) opens with a tribe dancing and moving in circles, making music with their wind instruments and through the sounds of their footsteps. Music is not only made by man-made instruments, but so to say, through "sound artifacts" of dance becomes source of music. Moreover, participants of this ritual seem to be *in the moment*, *know the choreography* well and be *in synchrony with each other* in their body movements. It is known that ancient humans engaged in various musical rituals, which are believed to influence the environment and vital activities (such as hunting or during dry seasons), facilitate information transfer across generations (such as agricultural knowledge) and manage social relationships (such as during a funeral ceremony) (Trehub et al., 2015). In addition to their significance, such dance-related musical activities are pleasurable, as is the experience of groove. With a hedonistic approach, the field of psychology describes human beings as hedonists who seek pleasure enhancement and pain avoidance (Huta, 2015; Ryan & Deci, 2001). This might be the reason for groove-related musical experiences having been part of human life for such a long time.

Even though the research findings presented in this dissertation were not directly aimed at understanding the functions of groove (or the role it plays in people's life), next, four reasons why groove might be a pleasurable state is offered.

6.5.1 Four Types of Pleasure Associated with Groove

The author proposes four types of pleasure related to the experience of groove, based on processing music, experiencing immersion, (desire for) movement and a social atmosphere. These types of pleasure operate on neurological, psychological, behavioural and social levels, respectively.

1. **Music-related pleasure (neurological).** Previous groove literature has discussed music-related pleasure using the theory of expectations (Witek, 2013; Huron, 2006; Meyer, 1956), predictive coding framework (Vuust & Witek, 2014) or dynamic attending theory (Large & Jones, 1999). In addition, it is known that establishing expectations while processing a sensory stimulus as well as violation of such expectations evokes pleasure in the perceiver (Salimpoor et al., 2011, 2015). Similarly, in the context of groove, this is tested using syncopation, with medium rhythmic complexity (syncopation) being deemed the most pleasure- and movement-inducing level (Witek et al., 2014; Witek et al., 2017).
2. **Immersion-related pleasure (psychological).** Music induces a flow-like, immersed state. Csikszentmihalyi (1988) describes a flow experience to be induced as response to activities that have a challenging mental or physical component. Linked with the previous argument (in music-related pleasure), it is logical to argue that medium levels of rhythmic complexity create such a challenge. Thus, a flow-like, immersed experience during music listening emerges. Csikszentmihalyi (1988) further states that a flow state (by its nature) is linked with high concentration, engagement, instant feedback, and goals, skills or abilities of a person. Thus, it is an inherently pleasurable experience. Research in the field of psychology also supports that flow-like immersed state, where being present in the moment (with mind not wandering) are reported as the happiest compared with other activities and mind wandering conditions (Killingsworth & Gilbert, 2010).
3. **Movement-related pleasure (behavioural).** Following the predictive coding framework, previous literature (Vuust and Witek, 2014; Stupacher et al., 2022) suggests that we move to music to reduce prediction error in rhythm perception. Therefore, as the listener moves along with the music, there might be a feedback loop regarding the re-evaluation of the rhythm. This is also in line with the action simulation for auditory prediction (ASAP) theory (Patel & Iversen, 2014). Furthermore, there is an alternative explanation to movement-related pleasure: it is well-known that movement, dance and exercise are pleasurable actions. One obvious way to explain this is the activation of neurohormonal mechanisms when the body is physically active (Tarr et al., 2014). During such bodily activities, the release of hormones such as endorphin and oxytocin might explain experienced pleasure.

4. **Social-related pleasure (social).** It is known that shared activities that involve coordinated movements of a group of people (like music making or dancing together) are associated with increased cooperation, coordination, affiliation, social bonding and prosocial behaviour, (Stupacher, Mikkelsen, et al., 2022; Savage et al., 2020; Solberg & Jensenius, 2017; Stupacher et al., 2017). These experiences can signal security and safety to the individuals of the group and can be rewarding (Savage et al., 2020).

In Figure 8, a diagram for the four types of pleasure associated with the experience of groove are presented. As detailed above, first, processing of music provides neurological reward, leading to one being immersed in music psychologically (conceptually, one might argue that musical processing on a neurological level *is* experiencing immersion in music on the psychological level). Then processing music on the neurological level and experiencing a compulsion towards music might give rise to bodily experience of (desire for) movement. If the listener indeed moves along with the music, according to the predictive coding and ASAP theories, movement feeds information back to processing of music on the neurological level. Finally, if there are other people present to be in synch with (or simply because music is a social activity), one might experience a social type of pleasure, in addition to the preceding hedonistic experiences. Similar to the presented arguments, in a recent paper, Fiveash et al. (2023) discuss how rhythm-moderated reward facilitates learning, memory, synchronisation and social connection.

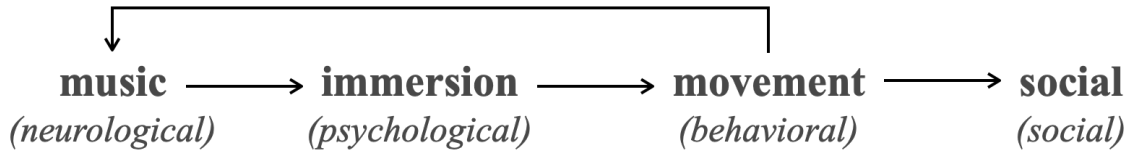

FIGURE 8 Diagram for four types of pleasure associated with groove experiences.

6.5.2 Applications of Groove Research

As part of the Human Affectome Project, Alexander and colleagues (2021) reviewed neuroscientific literature on positive emotions and proposed their promotion and implications for wellbeing. Similarly, because by its nature groove is a rewarding experience on multiple levels, it has various potentials to be implemented in areas outside of academia, such as to promote wellbeing.

Indeed, previous research has focused on some clinical applications of groove such as timing and motor impairment, gait and rehabilitation of walking, such as in Parkinson's Disease (Nombela et al., 2013; Leow et al., 2014; Hove & Keller, 2015; Krotinger & Loui, 2021; Pando-Naude et al., 2023). What's more, aspects of the concept of groove can be used in rehabilitation of other clinical groups. For instance, the immersive quality of groove experience shares some similarities with mindfulness-based cognitive therapy approaches (such as inviting the client to be in the moment), which are used in the treatment of chronic

pain, depression, addiction, anxiety and stress (Creswell, 2017; Hofman & Gomez, 2017). The rewarding and immersive qualities associated with the experience of groove has the potential to be used along with existing therapy approaches, in the treatment of mood-related disorders. One specific example of such applications might be encouraging clients to choose their own music in dialogue with their therapist in order to maximise their immersive experience. In addition, the social aspect of groove-related experiences can be considered with individuals who have social problems (such as autism and Asperger's Syndrome). It might be worth investigating whether combinations of certain musical features could induce groove-related experiences in such clinical groups and lead to enhanced communication and group cohesion.

Another possible application of groove research concerns non-clinical, healthy individuals and their daily wellbeing. Encouraging groove-related experiences of individuals daily could bring them into the moment, be more aware of their own body and emotions, have them experience more positive emotions and social bonding. A possible application for such an intervention could be encouraging people to consider their current emotions and body, choose suitable music for their current context and let themselves free if they wish to join in to the music with their body movements. Notably, findings of Article 2 (such as considering "regulation of mood and arousal" as a function of dance music) can be used as a scientific ground for such an intervention. Overall, such approaches might enhance the individual's overall wellbeing and life satisfaction.

Experience of groove can be encouraged in teaching context at schools too. Indeed, this idea was verbalised first by a masters' student (in music education, who is also a dance therapist) while the author was teaching a groove lecture[2] at the University of Jyväskylä. Part of the discussion section, the student suggested that 'because nowadays curriculums (for instance around the primary school) are targeting use of tablets for several hours, the students are growing without the awareness of their body, actual emotions and surroundings. As an intervention method she had suggested implementation of groove research into school settings. This idea would base on communicating research findings to teachers and policy makers, and mentioning the benefits of experiences of music-induced movements. She, as a dance therapist and future music teacher, argued that encouraging students to centre themselves around their own body and be more in touch with their peers for healthier generations.

Overall, the use of groove research outside of academia is a new field. In order to develop effective applications of groove research, solutions should not be suggested only from the researchers' perspective. Instead, a dialogue among the counterparts involving, for instance, therapists, health practitioners,

[2] The lecture was part of the lecture series in Contemporary Issues in Musicology course in 2021. Part of the narration, the lecturer (author) started the session with the video described in section 6.5 and posed students the question "*how the concept of groove might be experienced in this modern world compared with the past?"* (Nowadays, where people no longer dance for rain but instead, people listen to music ubiquitously for instance while commuting in a train and refrain from moving along with music possibly because it is not appreciated by other people.)

musicians, teachers, groove researchers as well as policy makers would carry tremendous value.

6.6 Limitations and Future Work

The main limitation of the current work relates to lack of actual movement data. According to Roholt (2014), groove can be experienced via overt movements. The fact that the empirical data collected for the articles presented in this dissertation were gathered mostly during the Covid-19 pandemic, there was only limited to no access to in-person data collection. Even though the main goal of the original PhD proposal was to carry out Study 2 extensively in a motion capture laboratory (comparing the experience of groove while passive versus active music listening), this goal could not be fully met. Recording actual movements of participants would certainly complement and enhance the current findings. This remains an open field for future exploration.

The second limitation relates to Article 2 and the topic of contexts of music listening in general. In Duman et al. (2022), an online survey method was used and participants were expected to name one song they move to and recall reasons why they are listening to that song. Even though the findings were novel and informative, the ecological validity of such a design can be improved for instance by using an Experience Sampling Method (ESM) (Randall & Rickard, 2012). In this way, momentary data regarding current mood and goals of the listener as well as the contextual details can be more accurately obtained. Further, this type of a design has the potential to detail the subject "different kinds of groove experiences". The current findings suggested that there are several types of dance songs, therefore it is reasonable to consider there to be various kinds of groove experiences too.

While the current work proposed immersion as the prerequisite and social connection as the secondary qualities of groove experiences, these proposals do not suggest a linear relationship among groove experiences (presented in Figure 1). In other words, it is hard to predict that "the more one is immersed in the music, one is experiencing higher levels of positive affect, desire to movement and thus social connection". Instead, a more complex relationship among the groove experiences might be expected (depending on various factors such as the very moment of listening or the individual who is listening). Moreover, each groove experience might relate and feed onto each other. For instance, when we are immersed in the music, we might feel an urge to fill in the gaps with our body, which might be pleasurable and then we see others dancing which gives us additional pleasure due to sense of feeling socially connected. Alternatively, we might find something pleasurable in music, this pleasure might manifest itself as bodily movements. In Figure 1, the groove experiences are presented in separate boxes, next to one another, since there is not enough knowledge about their actual relationship. For the future, it would be important to develop a set of

experiments to disentangle this relationship and how these components of groove experience interact with one another.

In addition, regardless of the employed method, the author hopes that future research will invest on the freshly introduced path of investigation of nuances or granularity for the concept of groove. For instance, in parallel with the proposal of different groove experiences, it is worth investigating whether there are groove experiences linked more with immersive, bodily, emotional or social aspects. If so, for instance, how do they differ in term of overt movement or experienced emotion? In a similar vein, future research can systematically and empirically test different types of pleasures associated with groove experience (presented in chapter 6.5.1.). Moreover, immersion and its relation to groove experience has not been systematically studied. Yet, as discussed earlier, measuring an immersed state comes with its own challenges. Therefore, as a basic recommendation, methodologies in previous literature to the concepts similar to immersion (such as flow, absorption and presence) in non-musical contexts (such as during gaming) can be scanned and appropriate approaches can be adopted. In addition to immersion, the social aspect of groove was proposed as a secondary quality of groove. As the social aspect is suggested as a resulting experience which comes into play as a consequence of shared group activities, quantifying the social aspect as well might not be as apparent as measuring pleasure and movement aspects of groove. Thus, careful experimental designs (such as indirect measures) of future studies related with the social aspect carries importance. Together, the proposed future studies would contribute to nuances of the experience of groove and facilitate development in the field.

Moreover, despite Article 3 explored the relationships between the Big Five personality traits and listeners' ratings of groove-related variables, as the proposed hypotheses were partially supported, future investigation of the topic is still required. Finally, the current work contributed to the existing groove model. Yet, there might be several other potential factors that relate with the concept of groove which future research can concentrate on. Some examples of such variables include current mood, substance use, experience of nostalgia, capacity for empathy, context or the environment component of the listening situation (especially details regarding location, social and temporal aspects).

SUMMARY IN FINNISH

Viimeisten kahden vuosikymmenen aikana rytmisen musiikin tutkimuksessa on nähty kasvua. Huolimatta alalla tapahtuneesta edistyksestä, on edelleen epäselvää, miten kuulijoiden kokemukset rytmistä muodostuvat. Tämän väitöskirjan keskeinen tavoite oli siksi tutkia groove-käsitteen monipuolisuutta erilaisista näkökulmista käyttäen monia luonnollisen tieteellisiä menetelmiä. Yhdistämällä useita kokeellisia ja analyyttisiä lähestymistapoja (erityisesti laadullisia analyysejä, musiikin tietojen hakuja, ulottuvuuden vähentämistä, korrelaatiota ja EEG-tutkimusta), tavoitteena oli auttaa meitä ymmärtämään ne tekijät, jotka vaikuttavat kuulijoiden groove-kokemuksiin ja edistämään kehitystä niin groove-tutkimuksessa kuin sen sovelluksissa akateemisen maailman ulkopuolella. Tätä varten koottiin neljä toisiinsa liittyvää artikkelia, jotka keskittyivät erityisesti seuraaviin tutkimuskysymyksiin:

1. Mikä tekee biisistä groovaavan?
2. Mitä grooveen liittyviä kappaleita ihmiset kuuntelevat ja miksi he kuuntelevat niitä?
3. Millainen rooli persoonallisuuden piirteillä on ihmisten groove-kokemuksissa?
4. Miten groove-musiikki käsitellään aivoissa?

Tämä väitöskirja esitti uusia löydöksiä aiheista (i) groove-käsite, (ii) grooveen liittyvät musiikilliset piirteet, (iii) grooveen liittyvät kokemukset, (iv) kuuntelijoiden ominaisuudet ja tavoitteet (ympäristössä) sekä (v) grooven neurologinen käsittely. Näitä eri aiheita käsiteltiin laajemmassa ekologisessa kontekstissa ja esiteltiin psykologisen käsitteen affordanssit kautta.

Pääasialliset tutkimustulokset tiivistettynä: Tämä väitöskirja ehdotti aiempaa päivitettyä ja laajempaa työmallia groovesta, esittäen sen moniulotteisena osallistavana kokemuksena (Duman, Snape et al., 2023). Tärkeää oli huomata, että grooven käsite liittyy musiikin kuuntelussa tiiviisti ”mielialan ja vireyden säätely” -toimintoon. (Duman et al., 2022). Lisätutkimukset (liittyen musiikillisiin piirteisiin, musiikin kuuntelu syihin ja persoonallisuuden piirteisiin) edistivät musiikkitieteellisen groovemallin kehittämistä (Duman et al., 2022; Duman et al., 2023a). Lisäksi, väitöskirja tutki vähän tutkittua aihetta liittyen siihen, miten luonnollisesti esiintyvää groovemusiikkia käsitellään aivoissa (Duman et al., 2023b). Lopuksi, keskusteluosiossa edistettiin grooven kliinisiä sovelluksia, avattiin grooven käsitteen tutkimisen merkitystä ei-kliinisissä ympäristöissä ja esitettiin lisää groovetutkimuksen sovellusmahdollisuuksia, kuten koulutuksen kontekstissa.

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ORIGINAL PAPERS

I

GROOVE AS A MULTIDIMENSIONAL PARTICIPATORY EXPERIENCE

by

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Abstract

Groove is a popular and widely used concept in the field of music. Yet, its precise definition remains elusive. Upon closer inspection, groove appears to be used as an umbrella term with various connotations depending on the musical era, the musical context, and the individual using the term. Our aim in this article was to explore different definitions and connotations of the term *groove* so as to reach a more detailed understanding of it. Consequently, in an online survey, 88 participants provided free-text descriptions of the term *groove*. A thematic analysis revealed that groove is a multifaceted phenomenon, and participants' descriptions fit into two main categories: *music*- and *experience*-related aspects. Based on this analysis, we propose a contemporary working definition of the term *groove* as used in the field of music psychology: "Groove is a participatory experience (related to immersion, movement, positive affect, and social connection) resulting from subtle interaction of specific music- (such as time- and pitch-related features), performance-, and/or individual-related factors." Importantly, this proposed definition highlights the *participatory* aspect of the groove experience, which participants frequently mentioned, for example describing it as an urge to be "involved in" the music physically and/or psychologically. Furthermore, we propose that being immersed in music might be a prerequisite for other experiential qualities of groove, whereas the social aspect could be a secondary quality that comes into play as a consequence of musical activity. Overall, we anticipate that these findings will encourage a greater variety of research on this significant yet still not fully elucidated aspect of the musical experience.

Keywords

groove, thematic analysis, musical features, immersion, movement, positive affect, social connection

Groove is a popular term in the field of music. Yet, when attempting to define it, we find various meanings depending on the describer, the context, and the era. Some examples of the term

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groove used in a sentence refer to a state of being, a specific style of performance, or a musical aspect. For example, "I am in the groove", "this band plays groovy", or "this song grooves". Difficulty in describing the essence of groove has been expressed in previous work as "koan-like" (Zbikowski, 2004, p. 272) or "catching water in a net" (Hosken, 2020, p. 182).

The history of groove

Over time, groove has been linked with a diverse range of concepts. In fact, earlier uses of groove demonstrate that it was originally not a musical term. The *Oxford English Dictionary* (n.d.) provides various examples of *groove* (n., v.), *grooving* (n.), *groovy* (adj.) in mining, music, or in reference to a channel (in wood, metal as well as the spiral cut in a vinyl record). Some of these dictionary examples (gathered in Supplementary Materials 1 online) describe groove as: *having a good time, an embodied state, performance/playing style, being related to rhythm, preference, referring to something as being good/cool/hip (slang), returning to one's old self, being immersed in a task smoothly and efficiently, experiencing a particular successful period, and being in fashion/up-to date*. Moreover, uses of "groove" in music are described rather as "transferred and figurative"[1]; the idiom "in the groove" is described originally in a nonmusical context as meaning "running accurately in a channel or groove", later used by jazz musicians from around 1920 onward to refer to a "good performance" (*Back in the Groove*, n.d.). Later, during the 1940s swing and jazz era, the phrase "in the groove" was used to refer to a specific musical routine, preference, or style, indicating its aesthetic properties (Kernfeld, 2002). During the 1970s, groove was mostly associated with music genres such as funk and soul (Hale, 2014). Around the same time, groove was even used as a phrase to say something is "cool" (Hein, 2011; Runyan et al., 2013). (For a German summary of the history of groove, see Pfleiderer, 2006, pp. 297–301.)

Groove in musicology

In addition to changing connotations over time, different branches of musicology have approached the term from different perspectives. From a music-historical approach, groove is associated with genres of North American and "Black Atlantic" music that emerged around the 1950s (Attas, 2011) such as jazz, funk, latin, reggae, and rock (Davies et al., 2012; Frühauf et al., 2013; Pressing, 2002). From an ethnomusicological perspective, groove is defined as an "unspecifiable but ordered sense of something that is sustained in a distinctive, regular and attractive way, working to draw a listener in" (Feld, 1988, p. 76). Groove has been described elsewhere in the ethnomusicological literature as being an important aspect of music (Keil, 1987, p. 96): "The power of music lies in its participatory discrepancies, and these are basically of two kinds: processual and textural. Music, to be personally involving and socially valuable, must be 'out of time' and 'out of tune.'" Keil (1995, p. 2) further explains about participatory discrepancies:

> [Participatory discrepancies] exist. Between players. Between the beginnings of their notes. In the moment when each of us chooses to snap fingers, or nod a head, or in the instant when many decide to get up and dance because the music is so contagious.

While *participation* is described as a human experience, a kind of connection with our surroundings (including the body, society, and nature), *discrepant* is defined as a musical phenomenon, a "strong vehicle for participatory consciousness and action" (Keil, 1987, p. 98). The relation between such participatory human experience and the "discrepant" musical qualities

is described as: "It is the little discrepancies within a jazz drummer's beat between bass and drums, between rhythm section and soloists, that create 'swing' and invite us to participate" (Keil, 1987, p. 98). A similar view is held by the (music) philosopher Tiger Roholt (2014, p. 2):

> There are two aspects to groove: (a) the music (whatever it is that musicians do to create a groove which has primarily to do with timing nuances); and (b) the felt dimension (the feel of a "leaning" groove or one that "pushes," "pulls" and so on).

From a music psychological point of view, groove is described as a "primordial aspect of music" (Madison, 2001), a "state of listening" (Witek, 2009), a "sensation of movement" (Davies et al., 2012), an "experience of music" that makes people dance (Madison, 2006; Madison et al., 2011; Stupacher et al., 2013) or that connects the body, mind, and music together (Witek, 2013). "A musical groove" is described as typically produced through the interaction of a small group of musicians (Zbikowski, 2004), through their "mutual tuning-in" as a mechanism of social entrainment (Doffman, 2009). With all these descriptions referring to the same term, it is hard to decide whether groove should be considered a historical, cultural, musical, or psychological phenomenon.

A decade ago, this ambiguity–or one might say *complexity*–was parsed out from the field of music psychology after the work of Janata and colleagues (2012). Since then, groove has been commonly operationalized in research as a *pleasurable desire to move to music*. After this milestone, groove has attracted the interest of many musicologists and led to a spike in research interest. To date, a number of intra- and extra-musical groove-related variables have been reported. While acknowledging the ease and applicability of this definition, and the fact that it has facilitated advancement in the field, we believe a more comprehensive definition would help develop further research in the field. In the current work, we sought to expand this definition by including recent findings as well as prior connotations of groove. To build our argument, we briefly reviewed the key variables reported in the groove literature over the last two decades in Supplementary Materials 2 online (for a more extensive review, see Levitin et al., 2018). Given the broad, multifaceted nature of the previous literature findings, defining groove simply as a pleasurable desire to move to music might be considered a little reductionist. To flesh out this argument we propose three reasons why groove should be defined more comprehensively (see Supplementary Materials 3 online for two additional reasons titled as "Dissimilar Definitions in the Literature" and "Different Methodologies Result in Limitations, Nuances and Challenges").

Reasons for a more comprehensive definition of groove

Groove is a complex multidimensional phenomenon. First, we are not the only musicologists to view groove as multidimensional. Frühauf and colleagues (2013) approached groove from its *musical and performance perspective*, highlighting its "dual nature"–a satisfying groove definition must contain a specific rhythmic structure as well as how that structure is performed. They elaborated that the experience of groove is constructed if musicians consciously modify microtiming by playing "in the pocket." More inclusively, Danielsen (2010) described the emergence of groove from the relationship between both the *qualities of music and the listener experience*. Similarly, Witek (2017, p. 138) advanced groove phenomenologically as being "distributed between mind, body, and music". Senn and colleagues (2020) reviewed various meanings of groove by pointing out the nuances between "a groove" (referring to a musical quality such as a repetitive pattern in specific music genres), "to groove" (denoting an effortless and well-coordinated performance), and "has groove" (indicating for pleasurable- and movement-inducing

music). Moreover, Senn et al. (2019) (for an updated version, see Senn et al., 2022) provided a psychological model of musical groove which encompasses "musical properties", "entrained body movement", "concrete listening situation" and "personal background", among other variables. The authors further propose that to experience groove, one "needs to have an inner representation of the music's temporal regularities, which allows for motor planning and synchronized body movement" (Senn et al., 2019, p. 1), and that music must induce in the listener the desire to move. These examples exhibit the concept of groove with its performance, music, and listener experience aspects.

Overlooked findings in the literature. Second, the few studies that have demonstrated groove to be a multidimensional phenomenon have been largely overlooked. Pfleiderer (2010) gives a comprehensive description of groove in the German language and presents the groove experience with four dimensions: "structural-cognitive", "movement", "emotional", and "social". It is possible that Pfleiderer's findings have been overlooked or rendered less accessible due to the language of publication. According to Pfleiderer (2010) perception and cognitive processing of rhythmic-melodic-harmonic sound structures are called "groove". Repetition of such cyclic patterns in popular music, which are produced by an interacting rhythm group (such as via percussion, bass, guitar, and piano), creates a foundation for the "experience of groove" and facilitates synchronized physical movements (such as dancing). This experience is also described with a positive emotional state that involves listeners, dancers, and musicians, and this is why it requires a social aspect such as a suitable ambience or an appropriate social framework (Pfleiderer, 2010).

Following a listening experiment, Madison (2006) operationally defined groove as "wanting to move some part of the body in relation to some aspect of the sound pattern" (p. 201). To arrive at a consensus, Janata and colleagues (2012) approached groove psychologically (other than a music-theory-based approach) and asked university students to provide free-text groove definitions, rate preselected items related to the experience of groove (which were generated based on general intuitions), and complete a series of listening and tapping tasks. For the free-text groove descriptions, a frequency-based analysis was described which was later linked with the rated items. Concepts that emerged from free-text groove descriptions included "movement and rhythm", "a sense of feeling and compulsion", and "integrating the movements of one's body with the music". Concepts that emerged from the rated items included "movement", "positive emotions", "a sense of integration with the music", and "the presence of salient beats" (Janata et al., 2012, p. 56). Despite the breadth of concepts that emerged, the provided groove description primarily focused on pleasure- and movement-related aspects of groove, stating that "The groove is that aspect of the music that induces a pleasant sense of wanting to move along with the music" (Janata et al., 2012, p. 56). This widely used definition encompasses neither some of their own findings about groove (such as integration with music or salient beat) nor some of their related findings (for instance, the word "flow" was reported to appear in their data 19 times, more than the word "enjoy"–15 times). Moreover, one could also argue that the extensive findings of this study have been overshaded by only referring to its movement and pleasure aspects when reported in other studies.

Possible missed opportunities and the future of groove research. Third, developing a more comprehensive representation of groove will facilitate progress in the field and bring granularity to our understanding of this phenomenon in future studies. For example, the Experience of Groove Questionnaire (Senn et al., 2020) primarily included only the two dimensions of "pleasure" and "urge to move" for groove. Only in a recent preprint Senn and colleagues (2022) reported

additional scales: "temporal regularity", "time-related interest" and "energetic arousal". Yet, in another recent paper, Senn et al. (2023) highlighted that the current groove model is incomplete, and that significant causal pathways which influence the groove experience are yet to be discovered. A revised definition of groove and careful consideration of its dimensions could, for instance, provide more substantial scale developments and help researchers to accurately measure the intensity of groove experiences.

The current work

The primary motivation for the study reported in this article was to develop a more holistic representation of groove. Since describing groove has been particularly stated as being koan-like (Zbikowski, 2004), we took a semiotic approach. Thus, we were interested in investigating *what groove signifies in people's minds*. To investigate what "groove" means to a diverse range of people, we used a free-text survey-based approach and did not restrict our sample. This method would enable us to reach a relatively common representation, regardless of any context or particular situation (such as while performing or listening), as well as to reach a sample who often participate in scientific studies (such as young university students). Yet, participants were still able to reflect on a particular case/variable.

On the basis of the diverse work reviewed above, our principal prediction was that respondents' definitions of groove would encompass a range of concepts that extended beyond pleasure and movement. We anticipated being able to construct a working definition of groove that would reflect this broader range of concepts, and that would in turn facilitate more finely nuanced investigations of groove in the future.

Method

Procedure

The research reported here formed part of an extensive online listening survey which was conducted to investigate a range of factors influencing people's groove experiences. The survey was distributed on webropol.com via personal social media accounts and the University of Jyväskylä emailing lists. Initially, participants were informed about the content of the survey and their rights as a participant, and were requested to declare their consent to participate. Subsequently, participants (1) provided demographic information, (2) completed a set of questionnaires, (3) performed a brief online listening task, (4) named a piece of music that they move to and rated associated reasons for music listening, and (5) self-evaluated their familiarity with the term groove and provided free-text groove descriptions. Participation and data processing were kept anonymous. Completing the entire survey took about 45 min, and participants had a chance to win a 50 € voucher upon completion. General Ethical Guidelines of the University of Jyväskylä were followed in the study.

Materials

The following materials were included in the extensive survey:

Questionnaires. Ten Item Personality Index (TIPI: Gosling et al., 2003), Short Test of Music Preferences (STOMP: Rentfrow & Gosling, 2003), and a 21-item questionnaire of reasons for music listening (Duman et al., 2022).

Online listening task. Participants were presented with thirty 25-s musical excerpts consisting of popular songs from a range of genres with tempi centered around 120 bpm and were asked to rate a number of groove-related variables.

As part of this particular study, only the last section of the online survey–data about participants' self-evaluated groove familiarity and free-text groove descriptions–was analyzed. All participants rated their familiarity with the term groove on a 7-point Likert scale (1 representing *not at all* and 7 *very much*). Subsequently, they were asked to respond to the question "could you describe below what makes a song 'groove' in your opinion" as free-text, on a voluntary basis.

Participants

One hundred five participants (61 women, 41 men, 3 other) aged 16 to 54 ($M = 27.07$, $SD = 6.46$) completed the entire survey. Participants originated from 19 different countries, with the majority of them reporting being Finnish ($n = 56$) or Turkish ($n = 23$) nationals. Fifty-nine of the participants were students. On average, participants reported 2.86 hr of music listening per day ($SD = 1.90$) and 1.85 hr of dancing per week ($SD = 2.21$). Moreover, three levels of musical training were observed among the participants: Eight years and above ($n = 29$, $M = 15.73$, $SD = 5.16$), less than 8 years ($n = 35$, $M = 3.41$, $SD = 2.14$), and no musical training ($n = 41$). Twenty-four of the participants received on average 3.69 years of dance training ($SD = 2.18$). Of the 105 participants, 88 provided free-text groove descriptions. As participation was voluntary, we assumed that participants had a sufficient command of English (the language of the survey) to complete all items. Additionally, we observed a satisfactory level of language competency in participants' responses.

Analysis

Since the aim of this research was to review definitions of groove with a more holistic approach, a mixed data analysis method, *abduction*, was preferred. Abduction is described as "a creative inferential process aimed at producing new hypotheses and theories based on surprising research evidence" (Timmermans & Tavory, 2012, p. 167; also see: Douven, 2021). An abductive approach can be seen as a combination of inductive and deductive approaches. While inductive analysis reaches conclusions from specific observations in the data, deductive analysis bases its conclusions on general rules and known facts. In this way, both theory- and data-led analyses could provide a detailed analysis of participants' free-text groove descriptions. Moreover, within the methods of qualitative research, thematic analysis was chosen since it is argued to be a "foundational method" of qualitative research that focuses on the identification of recurring patterns (themes) by affording "flexibility" for the researchers (Braun & Clarke, 2006). Therefore, thematic analysis provided the possibility to perform this mixed method, abductive, analysis.

As qualitative research is inherently subjective, to ensure reliability of the findings, there were initially two coders in this study. Furthermore, a method, *bracketing*, which aims to acknowledge the inherent preconceptions and biases of the researchers (Tufford & Newman, 2010), was considered in this article. Using the bracketing schema detailed in Tufford and Newman (2010), we explicitly state the mindset of the researchers who played a primary role in the design and analysis processes in Supplementary Materials 4 online.

For the analysis, while Author 1 familiarized herself with the data and generated initial codes with a theory-led, deductive approach, Author 2 investigated the data with a data-led, inductive approach. The particular difference between these two approaches in practice was

that with the theory-led, deductive approach, Author 1 kept the key findings in the groove literature (such as wanting to move and syncopation) in mind, whereas Author 2, being less familiar with particular groove-related variables, was able to analyze the data free from the established concepts and focus on particular observations in participants' responses. During analysis, authors followed a more *interpretivist approach* (rather than the so-called realism paradigm, where one considers words as names for concrete objects, etc), considering the aforementioned difficulty in describing the concept of groove. Interpretivism is a naturalistic approach welcoming individual differences by focusing on meanings and why or how a phenomenon might have occurred (Elliott & Timulak, 2005). Later, the codes generated by these authors were discussed and a mutual agreement upon categorization of the concepts was reached. As a final step, data were investigated one more time to ensure that the established categories did not leave out any further insights. Overall, a coding schema considering the six phases of thematic analysis (1—*familiarizing with data*, 2—*initial coding*, 3—*looking for themes*, 4—*revisiting themes*, 5—*naming themes*, and 6—*reporting*) described by Braun and Clarke (2006) was followed. The analysis and reporting procedures follow the reviewing and critiquing guidelines by Elliott and Timulak (2005). Furthermore, to ensure reliability of the analysis, a third, external coder (Author 3) then checked a subset of the data and provided a report about "dependability", "credibility", and "confirmability" of codes following the suggestions by Moon and colleagues (2016). This report can be accessed in Supplementary Materials 5 online.

Results and discussion

Groove familiarity ratings

The mean groove familiarity score was 4.6 ($SD = 1.868$), indicating that participants were somewhat familiar with the term. Participants were divided into three categories according to their familiarity ratings: ratings of 7–6 formed the high (very familiar, $N = 39$), 5–4 the mid (somewhat familiar, $N = 35$), and 3–2–1 the low (not very familiar, $N = 32$) groove familiarity levels. Participants with 8 years or more musical training reported higher groove familiarity ($M = 5.24$, $SD = 1.5$) compared with participants with fewer than 8 years ($M = 4.49$, $SD = 2.06$) and no music training ($M = 4.16$, $SD = 1.5$). An analysis of variance test revealed no significant difference in groove familiarity as a function of years of musical training, $F(2, 103) = 2.916$, $p = .058$. Four participants with more than 8 years of music training reported their groove familiarity as low.

Groove descriptions

The total word count across all groove descriptions was 2,348. The average length of responses was 27 words ($SD = 27.08$, *median* = 14). Several participants responded with a single word while another used 148 words. In Supplementary Materials 6 online, a visual representation of participants' word counts can be found. Moreover, frequencies of the most commonly used words are presented in Table 1 which largely aligns with the list provided by Janata et al. (2012). All words were first simplified to their basic forms, language mistakes were corrected, then articles, pronouns, and prepositions were removed from the list. Words occurring at least eight times are presented in Table 1.

In line with previous research, the emergent categories depict groove as a multifaceted phenomenon (Hosken, 2020; Pfleiderer, 2010; Stupacher et al., 2016; see also "Groove is a

Table 1. Frequencies of the Most Commonly Used Words.

Frequency	Word
44	Groove
43	Rhythm
43	Song
30	Make
29	Move
25	Bass
25	Music
22	Beat
19	Want
15	Melody
14	Feel
14	Good
14	Time
12	Drum
12	Instrument
11	Dance
10	Clear
10	Create
10	Guitar
10	Catchy
9	Flow
9	Like
9	Tempo
9	Well
8	Element
8	Line
8	Nice

complex multidimensional phenomenon" section). Despite the survey's explicit inquiry (the question asked being "what makes a song 'groove' in your opinion"), participants still provided definitions of groove beyond what can be derived from a song. Specifically, we observed a multidimensionality in participants' groove descriptions such that groove evoked concepts associated with music (both *what* and *how* music is performed), and experiences of the music by its listeners in relation to both their present and prior experiences. This highlights the multidimensional nature of groove, and how the notion is driven not only from the musical piece but how it is also significantly related both to one's personal experiences as well as how the music is communicated by its players. As a consequence, we categorized various aspects of groove which are presented in the following section.

Categories defining groove

Participants' groove descriptions revealed a tendency to refer to both music- (including what is played and how it is played) and experience-related variables of groove. While the musical aspect was referenced 159 times, the experiential aspect appeared a total of 109 times. Although these numbers should be approached with degree of caution in light of

Table 2. Main and Subcategories of Participants' Groove Descriptions.

Main categories	Subcategories
Musical aspect	Performance
	Artists (8)
	Instruments (32)
	Styles (12)
	Music-related features
	Time-related features
	Rhythm (36)
	Beat (14)
	Tempo (9)
	Pitch-related features
	Melody (12)
	Frequency range (13)
Experiential aspect	Immersion (17)
	Movement (32)
	Positive affect (13)
	Social connection (3)

The appearance frequency of subgroup being mentioned by different participants is presented in parentheses.

potential priming of music-related answers, this duality is in line with previous work (Roholt, 2014). Categories that we derived abductively from participants' groove descriptions are presented in Table 2.

Musical aspect

The musical aspect's main category relates to subcategories *performance* (*how* the music is played) as well as *music-related features* (*what* is being played). This finding is in alignment with what Keil (1966) argues; not only what is being played but also how it is played influences expressivity and thus the production and the perception of groove. The performance subcategory covers producers of groove (artists), musical instruments, and musical styles associated with groove. The music-related features subcategory mainly consists of time- and pitch-related features.

Performance. This subcategory can also be seen as *how* groove is produced. Such a production can be live or recorded music, made by a band, producer, or a single artist.

Artists. A musical performance associated with groove was described as being skillfully performed by artists. In other words, "performance ability of the players" contributes to the production of groove, which echoes Zbikowski's (2004) description of groove. P9 exemplified how a drummer's performance is relatable with groove:

> A great drummer can make a single symbol [cymbal] "swing", which can give a groove for a whole song.

Instruments. *Instruments* were mentioned rather frequently (32 times) and the most commonly named instruments related to groove were bass and drums, followed by guitars, wind instruments, and vocals. Especially "bass guitar and drums" instrument pair were associated

with groove, which is in line with Allan Moore's (2001) groove definition (p. 34): "the groove is more particularly the pattern laid down by the bass and drum kit." Their function was suggested to produce a "good" rhythm and a basis for other instruments. Moreover, the harmonious interplay of instruments was often commented upon. As P105 said,

> A song with a groove has a clear and funky bass line, some wind instruments, usually a saxophone and two trumpets. Then add some percussions and all these playing well together.

Styles. Related to the performance aspect, several musical styles were mentioned in participants' groove descriptions. Funk and jazz were the most frequently observed musical styles, followed by metal. Moreover, while some participants mentioned groove existing in various music styles, one associated groove with "funk and disco" and one other with "jazz and blues." For example,

> There can be many different kinds of great grooves that can be found in different music styles. (P9)

> I usually connect groove to songs that are or have funk or disco elements. (P82)

> I associate "groove" with jazzy-bluesy type of music. (P98)

While funk and jazz are often linked with groove (Danielsen, 2006), metal appearing as the third most common musical style associated with groove might at first be surprising. However, it is important to highlight that our sample included a large number of young students from Finland, known to have one of the highest numbers of metal bands in the world (DeHart, 2018). Thus, participants' groove descriptions might be naturally biased toward their musical preferences. Moreover, this would be in line with previous findings that reported musical taste influences the experience of groove (Senn, Bechtold, et al., 2021).

Music-related features. With this subcategory, we gathered participants' descriptions referring to *what* is being produced by the artists. This subcategory mainly contains musical features associated with groove, namely, as time- and pitch-related features. Similar to the "harmonious interplay of musical instruments," a delicate interaction between musical features was remarked upon as another factor in groove-related music. For example, P19 suggested groove as an interaction between rhythm and melody:

> It is a mix of rhythm and melody that work well together. Many times, a clear melody over more complex rhythm or beat, or a simple beat with a more complex melody.

Time-related features. Related to time-related features of groove, the most commonly emerging codes (rhythm, beat, and tempo) were further investigated. Certain timing variations in music such as using a steady beat as well as rhythmic complexity such as use of half notes or syncopation (appeared 3 times) were linked with groove. While in the groove literature, syncopation has received notable attention (such as Witek et al., 2014, 2017), it might appear surprising that there were only three mentions of syncopation. One logical explanation might be that syncopation is a musical term and not many of our participants were professional musicians. Nevertheless, certain key words appeared several times in the data which might be interpreted as referring to the function of medium levels of syncopation. Such words are clear (10), complex (3), interesting (6), and catchy (10). One can argue that for instance a

syncopated musical pattern is not too simple nor too complex but is catchy and interesting enough to attract the attention of the listeners and make them engaged with it (for similar interpretations see Matthews, 2021; Stupacher, Matthews, et al., 2022). This engagement aspect is elaborated further below.

Rhythm. Numerous responses used rhythm as a primary descriptor for groove. Beat was the other temporal musical feature associated with groove. The groove description of P30 demonstrated this temporal aspect, specifically explaining how the production of rhythm and beat contributes to groove. Indeed, highlighted temporal irregularities in this quote can be interpreted with Keil's (1987, 1995) participatory discrepancies in the music too:

> Groove is mostly rhythmic feel that a song or a band has. [. . .] Groove is not about getting everything perfectly on time and on the beat, but it is more like getting things in the right place related to the beat. For example, sometimes bass player has to play a little bit before the beat (maybe in jazz context) and sometimes a little bit behind the beat.

Related to participatory discrepancies, although there was no direct mention of microtiming, five participants referred to such timing variations by stating:

> "Enough air between notes" (P67) or "not perfectly on time" (P30), for example.

Tempo. Tempo was also mentioned in relation to groove. It was observed that groove might exist at different tempi, with some participants indicating their preference for slow, whereas others for fast tempo. P79, for example, remarked:

> I often prefer slower tempos that feel "heavy" but faster tempos can also be "groovy."

This contradicts previous findings which suggest an optimum tempo for groove around 100–120 bpm (Etani et al., 2018). However, this contradiction should be approached with care, as Etani and colleagues focused on the Japanese *nori* which is seen as an equivalent term for groove. Alternatively, this finding might hint at the existence of different types of groove experiences (as also hinted in Hosken [2020] and elaborated further in Bechtold & Witek, 2021). Different kinds of groove and their relation with experience of time have earlier been proposed by Keil (1995, p. 8): "each person has a unique feel for time and that bringing different or discrepant personalities together generates different kinds of groove." Moreover, while it is well known that dance songs typically have a tempo of around 120 bpm (Duman et al., 2022; Moelants, 2002), a recent study reported five subgroups of dance music (with various combinations of Spotify audio features, including tempo) associated with different listening reasons (Duman et al., 2022). This might also be related to why people embody music in various ways during spontaneous dance (Toiviainen & Carlson, 2022; Toiviainen et al., 2010). Therefore, we might suggest that groove is not necessarily limited to a typical tempo nor solely to experiences of pleasure and an urge to move, but instead to a combination of several factors (similarly as suggested with the groove model: Senn et al., 2019, 2023). Thus, it is clear that more research investigating different kinds of groove experiences is needed.

Pitch-related features. Pitch-related features of music were also often mentioned by participants. Particularly, a separation between high- and low-frequency ranges was noted. This separation might be further linked with bass and drum instruments creating a

rhythm-related basis for the other instruments, as they often carry low-frequency range acoustic features. For higher frequencies, however, a few participants mentioned the function of melody to add a flavor to the song. The following descriptions exemplified the role of pitch-related features on groove:

> Drums and bass create the foundation for it in a band and other instruments support it. (P30)

> A lot of groovy genres also have a separation in the range of instruments and voices. The bass is heavy and solid, and higher instruments sort of sparkle over the top. (P29)

This finding is in alignment with previous literature. As a function of our hearing organ, the cochlea, whereas lower-ranged frequencies deliver the rhythmic information (called the low-voice superiority effect), higher-ranged frequencies provide the melody (called the high-voice superiority effect) over a sound. Thus, timing variations are better detected at lower frequencies such as bass-ranged instruments (Hove et al., 2014) and strongly linked to groove ratings and with tapping stability (Stupacher et al., 2016).

Other music-related features

Lyrics. In addition to time- and pitch-related musical features, four participants referred to lyrical aspects of music. To the best of the authors' knowledge, no previous research has reported the role of lyrics in groove experiences. In our participants' descriptions, lyrics seemed to play a subsidiary role in experiencing groove. It was suggested that the function of lyrics was to help the listener to connect with the song. Thus, lyrical elements of music might be interpreted as making it easy for listeners to connect with the music and contribute to their groove experience, as P67 stated:

> The lyrics have a big contribution to it since the words make it easier to connect with the song.

Relationship between musical and experiential aspects

The above-mentioned musical variations that relate to groove might be further associated with establishing certain "musical expectations" in listeners. These expectations were derived from the adjectives that appeared frequently in participants' groove descriptions. Some of these adjectives that were linked with the musical aspect of groove and listener expectations were: *clear, predictable, consistent, stable, steady* and *simple,* whereas other adjectives demonstrated the function of violation of expectations such as *unexpected* and *sudden*. Similarly, in Hosken's (2020) thematic analysis, expectation/tension was an emergent concept. Involvement of such musical expectations might bring people closer to music, make them engage with it more deeply. As a result, the above-mentioned musical variables induce certain psychological and physical states (participatory experiences) in the listeners and impact their groove experiences (see below).

Moreover, while describing their groove experiences, participants used certain keywords that revealed their "engagement" with music. For example, participants used adjectives like *catchy, interesting, complex, intense, heavy, bonding* and *synchronizing*; verbs such as *make, create, want, keep, emerge, capture* and *drive*; nouns like *feel, weight, ambiguity, attention*, and *flavor*. These keywords demonstrate how music associated with groove makes listeners engage with it. The groove description by P10 exemplifies these findings:

> It has a clear rhythm so that it is easy to dance to it, but it can't be too predictable. The song also needs to have good energy and funny/clever/interesting lyrics. I'd say that if a song puts you in a good mood, has attitude and makes you want to move or sing, that song is groovy.

These arguments might be supported by recent studies by Senn and colleagues (2019, 2020, 2022) in which they developed additional scales for their Experience of Groove Questionnaire. They state having "inner representation of temporal regularity" as a prerequisite for experiencing an urge to move along with the music. Some of the items in this scale include keywords such as *regular beat, clear pulse, predictable/repetitive/steady rhythm*. They further argue that the temporal structure may facilitate increased "rhythmic interest". Some of the items in this scale include keywords such as *attention capturing/captivating/fascinating/interesting/exciting/boring/surprising rhythm*. Looking at these keywords, a similarity between the concepts of *expectations* and *engagement* (described above) with "inner representation of rhythmic regularity" and "rhythmic interest" (Senn and colleagues' additional scales) subsequently can be noticed.

Although further empirical research is needed to disentangle how music creates certain expectations and engagement leading to participatory bodily and psychological experiences in listeners, this rather automatic engagement or the compelling aspect of music might be understood within the predictive coding framework (Stupacher, Matthews, et al., 2022; Vander Elst et al., 2021; Vuust et al., 2018; Vuust & Witek, 2014). Predictive coding is described as a survival mechanism based on the idea of maximizing future predictions by minimizing the error between the perceptual input and the prior expectations in the brain (Vuust & Witek, 2014). From this point of view, musical rhythm might be regarded as facilitating constant predictions in the brain, substantiating experiences of pleasure and sensorimotor synchronization. Furthermore, validation of expectations has been suggested as a key to pleasure in music (Huron, 2006; Meyer, 1956) which should be considered as a contributor to the experience of groove as well.

The groove description by P29 further exemplifies how the musical aspect of groove creates a drive and leads to the experiential qualities of groove:

> Musically it's about slightly thwarting timing expectations, leaning back on the beat but always getting where you need to be. There's a naive physics to it; groove sounds heavier and stronger than other rhythms, but the momentum of it drives you to the next beat at the same time as holding you back, creating this sense of movement and weight that works well with some kinds of dancing [. . .] makes it fun to both dance and sing to.

Experiential aspect

The features of groove described thus far, which establish musical expectations and engagement, might be further interpreted as a bridge between the music and the listener. They invite the listener to participate and experience the music on a deeper level. According to Danielsen (2006), this invitation lies in tension produced by the interplay between the main beat and the counter rhythm which is then balanced by the listener by moving along or just thinking it. We present these experiences as aspects of engagement or participatory experiences with music, namely immersion, movement, positive affect, and social connection.

Immersion. Beyond finding groove-related music interesting and engaging, participants often mentioned being in an immersed state with music in describing their groove experiences. While immersion is described as a psychological state, referring to "being involved" mentally,

physically, and emotionally, other related terms to immersion–*absorption* and *presence*–are described as "extreme involvement" and "being there" subsequently (Wycisk et al., 2022). Similar to Wycisk and colleague (2022), by immersed state, we primarily refer to an "experienced connection or involvement with music." This involvement can be in any form such as mental, physical, or emotional. Qualities of such connections with music are various and observed from the following descriptions, which are also related to concepts of flow, time, and space:

> when you understand and get into the flow of the song (P33)
>
> feel the song and feel that you are a part of it (P78)
>
> something that hooks me (P3)
>
> feeling different from the present (P56)
>
> it gives the listeners space and allows them to be immersed in the song (P36)

Importantly, we propose that being immersed in music is a prerequisite for other experiential qualities of groove. Câmara and Danielsen (2018, p. 2) have described groove as an immersive state: "Groove happens in the here-and-now of performance, meaning that groove is, in a sense, ungraspable as such—the very moment one tries to come to terms with a groove experience, one is no longer in the groove". Thus, it could be the common case that participants are *not* truly aware of such an "ungraspable" state but instead have a tendency to relate such groove experiences to more external clues like dancing or feeling good, ignoring the trigger. Therefore, noticing or quantifying such an immersed state might not be as easy and apparent as the other–movement and affect-related–states. This difficulty in quantifying an immersed state further led us to consider indirect indications of an immersive state with the interpretivist approach (Elliott & Timulak, 2005). The interpretation of this analysis can be found in Supplementary Materials 7 online. With the following examples, the key role that immersion with the musical piece plays for the subsequent affect and movement aspect can be observed:

> It has to do with song having the ability to immerse you in it in an embodied way. (P48)
>
> It captures you to it's rhythm, makes you want to move along. (P97)
>
> Dig deep into the music and enjoy. (P31)
>
> Some kind of catchiness, a song you want to dance. (P6)

Furthermore, we highlight subtle nuances in the terms "immersion" and "flow." Previously, Stupacher (2019) reported that a flow state correlated with the experience of groove in a tapping experiment. However, the terms flow and immersion are not necessarily entirely interchangeable. Agreval and colleagues (2020) propose that states of flow and immersion differ depending on the activity one is engaged in having passive or active involvement. Unlike the experimental method that was used by Stupacher (2019), since our focus was primarily on listener's groove definitions (which do not necessarily involve active engagement), we prefer to use the term immersion instead of flow. We hope that future research would invest in the concepts of immersion, flow, absorption, and presence and develop reliable methods to quantify them.

Movement. Movement-related responses were frequently reported experiences in participants' groove descriptions. This subcategory covers the induced experiences, which include both the "psychological experiences toward movement" (such as a desire to move and sense of movement) and "bodily experiences of movement" (such as dancing, nodding, swaying, singing and jamming). Furthermore, this movement aspect was often mentioned as a "drive" rather than a quality that the listener consciously acts toward; as P16 and P68 described:

> A song that make your hips move even if your brain don't want to.
>
> Song has a groove when it immediately makes you want to move.

Such drive toward automatically moving to music has been shown empirically in a series of "stand still" competitions. Specifically, when asked to stand still, participants exhibit a greater amount of movement when musical stimuli are presented compared with silent moments (González-Sánchez et al., 2018; Zelechowska et al., 2020).

Positive affect. Participants often associated their groove experiences positively with words such as happy, enjoyment, and satisfying, which are gathered under the "positive affect" subcategory. Here are some examples of how participants described their induced positive emotional experiences associated with groove:

> It has to do with enjoyment. (P48)
>
> It needs to have a good feel to it. I mean it doesn't have to be happy, but it needs to have that something. (P13)
>
> A sudden change to 'half time feel' can be very satisfying, because there is a release for the built-up 'tension' of the fast parts. (P79)

Social connection. In addition to feeling an immersive state to music and experiencing it in relation with movement and positive affect, a final subcategory, "experience of social connection", emerged from the data. This social aspect subcategory is linked with experiencing affinity toward the performers of the music and/or the other people who share the same atmosphere with the listener. Instances of this induced experience of social connection with the performer and other people were described as:

> Something I feel through the artists. For example, I feel the groove in a Jazz band. (P42)
>
> Bonding you to the people who are also grooving at the same time. (P29)

It is well established that shared activities such as music listening and making, dance, and coordinated movements, as well as shared emotions, are closely linked with establishing social identity, bonding, and connection (Arewasikporn et al., 2019; Lee et al., 2020; Marsh et al., 2009; Savage et al., 2021; Solberg & Jensenius, 2017a; Stupacher et al., 2017; Stupacher, Mikkelsen, & Vuust, 2022). For instance, a motion capture study investigated structural components of EDM music (breakdown, build-up, and drop) and reported higher levels of group synchronization during such structural changes in the music (Solberg & Jensenius, 2017b). Additionally, participants of the study provided self-reports indicating that the involvement of the other participants shaped their own experience. Moreover, it is known that people feel

affinity toward others with whom they share similar musical preferences (Boer et al., 2011) and when a listener has affinity toward a musician, experience of perceived groove is reported to be higher (Kowalewski et al., 2020). Although these shared experiences, which are closely related to a sense of social connection, are also related to groove, research examining groove experiences in relation to social connection is scarce (Stupacher, Matthews, et al., 2022). One recent motion capture study reported increased groove ratings, movement energy, and interpersonal connection when participants were able to access social cues (eyes open versus eyes closed) (Dotov et al., 2021).

Witek (2017) proposes that groove disables boundaries between the music, mind, and body, enabling its listeners to "feel at one" with music and others in the same environment:

> Collectively filling the gaps in syncopation draws many bodies into the same space, in which bodies are distributed and the boundaries between different agents are further blurred. [. . .] The open spaces in syncopated groove become portals through which people can share the same mental, temporal and physical dimensions (p. 149).

Witek (2017) further describes syncopation as affording "social entrainment" in which temporal, psychological, and physical experiences of people are exchanged within the group. Thus, we suggest this social aspect as a secondary quality related to groove experiences which comes into play as a consequence of musical activity. Therefore, a social context (as also discussed in the groove model by Senn et al. [2019]) can add to primary experiences of groove and can shape the intensity or the granularity[2] of the experienced groove.

In light of these findings, it would be worth investigating further how experience of groove is linked to social cues. Importantly, in such endeavors, as social connection is proposed to play a secondary role in listeners' groove experiences, it might not be as apparent to the listeners as other experiences like the desire to move or positive affect, requiring careful experimental designs. It is also worth investigating whether one needs to be surrounded by other people, or whether solitary engagement with groove-related music is sufficient for a felt social connection, since music is inherently a social phenomenon and among the reasons why people engage with it (Boer & Fisher, 2012; Schäfer et al., 2013).

Other factors associated with the experience of groove

Thus far, we have presented various experiences of listeners associated with groove. The experiences of feeling immersed in music, movement, positive affect, and social connection appear to be affected by other individual-related factors. Our data provided evidence for two individual-related factors, namely, musical preferences and listeners' current state.

Musical preferences. People's listening habits, which also relate to their familiarity with music, shape their musical preferences (Senn et al., 2019). Participant responses that reflect features related to their musical preferences and groove are gathered in this subcategory. Such musical preferences were derived from descriptions when participants associated groove with their favorite music, referenced their genre preferences or gave musical examples of the artists that they listened to. Artists which appeared in groove descriptions either as participants' associations with groove or their musical preferences were: ABBA, Lamb of God, Pantera, Jamiroquai, Childish Gambio, Lady Gaga, Hozier, Christina Aguilera, Kool & the Gang, and Earth, Wind and Fire. Associated eras and the musical styles of these artists are various, leading us to the

consideration of groove as an individual and personal experience regardless of the kind or time period of the music. Moreover, the groove description by P13 exhibits how musical exposure (familiarity) might be linked with groove experience:

> It helps if I am at least somewhat familiar with the song.

Current mood. The current emotional state of the listener also seems to influence experiencing groove in a song. According to P47, to experience groove, music should match with the *current emotional state*:

> If a song expresses your emotions and emphasizes them, then song groove.

Although previous groove models consider the influence of personal background and concrete listening situation for groove experience (Senn et al., 2019, 2023), current mood of the listeners is a rather novel finding in the groove literature. Its contribution requires further investigation and might shed light on the personal and interindividual variance in experience of groove.

General discussion and conclusion

In this article, we initially provided a brief history of groove and then reviewed pertinent aspects of the groove literature, with a particular focus on how the term groove–with its numerous connotations–has been defined. Subsequently, we presented a new thematic analysis of groove descriptions which highlighted two main dimensions of groove, namely the musical and experiential aspects. Compared with previous literature, our findings can be seen as a combination of how Roholt (2014) and Pfleiderer (2010) conceptualize groove. While Roholt (2014) highlighted two dimensions of groove (music and experience), Pfleiderer (2010) introduced four, more nuanced aspects. While Pfleiderer's (2010) "structural-cognitive" dimension could be equivalent to our musical aspect, the "movement", "emotional", and "social" dimensions proposed by him could be seen as how we have explained our experiential aspect, with the addition of immersion.

We summarize our findings in Figure 1. The musical aspect of groove facilitates its experiential qualities which are mediated by other individual factors. These subcategories are interrelated with each other by their nature. In the musical aspect of groove, artists play the musical instruments that give rise to production of certain musical features which are then associated with specific musical styles. These musical styles then become part of listeners' personal music preferences, or listeners might prefer to listen to a certain type of music depending on their current mood; this influences people's groove experiences. Furthermore, by creating certain musical expectations, listeners engage with music which gives rise to psycho-physical participatory experiences. We explained this expectation and engagement with music in terms of participatory discrepancies and predictive coding frameworks. Moreover, we proposed immersion with music as the primary participatory experience which gives rise to (or manifests itself as) the experience of a desire to move and positive affect. Embodiment of music and experience of positive affect lead to a feeling of social connection, which was argued to play a secondary role in groove experiences. These steps further shape the listener's current mood and determine the degree of experienced groove (bidirectional arrows).

Overall, it should be noted that with these results we are not offering a magic recipe for groove. Although groove evokes certain semantic associations in people's minds, the ambiguity

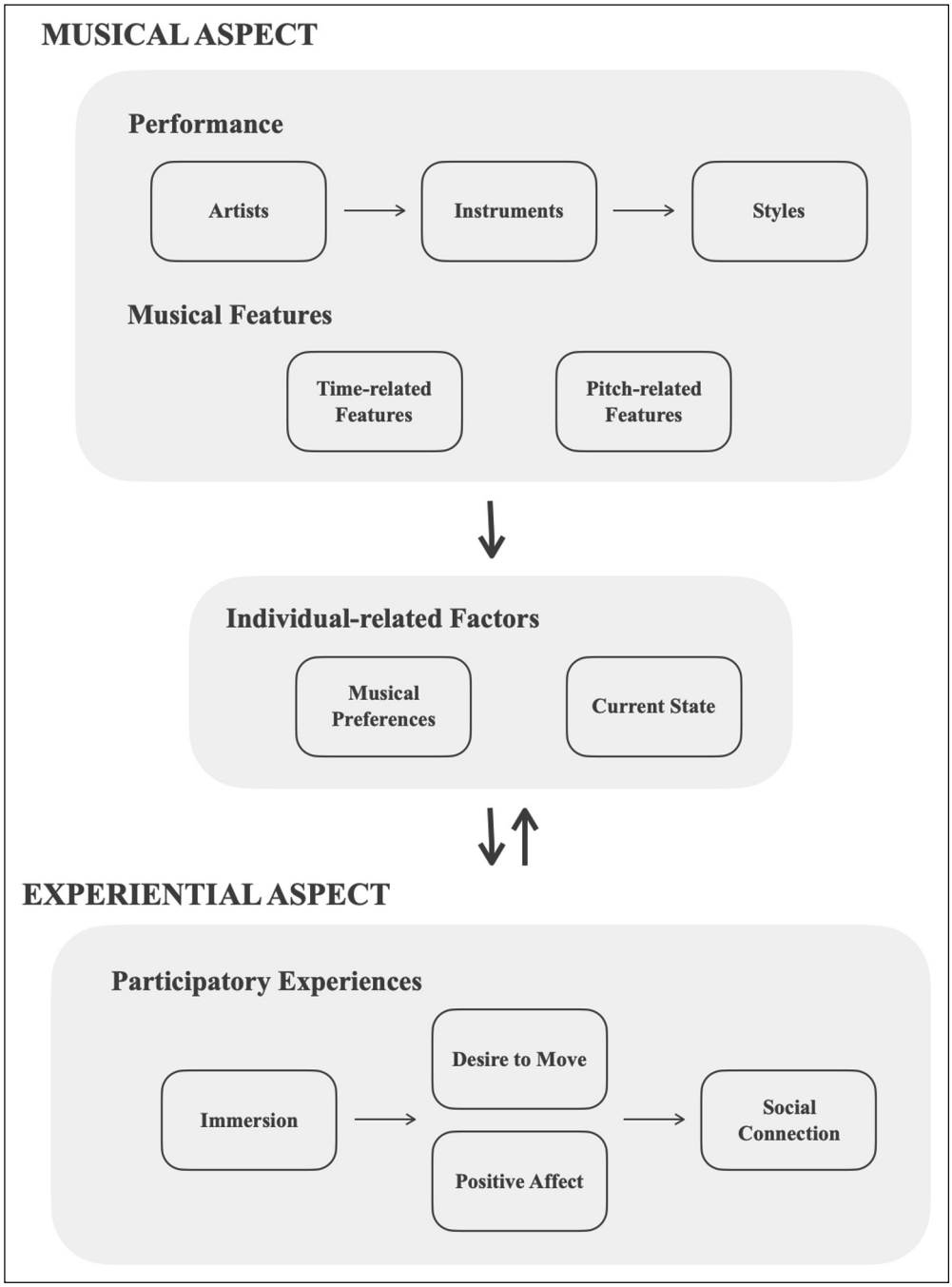

Figure 1. Summary of Main Findings, representing the relationship of the variables described by the participants. The musical aspect (performance and musical features) of groove facilitates its experiential qualities (participatory experiences) which are mediated by other individual-related factors.

surrounding its description may emerge because of its multifaceted and complex character. Groove is not a simple concept, but one that arises from various *interactions* between (a) the artists who are performing the music, (b) the musical elements that emerge during the performance, (c) its listeners and the artists, (d) the listeners as individuals, and (e) the listeners within a group. Thus, the elements creating the groove experience might not be easily formulated. Instead, elements that create groove are interwoven. In other words, it can be said that specific performance of music shapes people's personal groove experiences. Nevertheless, this model might not be complete; more research is needed in understanding how groove is produced and experienced.

A complementary definition of groove

Due to the evolving nature of groove over its history, definitions of groove remain ambiguous or confusing. Using categories derived from our thematic analysis, we hereby propose a more contemporary and complementary working definition of groove in the field of music psychology: "*Groove* is a participatory experience (related to immersion, movement, positive affect, and social connection) resulting from the subtle interaction of specific music- (such as time- and pitch-related features), performance-, and/or individual-related factors." Importantly, our findings led us to suggest a shift from movement- and positive affect-focused definitions and measurements of groove toward describing it as a participatory experience. This is an aspect of groove that participants frequently mentioned, for example, describing it as an urge to be "involved in" the music physically and/or psychologically. This is in line with Keil's (1987, 1995) participatory discrepancies and similar to what Levitin and colleagues (2018) describe by the "listener fills the missing beat" (p. 65) which can be interpreted as a contagious function of music. This might also extend the concept of groove as an invitation to "join", or, as Witek (2017) states, "filling in the gaps" (which is described in its original context as a sophisticated bodily reaction to syncopation), if not with instruments, with one's own body. In this way, groove induces participatory experiences in listeners in the form of an immersive state toward the music, a desire to move, an induction of positive affect, or a feeling of social connection. As described by Levitin and colleagues (2018), "when the music compels you to move along with it. This compulsion is the essence of groove" (p. 63). Overall, by defining groove as a "participatory experience" we highlight a compulsory or invitatory process (rather than a highly conscious act), which is also represented in the canonical definition with the word "urge." This notion of an automatic and unconscious process in which one embodies or becomes "one" with (or through) music (and thus with the group by which the listener is surrounded) requires further empirical testing.

Moreover, we suggest a similar distinction between musical and experiential aspects of groove (as referred to earlier in this paper) be explicitly used in the future research. Clearer reference to these distinct aspects of groove could enable a common language to be used in future research, leading to a more profound understanding of groove in the literature.

Limitations and future directions

When developing our definition of groove, our aim was to capture multiple facets of the term. However, it should be noted that our sample included many young students from Finland, and their groove descriptions might be naturally biased toward their own understanding of the term. The fact that our sample was skewed toward younger people also made it impossible to make comparisons between different age groups. Future research should consider comparing groove definitions among different age groups, as well as people from different expertise groups.

Other measures of individual difference that could be considered include personality, capacity for empathy, and daily music listening habits. Such research might reveal a more nuanced understanding of groove.

Moreover, since groove was reported to invite listeners to become "one with" or "participate in", such as by inducing the urge to move to the music, the experience of groove might also be considered as a dynamic state. This view is in alignment with the argument suggesting that groove cannot be experienced analytically, but via physical engagement with music (Roholt, 2014). In other words, there might be differences in experienced groove depending on whether the listener experiences the music only by passive listening or actively participates through movements and dance. We suggest that future research would investigate new perspectives (such as granularity or different kinds of groove experiences) and focus in more detail on such influences on the experience of groove.

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Supplemental material

Supplemental material for this article is available online.

Notes

1. Tiger Roholt (2014) starts his book *Groove a Phenomenon of Rhythmic Nuance* with such a figurative and transferred metaphor of driving a car on snow (p. 1):

   > As you change lanes you slide just a bit, then you feel your tires settle into grooves made by the tires of other cars. You have some sense of the firmness and path of these grooves—less by actually seeing them, more through your body. [. . .] In a musical groove, a musician, dancer, or an engaged listener has a similar feeling of being pulled-into a musical "notch," guided-onto a musical "track," buoyed by a rhythm, being lifted up and carried along. [. . .] Loosely speaking, a groove is the feel of a rhythm.

2. The term granularity here is used similarly to emotion literature which refers to "the ability to make fine-grained, nuanced distinctions between similar emotions" (Smidt & Suvak, 2015, p. 48).

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II

MUSIC WE MOVE TO: SPOTIFY AUDIO FEATURES AND REASONS FOR LISTENING

by

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Music we move to: Spotify audio features and reasons for listening

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Abstract

Previous literature has shown that music preferences (and thus preferred musical features) differ depending on the listening context and reasons for listening (RL). Yet, to our knowledge no research has investigated how features of music that people dance or move to relate to particular RL. Consequently, in two online surveys, participants (N = 173) were asked to name songs they move to ("dance music"). Additionally, participants (N = 105) from Survey 1 provided RL for their selected songs. To investigate relationships between the two, we first extracted audio features from dance music using the Spotify API and compared those features with a baseline dataset that is considered to represent music in general. Analyses revealed that, compared to the baseline, the dance music dataset had significantly higher levels of energy, danceability, valence, and loudness, and lower speechiness, instrumentalness and acousticness. Second, to identify potential subgroups of dance music, a cluster analysis was performed on its Spotify audio features. Results of this cluster analysis suggested five subgroups of dance music with varying combinations of Spotify audio features: "fast-lyrical", "sad-instrumental", "soft-acoustic", "sad-energy", and "happy-energy". Third, a factor analysis revealed three main RL categories: "achieving self-awareness", "regulation of arousal and mood", and "expression of social relatedness". Finally, we identified variations in people's RL ratings for each subgroup of dance music. This suggests that certain characteristics of dance music are more suitable for listeners' particular RL, which shape their music preferences. Importantly, the highest-rated RL items for dance music belonged to the "regulation of mood and arousal" category. This might be interpreted as the main function of dance music. We hope that future research will elaborate on connections between musical qualities of dance music and particular music listening functions.

Introduction

Throughout the lifespan, people interact with music for different reasons across a variety of listening situations [1]. Music can be used for entertainment, relaxation, improving mood, self-awareness, forming and maintaining relationships, feeling connected, diversion, and dancing, as well as to accompany daily human activities such as exercising, partying, commuting,

sleeping, and so on [2, 3]. Moreover, musical preferences and associated reasons for listening (RL) have been reported to differ depending on factors such as personality traits [4], listening habits [5], and age [3]. In a study of motivations for listening to music and contexts in which that listening took place, Boer & Fischer [6] proposed that listening to music serves six main functions: background listening, memories, diversion, emotional regulation, self-reflection and social bonding. A more recent study narrowed these down to three main functions: regulation of arousal and mood, achievement of self-awareness, and expression of social relatedness [2]. All of these functions can be interpreted as what music broadly offers listeners and in what possible ways people listen to music.

Music listening as an immersive, affective, movement-inducing and social experience

It is notable that, in some languages such as Sanskrit, Thai and Igbo of Nigeria, there is no clear terminological distinction between music and dance, being understood as aspects of the same "musical activity" [7]. Ancient musical activities were part of daily rituals (such as funeral ceremonies, hunting, or rain dancing) and are shown to have the functions of establishing and expressing social identity, evoking and regulating emotions, promoting social bonding, group cohesion, and prosocial behaviour. Music and dance are even argued to have originated together [8]. While pinpointing the birth of music and dance is challenging, it can certainly be said that music and dance share some common functions in daily life.

Music is a powerful driver of affect- and motion-related experiences. Music listening frequently creates feelings of pleasure, and induces spontaneous movements such as foot-tapping, swaying or head nodding [9]. The fact that even infants move to music rather automatically [10] demonstrates the interwovenness of dance and music. Moreover, in the absence of overt movements (e.g., during passive listening), particularly in rhythm and beat perception, it is not only auditory regions of the brain that are activated; motor [11–13], and reward [14] regions also fire. Thus, one might describe the perception of music as a pleasurable and movement-inducing state.

The popular musical term, *groove*, commonly understood as a pleasurable desire to move to music [15] has recently been more comprehensively described as a *multifaceted participatory experience* [16]. More specifically, Duman and colleagues [16] argue that an experience of groove is not only connected with movement and positive affect but also associated with sensations of immersion and social connectedness shaped by a delicate interaction of specific music- performance-, and individual difference-related variables. Previous groove literature reported several intra- and extra-musical variables relate to groove experience. One recent study has reported that there are "different types of groove" experiences depending on musicians' strategies [17] which give rise to certain musical features [18, 19] such as clear pulse and meter [20], low frequency range [19], tempo around 100–120 beats per minute (bpm) [21], medium levels of syncopation [9], and harmonic complexity [22] being associated with higher groove ratings (mainly based on the induced experiences of pleasure and desire to move). Experiences of flow [23] and social connection [24] have received some attention, too. Other work has demonstrated the role individual differences such as musical preferences and familiarity influence the experience of groove [25]. Additionally, although pop and funk musical styles in particular have been linked with high groove ratings, groove is also associated with other genres, including classical music [26].

While there is a growing amount of research investigating the concept of groove, to the best of the present authors' knowledge, no research has examined the influence of listener's current state, goals, or RL on the experience of groove. Thus, questions such as why and how people

move to music remain open to further exploration. Our focus in this paper was to better understand why people choose to listen to specific music for dancing as a function of both musical features and RL. Before describing the current study in detail, we summarise literature that has examined connections between musical features and RL.

Literature on Spotify audio features and reasons for listening

One focus of such research has been on retrieving musical information from songs on playlists designed with certain moods or listening situations in mind. Since we employed Spotify audio feature analysis in the current study, we focus here on previous research that has utilised a similar method. This approach has revealed that such playlists do indeed vary in terms of their Spotify audio features [27]. Using Spotify data, recent research demonstrated that people's musical preferences follow a certain pattern depending on the period of the day [28, 29]. In other words, Spotify audio features of music that people listen to fluctuate throughout the diurnal cycle. Musical preferences are characterized in the morning by high loudness, valence and energy, in the afternoon by an increase in tempo, beat strength and danceability, and during the night by the lowest values of loudness and tempo [28]. What's more, a moderately significant correlation between diversity of human activity during the day and variability in the average Spotify audio features has been identified [28]. This suggests that Spotify audio features of music people choose to listen to vary depending on the activity they engage with. For instance, one study investigated songs that are used for sleeping [30]. Such songs were found to be generally softer, slower and often instrumental compared to general music. However, results of a cluster analysis revealed six different subgroups of sleep music, including some with songs that are fast, loud, and energetic. This surprising finding was interpreted as a possible explanation for various motivations for listening to music. Other work has linked musical preferences with stress management and emotional coping strategies during the COVID-19 pandemic [31, 32] and with patients' pain management [33]. In particular, Spotify audio features such as high valence, energy, danceability, tempo and low instrumentalness were found to correlate with the music people choose associated with emotional coping mechanisms. These studies exemplify how certain Spotify audio features and reasons or functions of listening to music are associated.

The current study

Despite the growing amount of research that links musical features with certain listening contexts and reasons, no study appears to have investigated connections between qualities or features of music that people choose for dancing and RL. Thus, our aim was to investigate Spotify audio features of dance music, and whether these features are homogenous or reveal different types of such music as determined by different combinations of audio features. Note that "dance music" in this paper refers to music which people dance / move to, not any specific commonly-understood genre or style.

We hypothesised that a dance music dataset will exhibit higher levels of Spotify audio features such as danceability, energy, and valence compared to a baseline dataset. Additionally, in a similar vein to the work on sleep music by Scarratt et al. [30], we expected to identify several subgroups of dance music, especially in light of the different ways and styles in which people move to music. Moreover, we explored other reasons why people listen to music for dancing, in particular with the aim of differentiating dance-related listening reasons from more general reasons. Considering the various factors influencing people's musical preferences associated with RL, we expected to observe a variation in the music people dance to associated with their particular listening purpose. Finally, we explored whether Spotify audio features of dance

music can be linked with specific RL. We hypothesised that certain subgroups of dance music would be more suitable for specific RL. We thus sought answers to four principal research questions:

1. What are the general Spotify audio features of dance music?
2. Does all dance music have similar characteristics, or can we identify multiple subgroups of dance music, each with different combinations of Spotify audio features?
3. Can the music people choose to dance to be associated with other typical RL?
4. Can Spotify audio features of dance music be related to people's RL?

To answer these questions, we conducted two online surveys in which we asked participants to name songs that they "want to move to" and rate these songs in terms of their associated RL.

Method

Participants

Survey 1. One hundred and five participants (61 women, 41 men, 3 other) aged 16 to 54 ($M = 27.07$, $SD = 6.46$) completed the entire survey. Participants originated from 19 different countries, with the majority of them reporting to be Finnish ($N = 56$) or Turkish ($N = 23$) nationals.

Survey 2. Sixty-eight participants (39 women, 28 men, 1 other) aged 14 to 53 ($M = 29.34$, $SD = 7.88$) completed the survey. Participants originated from 21 different countries, with the majority of them reporting to be from the USA ($N = 14$), Turkey ($N = 9$) and Finland ($N = 9$).

Procedure and materials

Survey 1. Data were gathered as part of the online listening survey described in Duman et al. [16]. For the present study, participants rated their *general* music listening habits using a questionnaire containing 21 RL items. These items were gathered and adapted mainly from two papers: (1) by Schäfer and colleagues [2] which provides a comprehensive review of functions of music listening literature, and (2) by Randall & Rickard [34] which presents brief use of RL items in research utilising the experience sampling method. Responses were given on a 5-point likert scale (never—rarely—sometimes–often–very often). In addition, they were asked to "give an example song which 'makes you want to move'" and subsequently "select all the reasons why you listen to the song you provided above in your daily life" from the 21 RL items (as boolean: true/false). Hereafter, these ratings will be denoted as *RL general* and *RL dance*, respectively.

Survey 2. In a separate online survey, in order to increase the sample size for musical analysis of the provided songs, participants were asked to "give 3 different song examples which 'make you want to move'". Additionally, demographic information was collected, but no RL data were gathered. All participants declared that they had not taken part in *Survey 1*.

In both surveys, data were collected on webropol.com via personal social media accounts and University of Jyväskylä emailing lists. Participants were informed about the content of the survey, their rights as a participant, and were requested to provide their written consent to participate. Participation and data processing were anonymised. According to the University of Jyväskylä's guidelines, no further ethical approval was required as the study did not have a potential risk for participants.

Analysis

General characteristics of dance music

In order to determine common Spotify audio features of dance music, data representing music in general were gathered from 3.706.623 songs in the Music Streaming Sessions Dataset (MSSD) [35] to use as a baseline against which to compare the dance music dataset consisting of 278 unique songs named by participants. The dance music dataset is available under the Spotify playlist ID: 7hLTtnu2eJXuYTYhVxPe2m. Since several songs were named more than once, the repeating songs ($N = 13$) were included only once in this dataset. Additionally, as the Spotify API was used for analysis, songs that were not found on Spotify ($N = 12$) were also excluded. While the Spotify audio features can be found from MSSD dataset, to extract dance music dataset's Spotify audio features, we modified a Python script called "GeneralizedSpotifyAnalyser" provided by Ole Adrian Heggli [30]. Spotify audio features pertaining to energy, acousticness, danceability, valence, loudness, instrumentalness, speechiness, liveness and tempo were then gathered for both the baseline and dance music datasets. Note that, since Spotify does not provide extensive descriptions of how these features are calculated (as also discussed by Heggli and colleagues [30]), the exact meaning and calculation method of these features are debatable. Spotify does provide brief description of these features which can be found in S1 Text. Furthermore, while Spotify uses "audio features" as a general term, they are not purely audio properties of music. For instance, while loudness can be seen as an audio feature, danceability relates to the use of music. Spotify states the following categorization for these features: "mood" for danceability, valence, energy, and tempo; "properties" for loudness, speechiness, and instrumentalness; and "context" for liveness and acousticness as described in Features | Spotify for Developers [36]. To be consistent with their general terminology, in this paper we refer to those extracted features as "Spotify audio features".

A series of two sample t-tests were applied to each Spotify audio feature comparing baseline and dance music datasets. Due to unequal variance between samples, *Welch's* t-test method was adopted. The t-tests were later corrected for multiple comparison error with a conservative -*Bonferroni*- method ($\alpha = .01$). Additionally, effect sizes were calculated using *Cohen's d*. *Cohen's d* effects sizes are commonly interpreted in behavioural sciences as small ($d = 0.2$), medium ($d = 0.5$) and large ($d = 0.8$) [37]. Given its size, the baseline dataset was treated as a population of the dance music dataset and we applied one-way t-tests for comparison. The results of these one-way t-tests revealed similar findings compared with two sample's Welch's t-tests, thus we opted for only reporting the results of two sample t-tests.

Subgroups of dance music

In order to investigate homogeneity of dance music characteristics, we ran a *k-means clustering analysis* on the audio features of the 278 dance music songs. An *elbow analysis* was used to determine the number of clusters and showed optimal results for solutions with 4–6 clusters. For the clustering analysis, data were standardized and the maximum iteration parameter was set to 3000. Three separate k-means clustering analyses were run, one for each of the candidate optimum number of clusters ($k = 4–6$). The results were compared in terms of their distributions (the percentage of the data that each cluster had) and the interpretability of each cluster. The 5-cluster solution was deemed optimal and subsequently selected.

Reasons for listening

Comparing RL general and dance ratings. To investigate people's RL associated with dancing, our third analysis focused on participants' *RL general* and *dance* ratings. All

subsequent analyses were based on the data collected in Survey 1 concerning 100 dance songs as the RL data were collected only in Survey 1. Taking the scale difference between the two ratings into account, the data were first z-scored and then a comparison between *RL general* and *dance* was made by plotting the frequency distribution of the z-scored ratings. Additionally, to reveal differences between *RL general* and *dance* ratings further, ratings of RL items were rank ordered (from 1 to 21; 1 representing the highest, 21 the lowest ranks) and differences in ranks were calculated by subtracting *RL general* and *dance* ranks for each item.

Factor analyses. Next, in order to deepen our comparison of *RL general* and *dance*, we employed factor analyses to reduce dimensionality of the data using Python's "factor_analyzer" package with *method* set to 'principal' and *rotation* set to 'promax'. This was the preference as we expected the latent variables (factors) to be correlated with each other. The most meaningful number of principal components was determined visually through *Cattell's scree test* (1966) [38], and statistically through *Velicer's Minimum Average Partial test* (MAP) [39]. These tests are reported to be among the most reliable graphic and numeric based methods, respectively [39, 40].

Relating RL to subgroups of dance music

For the purpose of relating subgroups of dance music (determined by clusters of Spotify audio features) to participants' *RL dance* ratings, we plotted percentages of *RL dance* item ratings for each subgroup of dance music as a heatmap. The percentage calculation was made by dividing the actual *number of total selections* with *possible (maximum) number of total selections* (which is equal to all songs, $N = 100$).

Results

General characteristics of dance music

The t-tests on Spotify audio features of the *dance* and *general* music datasets revealed significant differences for all features except liveness and tempo. Medium effects (as measured with *Cohen's d*) were observed for energy, acousticness, danceability, valence, and loudness, and a low effect for speechiness (See Fig 1a–1i). Although the result of the t-tests yielded no statistical difference between the dance and baseline dataset in terms of liveness and tempo (Fig 1h and 1i), with visual inspection, one can suspect that there might be significant differences between the two datasets for tempo (Fig 1i). Therefore, *Kolmogorov—Smirnov (K-S) goodness of fit* tests were applied for each feature. K-S is a non-parametric test that focuses on the maximum difference between two distributions [41]. While result of the K-S test indicated no difference in distributions for liveness, all other features, including tempo, revealed significantly different distributions between dance and baseline datasets. All of the statistics can be found in Table 1. As hypothesized, compared with the baseline, the dance music dataset has higher levels of energy, danceability, valence, and loudness. Moreover, the dance music dataset is characterized by lower levels of acousticness, instrumentalness and speechiness. Importantly, despite both dance music and baseline datasets having average tempi around 120 bpm (Fig 1i), deviation from the average tends to be smaller for the dance music dataset, suggesting that music people dance to is more tightly clustered around 120 BPM.

To provide a general picture of the kinds of songs participants reported a desire to move to, we present 30 songs from the dance music dataset with the highest Spotify danceability scores in descending order in Table 2. The song *Macarena* by Los Del Rio has the highest Spotify danceability score in our dance music dataset. This song is known by many people for its song-specific dance routine, and is tagged as Tropical by Spotify. In contrast, the song with the second-highest danceability score, *Thunderstorm* by Boris Brejcha, is less well known, and is

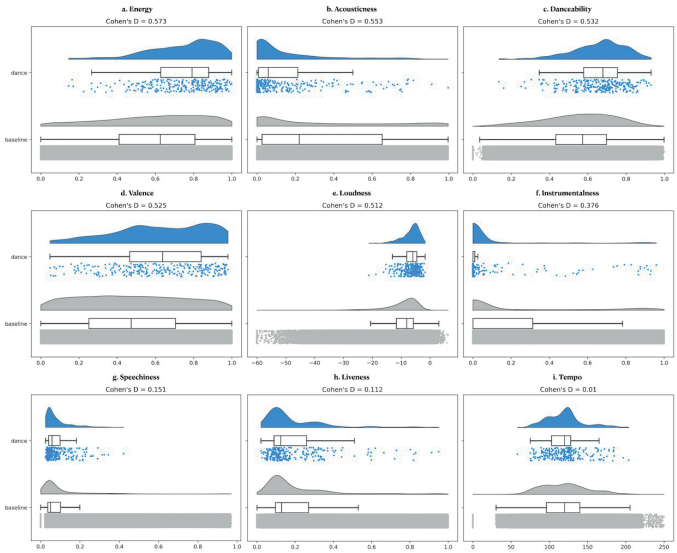

Fig 1. Spotify audio features comparing baseline (grey) and dance (blue) music datasets. Two sample's t-tests revealed significant differences for all features except for liveness (h) and tempo (i). Calculated with Cohen's *d*, medium effect sizes for energy (a), acousticness (b), danceability (c), valence (d), loudness (e), instrumentalness (f); small effect size for speechiness (g) were found. An additional K-S test revealed significant difference between dance and general datasets' tempo feature (i). To summarise, dance music can be differentiated from the music in general to be typically around 120 bpm, with higher energy, danceability, valence, loudness, and lower acousticness, instrumentalness, and speechiness Spotify audio features.

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tagged as German house / techno by Spotify. The list also includes several classic tracks produced in the 1970s and 1980s associated with disco, R&B, funk, and motown (e.g., *Funkytown* by Lipps Inc., *People Get Up and Drive Your Funky Soul* by James Brown, and *Get Down On It* by Kool & The Gang) as well as newer tracks produced after the turn of the millennium associated with genres like dance pop, electronic, and R&B (e.g., *Treasure* by Bruno Mars, *Lose Yourself to Dance* by Daft Punk & Pharrell Williams, and *Shape of You* by Ed Sheeren). Moreover,

Table 1. Results of the two samples' Welch's t-tests, Cohen's *d* and Kolmogorov-Smirnov tests between the dance and baseline music datasets.

Spotify Audio Features	Dance Music Dataset (N = 278)		Baseline Dataset (N = 3.706.623)		Welch's t-test		Cohen's *d*	Kolmogorov-Smirnov test	
	Mean	Standard Deviation	Mean	Standard Deviation	*t*—value	*p*—value	*d*—value	Statistics	*p*—value
Danceability	.66	.14	.56	.19	$t(277) = 11.61$	< .001	0.53	.26	< .001
Energy	.74	.18	.59	.26	$t(277) = 13.92$	< .001	0.57	.26	< .001
Loudness	-6.7	3.07	-9.6	5.73	$t(277) = 15.95$	< .001	0.51	.28	< .001
Speechiness	.08	.07	.11	.14	$t(277) = -5.37$	< .001	0.15	.11	< .01
Acousticness	.16	.21	.35	.34	$t(277) = -14.83$	< .001	0.55	.27	< .001
Instrumentalness	.08	.21	.21	.35	$t(277) = -10.24$	< .001	0.38	.28	< .001
Liveness	.19	.17	.21	.19	$t(277) = -2.18$	= .30	0.11	.07	= .14
Valence	.62	.24	.48	.27	$t(277) = 9.87$	< .001	0.53	.25	< .001
Tempo	119.78	24.25	120.07	30.43	$t(277) = -0.20$	= 1	0.01	.14	< .001

Please note that *p*—values are corrected using the *Bonferroni* method.

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Table 2. 30 songs from the dance music dataset with the highest Spotify danceability scores.

	Song Name	Artist Name	Genre
1	Macarena	Los Del Rio	tropical
2	Thunderstorm	Boris Brejcha	german house, german techno
3	Funkytown	Lipps Inc.	disco, minneapolis sound
4	A Message to You Rudy	The Specials, Rico	punk, ska
5	Lose Control	Missy Elliott, Ciara, Fatman, Scoop	dance pop, hip hop
6	Swagga	Cali Flow Latino	salsa choke
7	Mango Drive	Rhythm & Sound	electro jazz
8	Dont Stop Til You Get Enough	Michael Jackson	pop, r&b
9	Treasure	Bruno Mars	dance pop, pop
10	Tieduprightnow	Parcels	aussietronica, indie soul
11	ZEZE	Kodak Black, Offset, Travis Scott	florida rap, hip hop
12	Make Me Feel	Janelle Monae	afrofuturism, alternative r&b
13	yours truly.	Super Whatevr	alternative emo, anthem emo,
14	Uptown Funk	Mark Ronson, Bruno Mars	dance pop, neo soul
15	You Rock My World	Michael Jackson	pop, r&b
16	People Get Up And Drive Your Funky Soul	James Brown	funk, motown
17	Get Down On It	Kool & The Gang	disco, funk
18	Jump (For My Love)	The Pointer Sisters	dance pop, disco
19	Kill The Lights	Alex Newell, DJ Cassidy, Vinyl on HBO, Nile Rodgers	indie poptimism
20	Always On Time	Ja Rule, Ashanti	dance pop, east coast hip hop
21	Dang!	Mac Miller, Anderson.Paak	hip hop, pittsburgh rap
22	Faded	Cool Company	alternative r&b, indie r&b
23	Lose Yourself to Dance	Daft Punk, Pharrell Williams	electro, filter house
24	Hasta el Amanecer	Nicky Jam	latin, latin hip hop
25	Shape of You	Ed Sheeran	pop, uk pop
26	Freestyler	Bomfunk MC's	bubblegum dance, eurodance
27	Hot Stuff	Donna Summer	dance pop, disco
28	Magalenha	Sergio Mendes	bossa nova, brazilian jazz
29	24K Magic	Bruno Mars	dance pop, pop
30	Turn Down for What	Dj Snake, Lil Jon	dance pop, edm

List of 30 songs named by 30 participants that they want to move to which is ordered according to the highest Spotify danceability scores from the dance music dataset in descending order. Only the first two genre tags extracted from Spotify are presented in this table.

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the list is not limited to popular songs and typical genres; it also includes salsa, Latin and Brazilian jazz styles, as well as culture-specific songs. All in all, this variety led to the next analysis for which we sought possible types of dance music.

Subgroups of dance music

To determine whether or not all dance music had similar Spotify audio features, we performed a k-means clustering analysis. The results revealed 5 different subgroups of participants' dance songs depending on their Spotify audio features. See Fig 2 for a visual representation of this analysis.

Cluster 1 (C1) consisted of 101 songs characterised by elevated levels of valence, danceability, loudness, and popularity. Songs in this cluster came from a range of genres, in particular pop, rock, dance, hip-hop, rap, soul, funk, and indie (e.g., *Thriller* by Michael Jackson, *Lose*

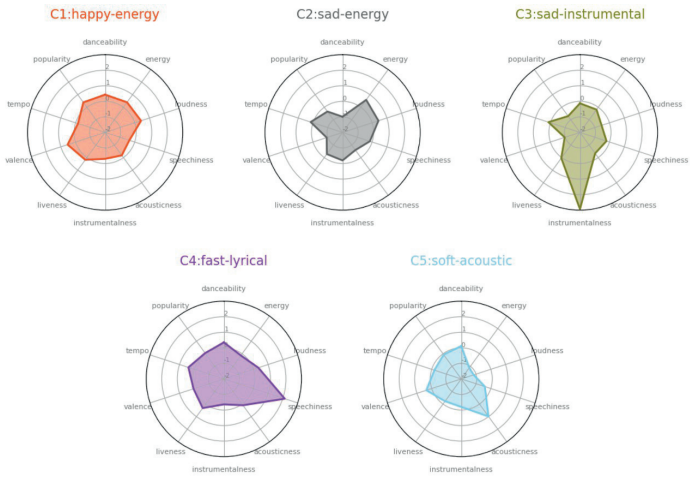

Fig 2. Subgroups of dance music. Five clusters of dance songs ($N = 278$) are illustrated with individual Spotify audio feature variation. Clusters were named as "happy-energy" ($N = 101$), "sad-energy" ($N = 60$), "sad-instrumental" ($N = 23$), "fast lyrical" ($N = 35$) and "soft-acoustic" ($N = 59$) according to their most distinctive audio features. Please note that all of the features are standardised.

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Yourself to Dance by Daft Punk and Pharrell Williams, *Smooth* by Santana and Rob Thomas). *Cluster 2* (C2) consisted of 60 songs characterised by lower levels of danceability, valence, and acousticness, and higher levels of energy and loudness. In this cluster, pop, rock, dance, metal, and house were the most frequent genres (e.g., *Titanium* by Sia and David Guetta, *Under Control* by Calvin Harris, Alesso and Hurts, *Laid to Rest* by Lamb of God, *Sad But True* by Metallica). *Cluster 3* (C3) consisted of 23 songs characterised by higher levels of instrumentalness, and lower levels of valence, popularity, and loudness. House, trance, and pop genres dominated in this cluster (e.g., *Insomnia* by Faithless, *Bravo* by Factor B, *You are My High* by Demon). *Cluster 4* (C4) consisted of 35 songs characterised by higher levels of speechiness and tempo. The most common genres here were pop, rock, and hip-hop (e.g., *I* by Kendrick Lamar, *00:00 (Zero O'Clock)* by BTS, *Don't Stop Me Now* by Queen). *Cluster 5* (C5) consisted of 59 songs with higher levels of acousticness, and lower values of loudness and energy. Pop, jazz, and soul were the most frequent genres in this cluster (e.g., *I Wish I Knew How It Would Feel to Be Free* by Nina Simone, *Sway* by Dean Martin, *Blue Skies* by Doris Day).

As observed, while pop was the reoccurring genre in all of the subgroups of dance music, musical characteristics and genre differed across all 5 clusters. We opted to name the clusters based on their musical characteristics. C1 was named "happy-energy" after its audio features of high valence and energy. C2 and C3 contrasted with C1 in terms of their valence scores. C2 was subsequently named "sad-energy" due to low valence and high energy songs, and C3 was named "sad-instrumental" since it was characterized by high instrumentalness and low valence. C4 contained songs with high speechiness and tempo values, and was thus named "fast-lyrical". Finally, C5 included songs characterised by high acousticness, and low energy and loudness, and was named "soft-acoustic".

Reasons for listening

Comparing RL general and dance ratings. In order to compare *RL general* and *dance*, we z-scored the RL *dance* and *general* ratings and plotted them in the same figure in descending

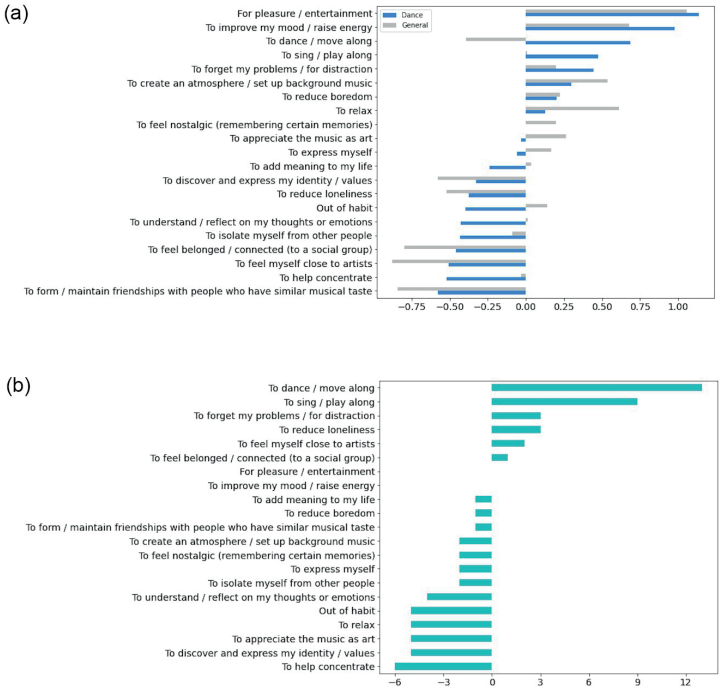

Fig 3. Z-scored distributions of ratings for *RL dance* and *general*. (a) Z-scored frequency distributions of ratings for *RL dance* (blue) and *general* (grey) are plotted. (b) Z-scored rank difference distribution for *RL dance* and *general* ratings. Rank scores of *RL general* items were subtracted from *RL dance* items.

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order of RL *dance* ratings (see Fig 3a). It can be seen that, for both dance music and music listening in general, the highest-rated RL were "For pleasure / entertainment" and "To improve my mood / raise energy." For *RL dance*, the lowest-rated RL were "To form / maintain friendships with people who have similar musical taste" and "To help concentrate"; for *RL general*, the lowest-rated RL was "To feel myself close to artists". Moreover, whilst the smallest overall difference between *RL dance* and *general* ratings was for "To reduce boredom", the largest difference was for "To dance / move along". In other words, people tend to give higher ratings to this item in *RL dance* compared with *RL general*. "To sing / play along" and "To forget my problems" received the next high ratings in *RL dance*. The item "To relax" tended to be rated much higher in *RL* general, indicating greater relevancy for music listening in general compared with a dance related context. Moreover, to illustrate differences between *RL dance* and *general* ratings, the change in rank-ordered RL items from dance to general are plotted in Fig 3b. This figure complements Fig 3a and highlights the following three results. First, it can be seen that the biggest difference in rank order relates to "To dance / move along", followed by "To sing / play along". Second, the items "For pleasure / entertainment" and "To improve my mood / raise energy" seem to be equally relevant for both *RL dance* and *general* since there is no change in their rank order for both ratings. Third, the item "To help concentrate" tends to be associated with *RL general* more than *RL dance* since it was ranked 6 places higher in *RL general*.

Factor analyses. Next, two separate factor analyses were performed in order to extend the comparison for *RL general* and *dance* ratings. Initially, the results of the two Cattell scree tests

Table 3. Factor analysis for the *RL general* ratings.

Reasons for Listening to Music	F1	F2	F3
	Achievement of Self-Awareness	Regulation of Arousal and Mood	Expression of Social Relatedness
To express myself	**.85**	-.13	-.06
To understand / reflect on my thoughts or emotions	**.78**	.10	-.41
To discover and express my identity / values	**.69**	-.22	.25
To add meaning to my life	**.67**	.23	-.06
To appreciate the music as art	**.66**	-.11	.05
Out of habit	**.55**	.14	-.00
To feel nostalgic (remembering certain memories)	**.47**	-.00	.13
To isolate myself from other people	.27	.19	.16
To improve my mood / raise energy	-.07	**.80**	-.05
To create an atmosphere / set up background music	-.13	**.76**	-.00
To reduce boredom	-.11	**.75**	.06
To relax	.21	**.64**	-.05
To forget my problems / for distraction	-.09	**.63**	.19
To help concentrate	.02	**.51**	-.00
For pleasure / entertainment	.30	**.47**	-.08
To reduce loneliness	.25	**.41**	.07
To form / maintain friendships with people who have similar musical taste	-.08	.14	**.84**
To feel belonged / connected (to a social group)	-.13	.12	**.79**
To sing / play along	.18	-.27	**.58**
To dance / move along	-.12	.14	**.57**
To feel myself close to artists	.35	-.06	**.53**

Factor analysis revealed three main functions for the *RL general* ratings. Items with high loadings (> .40) are shown as bold.

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[38] revealed the optimum number of factors to be 3 for the *RL general* ratings and 1 for the *RL dance* ratings. Subsequently, the optimum factor numbers were applied in each factor analysis. Table 3 shows the three factor loadings for *RL general*. While the items related to self-awareness and expression such as "To express myself" and "To understand / reflect on my thoughts or emotions" loaded highly on the Factor 1, for the Factor 2 items related to mood and arousal such as "To improve my mood / raise energy" and "To reduce boredom" have high loadings. The Factor 3, on the other hand, is associated with social-related items such as "To form / maintain friendships with people who have similar musical taste" and "To feel belonged / connected (to a social group)", as well as the items "To sing / play along" and "To dance / move along". Although one can sing and dance along with the music without anybody being around, such activities are often performed in groups, and the evolution and functions of human dance are frequently discussed as being rather social in nature [42]. Thus, the placement of these items among other social-related items are not surprising. Moreover, the factors explained a total of 47% of the cumulative variance with individual proportions of 18%, 17%, and 13% for the subsequent factors. It's clear that these are in line with the categorization by Schäfer and colleagues [2]. Thus, we named the emerging factors as *Achievement of self-awareness*, *Regulation of Arousal and Mood*, and *Expression of Social Relatedness*. Since the optimal number factor solution for *RL dance* ratings was 1, the *RL dance* ratings (not factor scores) were used as individual items for the next analysis.

Relating RL to subgroups of dance music

The final research question concerned relationships between musical characteristics of dance music and people's RL. Fig 4 shows the distribution of participants' ratings of individual RL items associated with their subgroups of dance music. As predicted, there are variations in the music that people dance to (subgroups of dance music) associated with their particular listening purpose. This suggests that specific subgroups of dance music might be more suitable for specific RL. In the discussion section this figure is interpreted in detail.

Discussion

We investigated the relationships between Spotify audio features of dance music with associated reasons why people listen to these songs. Specific research questions concerned (1) general audio characteristics of dance music, (2) possible audio feature-based subgroups of dance music, (3) particular RL to dance music and (4) relationships between subgroups of dance music and dance-related RL. In what follows, we discuss our findings.

General characteristics of dance music

As regards audio characteristics of dance music, the results appear logical: Songs that are typically around 120 bpm, loud, energetic, positively valenced, and score highly on Spotify's own danceability metric are likely more inviting for listeners to engage with via their body.

While both of the datasets are centred around tempi close to 120 bpm, the baseline dataset's distribution is rather flat, revealing a wide range of tempi. In contrast, the dance sample has a higher peak around the centre. Interestingly, the shape of the tempo distribution for dance music appears very similar to an earlier study by Moelants [43]. Previous research showed that 120 bpm is not only described as the most efficient locomotion frequency [44] but also mentioned as key to human motion [45]. One other study on music preferences (based on tempo) reported that while engaged in physical exercise, people tend to pick higher tempo ranges compared with slower (95–100 bpm) [46]. In a similar vein, most of the dance songs were reported to particularly be around 120 bpm [47] which is in alignment with the typical speed of human motion, 2 Hz per second [48]. These findings would explain why tempo distribution of dance music (shown in Fig 1i) centred more strictly around 120 bpm with lower variation

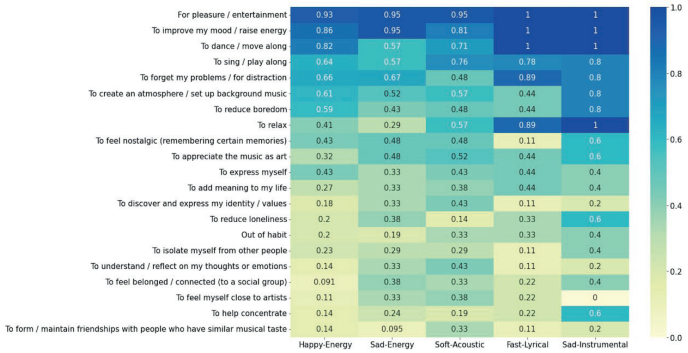

Fig 4. The distribution of participants' ratings of individual RL items associated with their subgroups of dance music. To relate subgroups of dance music with RL, ratings of the individual *RL dance* items were plotted as percentages for each of the 5 subgroup of dance music ($N = 100$) as a heatmap.

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compared with the baseline dataset. Thus, considering various ways and contexts that music is listened to in general, a higher variation in tempo is expected for music in general.

Subgroups of dance music

The clustering analysis identified five distinct audio feature-based subgroups of dance music. Songs from these subgroups might be preferred depending on several variables, including as contextual and psychological. Specific examples follow. The "happy-energy" subgroup might be in general associated with popular or mainstream music played, for instance, on TV, radio, and in shopping centres, i.e., music familiar to many people. In contrast with this first subgroup, especially along the valence dimension, the second, "sad-energy" subgroup includes the rock and metal songs. Consisting of sixty tracks, this subgroup was the second largest in our dance music dataset. At first glance, the association of metal and rock music with dance might appear surprising. The demographics and musical preferences of our participants, however, may help explain this relationship. This is because the majority of our data was provided by Finnish participants, and Finland has one of the highest prevalence of metal bands in the world [49]. Thus, this finding might be reflecting musical preferences of many individuals in our sample. With only twenty-three house and trance like songs, the third "sad-instrumental" subgroup includes the least number of songs. Since these tracks have low popularity values too, sad-instrumental dance songs might be preferred less frequently than the other types of dance music. The last two subgroups, "fast-lyrical" and "soft-acoustic", also contrast in terms of their Spotify audio features. An example song from the fast-lyrical subgroup is *Don't Stop Me Now* by the Queen. Listeners might prefer such songs firstly to get energised or match their energy level with the song. The high levels of speechiness or lyrical content of the piece might also allow listeners to express themselves and their emotions. These functions might further engage listeners on a bodily level. Soft-acoustic songs, on the other hand, might serve a slightly different function, and afford different types of engagement. Taking Nina Simone's *I Wish I Knew How It Would Feel to Be* as an example, one might prefer to listen to this song to feel relaxed, sway along with the song slowly, or dance with a partner possibly romantically as well. Nevertheless, the scope of the current study does not allow us to understand in detail how and why these subgroups are preferred in people's lives. Yet, listening preferences for specific dance music might vary depending on several factors. Because of this, further research considering context-dependent variables and accounting for individual differences is encouraged.

Previous research has also demonstrated that there are different types of dance music according to a musical analysis [43]. In particular, focusing on genre classification of dance music depending on tempo distribution, Moelants [43] reported five distinct subgroups: (1) "Trance" (as an "uplifting" type of dance music with an average tempo of 141), (2) "Afro-American" (concentrated on hip-hop, R&B and soul, peaking around 95 bpm), (3) "Fast" (consists of old-style rock & roll and hardcore techno, peaking around 150 bpm), (4) "House" (described as the origin of all modern electronic dance music, peaking around 125–130 bpm), and (5) "General" (consists of different substyles, with style specific variations). Overall, there seem to be typical genre and audio feature combinations for each subgroup of dance music. Moreover, it can be said that individuals' musical preferences and familiarity with music are among the determinants of the music that people move to. This would explain the diversity of songs presented in Table 2. Previous research is aligned with this interpretation too, since taste and familiarity have been found to influence people's experience of groove [25]. Thus, it can be said that not only musical features (such as tempo variation) but also interpersonal differences play a role in music being movement-inducing. Therefore, it can be challenging (if not impossible) to nominate "songs that everybody moves to" or "the grooviest song" of all time.

Reasons for listening

To compare general and dance related RL, we initially plotted participants' RL for dance and general ratings (see Fig 3). While the distributions were described in detail earlier, the overall picture demonstrates that people tend to listen to music associated with dance for pleasure and entertainment, to improve their mood and raise energy, to dance / move and sing / play along, as well as to distract themselves and forget their problems. Moreover, in order to deepen the comparison of *RL dance* and *general*, we further conducted two factor analyses. While the three-factor solution for general music listening echoes previous literature [2], reflecting general functions associated with music listening, the emergent one-factor solution for *RL dance* should be approached with caution. This solution might be interpreted either as there being only one main function of listening to music associated with dancing, or it could be due to the way the question was presented as it left no room for other functions to be revealed with the current method. In other words, because of time constraints and methodological choices, we were unable to investigate possible contextual variation of music preferences associated with movements. Thus, participants rated these dance-related listening reasons according to the only song they exemplified that they move to. A more detailed study design could inform about the possible other functions for listening to music associated with dance music. This suggestion is discussed further under limitations and future directions.

Relating RL to subgroups of dance music

Results of the factor analysis (regarding *RL general*) could be used further while interpreting the relationship between the subgroups of dance music with *RL dance* ratings. Fig 4 shows a heatmap plotted for each *RL dance* item separated for each subgroup of dance music. Notably, the most highly-rated *RL dance* items (including "For pleasure / entertainment", "To improve my mood / raise energy", "To forget my problems / for distraction", "To create an atmosphere / set up background music" and "To reduce boredom") have high loadings for "regulation of mood and arousal" and "expression of social relatedness" factors of *RL general* ratings (as shown in Table 3). Notably, this might signal that the primary function of music listening associated with dance is to regulate one's emotions and arousal level as well as to express social relatedness. However, this interpretation requires further exploration as not all items (such as "to feel belonged / connected to a social group) from the expression of social relatedness factor were rated highly, as seen in Fig 4.

More detailed consideration of specific subgroups of dance music with particular *RL dance* items yields at least five points worth noting. First, the items "For pleasure / entertainment" and "To improve my mood / raise energy" were mentioned for almost all dance music tracks, and might thus be interpreted as the common RL associated with dancing to music. These can be compared to items such as "To help concentrate" and "To form / maintain friendships with people who have similar musical taste", which might be interpreted as being the least common RL when dancing to music. Second, the item "To dance / move along" received lower ratings for the dance music subgroup "sad-energy". Participants' lower rating of this item makes sense considering the low danceability values of songs in this subgroup. Additionally, the item "To relax" also received lower ratings for this subgroup. With characteristics of high energy and loudness, it seems logical that songs in the "sad-energy" subgroup are not used for relaxation purposes. Third, compared to other subgroups, the item "To feel nostalgic" received lower ratings in the subgroup "fast-lyrical", which is characterised by high tempo and speechiness. It might be interpreted that songs in this subgroup are not really used to evoke nostalgia. Fourth, compared with other clusters, the "happy-energy" subgroup has the highest number of songs, many of them in the pop genre, and they are characterised by audio features such as high

danceability and valence. Considering that many songs for dancing are energising and mood-improving, a greater number of participants' dance songs accumulating in this category would be expected. Finally, due to there being only 5 songs in the "sad-instrumental" subgroup, we refrain from drawing meaningful conclusions. Further research is clearly needed.

Limitations and future directions

As mentioned above, the main limitation of the research presented in this paper relates to the study design and data collection method. Since data were collected as part of an extensive survey, details about particular situations of the listener and listening experience were not obtained. Future experimental designs which consider current mood, energy level, personal habits, goals, specific situations (such as listening alone or in a group setting, in a club or house party, or while commuting) could shed further light on the occasions when and how often people listen to particular subgroups of music. In particular, we suggest that subsequent work employs an experience sampling method [34, 50]. We believe this would be a reliable and sensitive method for measuring variables that could influence dance-related RL. We might predict that, depending on the variables related to listener, music, and situation, RL associated with dancing would vary. For instance, while listening to a song in a club with your friends could be more related to expression of social connection, listening to the same song the next day while commuting could be associated with nostalgia and self-awareness. Thus, these functions might appear not fixed, but context-dependent.

A second limitation relates to sample size. While previous research on different types of sleep music [30] collected data solely from Spotify, which thus allowed investigation of a substantial sample, the goal in the current study of investigating particular reasons associated with songs that people move to required a questionnaire method which limited the data for dance music to the number of respondents. Especially when *RL dance* ratings were divided according to the subgroups of dance music, the size of some of the subgroups did not allow for further interpretation. Hence, we hope that future research will pay attention to connecting different RL for different dance music types with a bigger sample. Similarly, targeting a larger sample of individuals would enrich our understanding of culture-specific preferences for dance music (as exemplified earlier by Finns' preferences for rock and metal music) and thus could present a more elaborate representation of music that people use for dancing.

In summary, the research presented in this paper described audio features and reasons for listening associated with songs that people move to. We reported that loud, energetic songs with positive valence, high danceability and a tempo close to 120 bpm primarily work to regulate mood and arousal through bodily movement. At the same time, some variation in Spotify audio features and associated RL was apparent. In addition to more research connecting audio features of dance music with RL, other noteworthy issues concern the extra- and intra-musical prerequisites of certain songs that induce movements, as well as how music-induced movements vary depending on these extra- and intra-musical variations. In other words, what specific features are necessary to make music danceable and how do people's psycho-physical experiences differ depending on those variables? The relationship between music and movement, particularly the idea of "different types of groove experiences" [17] thus remains open for further discoveries.

Supporting information

S1 Text. Description of Spotify audio features.
(DOCX)

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III

CORRELATIONS BETWEEN PERSONALITY TRAITS AND EXPERIENCE OF GROOVE

by

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Correlations Between Personality Traits and Experience of Groove

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Abstract

Groove, the popular musical term, is described as a multifacted, complex experience associated with immersion, desire to move, positive affect, and social connection. While previous groove literature has demonstrated the influence of several intra- and extra-musical features on the experience of groove, there remains a gap in our understanding of how listeners' personality traits influence their groove experiences. To fill this gap, we investigated the role of personality traits on the experience of groove. Participants (N=105) took part in an online listening survey in which they responded to the Ten Item Personality Inventory (TIPI), and, in a listening task, rated a series of groove-related items for 30 musical excerpts (which varied in their level of groove). Results of correlational analyses demonstrated that Extraversion and Conscientiousness were positively correlated with selected groove-related variables. These findings contribute to the development of a psychological model of groove, demonstrating that personality plays a role in one's experience of groove.

Introduction

Groove is described as a multifaceted phenomenon resulting from a delicate interaction of music-, performance-, and individual-related variables, described with experiences of immersion, desire to move, positive affect, and social connection (Duman et al., 2021). Demonstrating its complexity, Senn and colleagues (2019; 2022) proposed a psychological model of the groove experience in which various factors such as musical features, listening situation, entrained body movements, as well as personal background contribute to listeners' groove experiences. In fact, over the past ten years, researchers have identified several factors related with the experience of groove, such as specific audio features (Stupacher, Hove, & Janata, 2016), rhythmic and harmonic complexity (Witek et al., 2014, 2017; Matthews et al., 2019) familiarity with the music (Senn et al., 2018), musical preferences (Senn, Rose, et al., 2019) and musicianship (Senn, Bechtold et al., 2019; Witek et al., 2017).

Despite research on various factors associated with the experience of groove, our understanding of the role played by personality remains limited. One previous study (Senn et al., 2016) reported null results concerning the relationship between self-reported groove ratings and personality traits (measured with NEO Five Factor Inventory: McCrae & Costa, 1987). However, several studies have shown that personality traits of listeners are a key factor in phenomena associated with groove, including music-induced emotions (Vuoskoski & Eerola, 2011a; Luck et al., 2014) and music-induced movements (Burger, 2013; Mendoza Garay, Burger, & Luck, 2022). In particular, Vuoskoski and Eerola (2011a) reported that perceived sadness in music was positively correlated with Neuroticism, while other traits (except Conscientiousness) had negative correlations. In another study, the same authors (2011b) reported positive correlations between Extraversion and induced happiness, sadness and tenderness. In a motion capture study, Burger, Polet and colleagues (2013) asked participants to move to music spontaneously and reported Extraversion as a moderator between low-frequency spectral flux and head movements. Similarly, Luck and colleagues (2010) reported Extraversion and Neuroticism to be particularly strongly associated with different patterns of movement. Additionally, Carlson and colleagues (2016) reported that people who score high in Conscientiousness are more likely to follow tempo changes in music compared with people who score high in Extraversion. Furthermore, Agreeableness has been identified as a predictor of speed of entrainment to music (Wakabayashi et al., 2006).

Aims & Hypothesis

The aim of the current study was to explore relationships between the Big Five personality traits and listeners' groove experiences, including their interaction with other groove-related variables such as liking and familiarity. In line with previous literature (such as Luck et al., 2010), we hypothesised that groove-related variables would correlate positively with Extraversion and negatively with Neuroticism.

Method

Participants

One hundred and five participants (61 women, 41 men, 3 other) aged 16 to 54 (M = 27.07, SD = 6.46) took part in a detailed online listening study, part of which included the data collected and reported here.

Procedure and Materials

The online survey investigated various factors influencing people's groove experiences. After being informed about the content of the survey and their rights, participants gave their consent to participate. Subsequently, participants (1) provided demographic information (which included an inquiry related to *how easy they find it to dance to music in general* – referred to as "dance ease"), (2) completed a set of questionnaires including the Ten Item Personality Inventory (TIPI: Gosling, Rentfrow, & Swann Jr, 2003) and (3) performed a brief online listening task. For further details about the survey, please see Duman et al., 2021 and Duman et al., 2022.

Listening Task. In the listening task, participants were presented with 30 musical excerpts (shown in *Table 1*) from various genres of commercial music with tempi around 120 -/+ 20 bpm. For each excerpt, participants were asked to rate 6 groove-related items – *wanting to move, liking, familiarity,*

desire to sing along, experience of nostalgia, and *perceived beat clarity* – on a series of 5-point likert scales.

Analysis

Data were analysed in Python. First, in order to understand the relationship of the groove-related items, a correlation matrix was calculated. Second, to investigate the relationship between groove-related items and personality traits, several *Pearson's* correlations were calculated between groove-related ratings and each of the five personality traits.

Results and Discussion

The correlation matrix of groove-related variables is shown in *Figure 1*. High correlations were observed between groove-related items. The highest correlations are between the items wanting to move and wanting to sing along (r (103) = .77, $p < .001$), wanting to move along and liking (r (103) = .69, $p < .001$) and liking and familiarity (r (103) = .63, $p < .001$). These correlations are in line with previous literature findings (Madison et al., 2011; Janata et al., 2012; Senn et al., 2018). Moreover, contributing to the literature, we demonstrated the relationship between the experience of nostalgia with other groove-related variables such as familiarity (r (103) = .58, $p < .001$), liking (r (103) = .33, p = .001) and wanting to move along (r (103) = .31, p = .002).

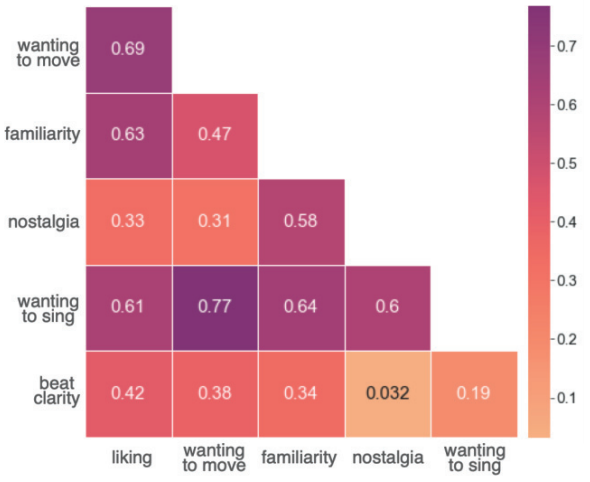

Figure 1. Correlation matrix of groove-related variables.

The stimuli used in the current study, along with their wanting to move ratings, are shown in *Table 1*. Because most of the groove-related items correlate with each other, for simplicity only the wanting to move ratings are displayed. As can be observed, the highest-rated stimuli represent a range of genres. This supports the argument that the experience of groove is personal and in parallel with the listener's musical taste and familiarity (Senn, Bechtold, et al., 2019).

Table 1. Stimuli with wanting to move ratings (descending order)

Order	Artist	Song	Wanting to Move Rating
1	Queen	We Will Rock You	4,29
2	Bruno Mars	Uptown Funk	4,11
3	Daft Punk	Get Lucky	4,05
4	Earth, Wind & Fire	September	4,03
5	LaBelle	Lady Marmalade	3,79
6	KISS	I was Made for Loving You	3,71
7	Frank Sinatra	Fly Me to the Moon	3,70
8	War	Galaxy	3,69
9	Santana	Smooth	3,66
10	The Fratellis	Chelsea Dagger	3,59
11	DNCE	Cake by the Ocean	3,56
12	Bob Marley	Is This Love	3,52
13	Buena Vista Social Club	El Cuarto de Tula	3,51
14	Justin Timberlake	Can't Stop the Feeling	3,45
15	Avicii	Waiting for Love	3,44
16	Florence the Machine + Calvin Harris	Say My Name	3,44
17	Lyn Collins	Think About It	3,37
18	Vulfpeck	Dean Town	3,30
19	Imagine Dragons	Believer	3,29
20	Incredible Bongo Band	Bongo Rock	3,25
21	Parliament	Flashlight	3,19
22	Bruno Mars	Liquor Store Blues	3,10
23	Iron Maiden	Run to the Hills	3,05
24	Gotye	Somebody that I used to	3,00
25	Beyonce	Halo	2,99
26	Stevie Wonder	I Just Called to Say I Love	2,96
27	Lorde	Perfect Places	2,57
28	Kaleida	Think	2,57
29	Gwen Stefani	Cool	2,49
30	No Doubt	Simple Kind of Life	2,38

In terms of the correlation analyses between personality scores from the TIPI and each of the groove-related variables, significant correlations were obtained for two personality dimensions, Extraversion and Conscientiousness. Extraversion was positively correlated with dance ease (r (103) = .37, $p < .001$), wanting to sing along (r (103) = .22, p = .02), and wanting to move along (r (103) = .24, p = .01). Conscientiousness was positively correlated with dance ease (r (103) = 0.23, p = .02) and liking (r (103) = .22, p = .02). Scatterplots of significantly correlated personality traits and groove-related variables are shown in *Figure 2*.

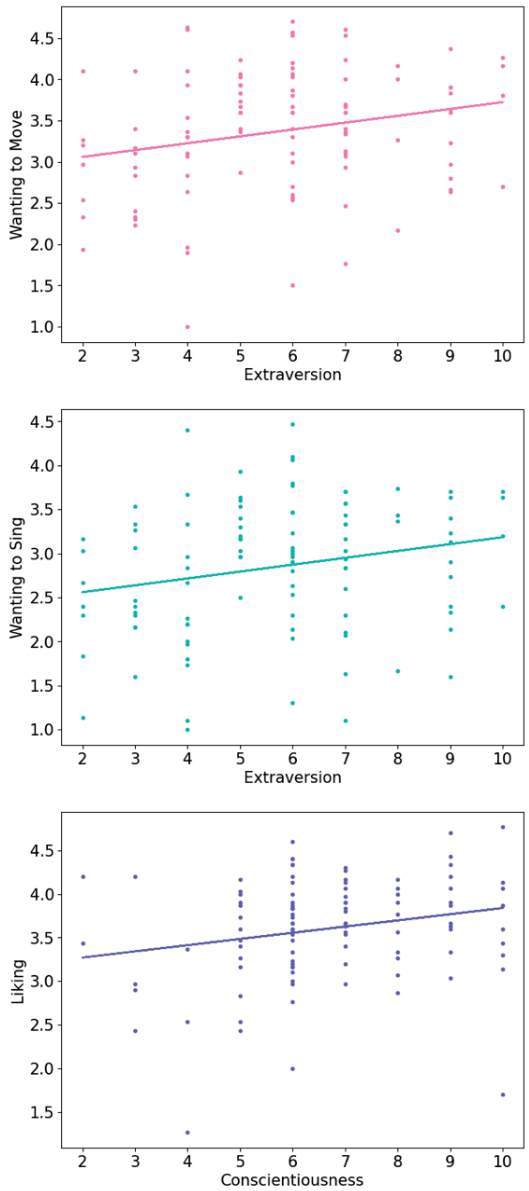

Figure 2. Scatter plots of significantly correlated personality traits and groove-related variables. While Extraversion correlated positively with wanting to move along and wanting to sing along, Conscientiousness correlated positively with participants' liking ratings.

These findings have several impacts. First, people who score higher in Extraversion tend to find moving to music easier in general, and were likely to want to move and sing along with the presented musical stimuli. Second, people who score higher in Conscientiousness also tend to find it easier to move to music in general, and were more likely to report enjoying the presented musical stimuli. These findings are also in line with previous literature on the relationships between personality traits and musical preferences (Carlson et al., 2017) and music-induced movements (Carlson et al., 2016).

Conclusions

The current study explored the relationships between the Big Five personality traits and listeners' ratings of groove-related variables. Our hypotheses were partially supported, with Extraversion being most strongly correlated with the groove-related variables. That Conscientiousness and not Neuroticism was also strongly correlated warrants further investigation in the groove literature. These findings contribute to the development of a psychological model of groove, demonstrating that personality plays a role in one's experience of groove.

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IV

INVESTIGATION OF MU OSCILLATIONS TO NATURALISTIC GROOVE MUSIC

by

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Investigation of Mu Oscillations to Naturalistic Groove Music

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Abstract

In the field of music psychology, groove is described as a multifascated participatory experience, linked with the concepts of immersion, desire to move, positive affect, and social connection. While several intra- and extra-musical features have been reported to influence groove experiences in the previous literature, it is still unclear how groove music is processed in the brain. In the current electroencephalogram (EEG) study, eight partcipants listened to naturalistic stimuli differing in level of groove (high, mid, low) while they were instructed to sit still. Subjective groove ratings (wanting to move, enjoyment and familiarity) were also collected. In line with previous literature, we hypothesised that stimuli which received higher as opposed to lower groove ratings would induce larger mu oscillations as an indicator of greater motor inhibition during the passive listening task. Results of the spectral analysis showed no difference in mu power to stimuli with different groove levels. Yet, this finding should be approached with care. We propose that (1) further data collection, (2) consideration of different stimuli selection, (3) simultaneous movement measures, (4) alternative analysis and (5) design approaches might be necessary for future research in understanding the complex nature of groove experiences and how they are processed in the brain.

Introduction

Groove is associated with experiences of immersion, desire to move, positive affect, and social connection (Duman et al., 2021). Previous literature has reported several intra- and extra-musical variables associated with the experience of groove. Tempo (Etani et al., 2018), pitch (Stupacher et al., 2016; Hove, Martinez, & Stupacher, 2019), rhythmic (Fitch, 2016; Madison et al., 2011; Witek et al., 2014, 2017) and harmonic (Matthews et al., 2019) complexity as well as familiarity (Senn et al., 2018), musical preferences (Senn, Rose, et al., 2019) and musicianship (Senn et al., 2019; Witek et al., 2017) are among the variables that influence the experience of groove.

A few studies have investigated groove with a neuroscientific approach. Increased neuroscientific understanding of groove could lead to implementation in specific groups of individuals, for instance to create clinical advice concerning patients with Parkinson's Disease (Hove & Keller, 2015; Nombela, Hughes, Owen & Grahn, 2013). Some studies explained groove within a predictive coding framework and proposed the experienced of groove as part of brain function that facilitates successful predictions (Vuust, Dietz, Witek, & Kringelbach, 2018; Vuust, Gebauer, & Witek, 2014; Vuust, 2017; Stupacher et al., 2022). More specifically, in a functional magnetic resonance imaging (fMRI) study, Matthews and colleagues (2020) reported rhythms with medium complexity to result in higher groove ratings and linked with reward, motor and beat perception related brain regions. In another fMRI study, Engel and colleagues (2022) found that listening to "in sync" samba percussion excerpts (produced by various instruments) activated motor-related brain regions and reinforced audio-motor links (compared with "out of sync" excerpts). They further propose this motor activity as foundational for the experience of groove.

An electroencephalogram (EEG) study (Cameron et al., 2019) reported stronger neural entrainment towards rhythms produced by humans which correlated positively with desire to move ratings (compared with mechanical versions created with precise timings using MIDI samples). These findings were interpreted as suggesting an interaction between low-level stimulus features with high-level cognitive processing and groove as a complex musical experience. In a transcranial magnetic stimulation (TMS) study, Stupacher and colleagues (2013) found that listening to high-groove music activated motor systems to a greater extent than low-groove music. Importantly, activation of motor areas (even during motor planning and an absence of overt movements) is suggested to support processing of auditory information (Patel & Iversen, 2014).

A recent study demonstrated enhanced mu activity during passive music listening, believed to reflect motor inhibition (Ross et al., 2022). Neural activity around beta (13-30 Hz) and *mu* bands (near somatosensory areas around 8-12 Hz and its harmonics 18-22 Hz) are known to be involved in sensory-motor processing (Engel & Fries, 2010; Khanna & Carmena, 2015). Specifically, one study (Mazaheri et al., 2009) described mu activation as an indicator of inhibition of motor activity. Another study (Pfurtscheller, 1981) reported that beta desynchronisation in central brain regions is involved in activation of sensory-motor cortex and an indicator of voluntary movement. In contrast, using EEG and electromyography (EMG), a recent study (Nijhuis et al., 2022) reported no influence of musical groove on cortico-muscular coherence (measured with beta power) while isometric contraction. This lack of clarity encourages further research on the topic.

Aims & Hypothesis

The aim of this study was to examine mu oscillations to naturalistic stimuli – commercial music recordings – rated from high to low groove. To the best of our knowledge, no previous study has reported *mu* oscillations to naturalistic stimuli with varying degrees of groove. Thus, the current exploratory work focuses on investigating cortical mu activation to musical stimuli associated with various levels of groove. Greater mu power was hypothesised for the stimuli that received higher groove ratings (compared with low groove) as an indicator of greater motor inhibition.

Method

Participants

Eight healthy Finnish participants (aged *M*=25.38, *SD*=1.3, 2 female) took part in the experiment.

Stimuli

Stimuli was selected in two steps. First, in a detailed online survey participants (*N*=105) listened to 30 short musical excerpts (from various genres of commercial music, with tempo around 120 -/+ 20 bpm) and rated groove-related items (i.e., wanting to move, enjoyment and familiarity) for each excerpt. (Further details about the survey can be found in Duman et al., 2021 and Duman et al., 2022.) Based on these groove ratings, 3 stimuli were selected for each groove level (low, mid and high) for the current experiment (presented in *Table 1*). Each of the 9 stimuli lasted around 25 seconds and were presented 5 times in randomised order.

Table 1. Stimuli with initial wanting to move ratings

Order	Artist	Song	Wanting to Move Rating
1	Bruno Mars	Uptown Funk	4,11
2	Daft Punk	Get Lucky	4,05
3	Earth, Wind & Fire	September	4,03
4	Florence the Machine + Calvin	Say My Name	3,44
5	Lyn Collins	Think About It	3,37
6	Gotye	Somebody that I used to know	3,00
7	Stevie Wonder	I Just Called to Say I Love You	2,96
8	Kaleida	Think	2,57
9	Gwen Stefani	Cool	2,49

Procedure

The data collection took part in the EEG lab of the Department of Music, Art and Culture Studies, University of Jyväskylä, Finland. Upon arrival, participants were informed about the procedure, their rights as participants, and informed consent papers were collected. Participants completed a *passive listening task* while wearing an EEG system (BioSemi 64 channels). They were seated, asked to listen to the presented stimuli and to try not to move while their eyes were fixed on a point in space. The data collection took about 25 minutes. Subsequently, participants were presented with the stimuli to collect ratings of (a) enjoyment, (b) wanting to move and (c) familiarity of each track on a 5-point likert scale.

Pre-processing

Data were pre-processed using EEGLAB toolbox (Delorme & Makeig, 2004) in MatLab (2019b). Data were filtered using 1 Hz and 50 Hz high and low pass filters, respectively, referenced to the average of all channels, and down sampled to 128 Hz. Next, pre-processed data were submitted to independent component (IC) analysis (Onton & Makeig, 2006). ICs were visually inspected with the help of the *IC Label* function (Pion-Tonachini, Kreutz-Delgado, & Makeig, 2019) and a maximum of 10 artifact-like components (including eye, muscle, line and other) among the highest-weighted 25 ICs were removed from the data. Data were epoched to 11 seconds [-1 10]. Finally, a baseline correction was applied to the epoched data referencing the 1000 milliseconds before the sound onset.

Analysis

The pre-processed data were analysed using *mne-python* package (Gramfort et al., 2013). Spectral decomposition was applied with *Welch's* method using *psd_welch* function with multitaper (window length set to 4 seconds) to investigate spectral power to musical stimuli with various levels of groove at the individual and group level.

Results

As expected, participants' groove ratings were in line with the initial online experiment. In agreement with previous literature findings (Madison et al., 2011; Senn et al., 2018), because *Pearson's* correlations demonstrated significant relationship for ratings of wanting to move and familiarity (r (103) = .63, $p < .001$), and enjoyment (r (103) = .69, $p < .001$), subsequent analyses were completed based only on the wanting to move ratings. *Figure 1* demonstrates averaged wanting to move ratings of the stimuli. While for high groove stimuli a smaller variability across participants' ratings were observed (also reflecting a ceiling effect), a greater variability was noticed for mid and low groove stimuli. This could indicate the subjective nature of participants' movement experiences.

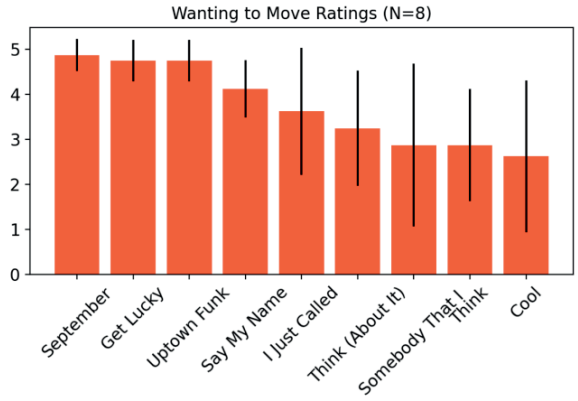

Figure 1. Wanting to move ratings of the stimuli

Although according to the previous literature (such as Ross et al., 2022), a greater mu power to high groove stimuli would be expected, no difference in mu power was observed for stimuli with different levels of groove in the grand averaged spectral decomposition. *Figure 2* shows power spectral density distribution of the data averaged acrossed participants.

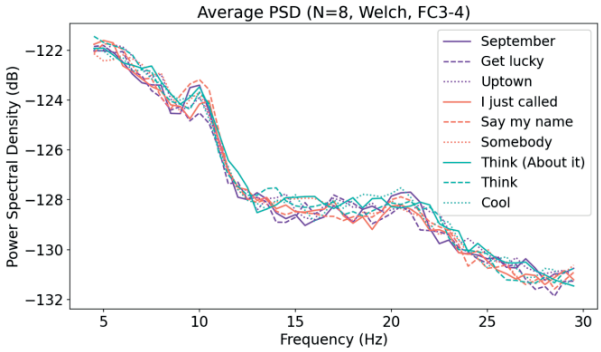

Figure 2. Power spectral density respresentation of the stimuli, averaged across participants

Since there can be inter-subject variation in spectral characteristics of the EEG signal (Croce et al., 2020), the data were inspected on an individual level as well. The individual spectral decompositions demonstrated various patterns as presented in *Figure 3.* Still, no relationship between subjective groove ratings and mu activity was detected.

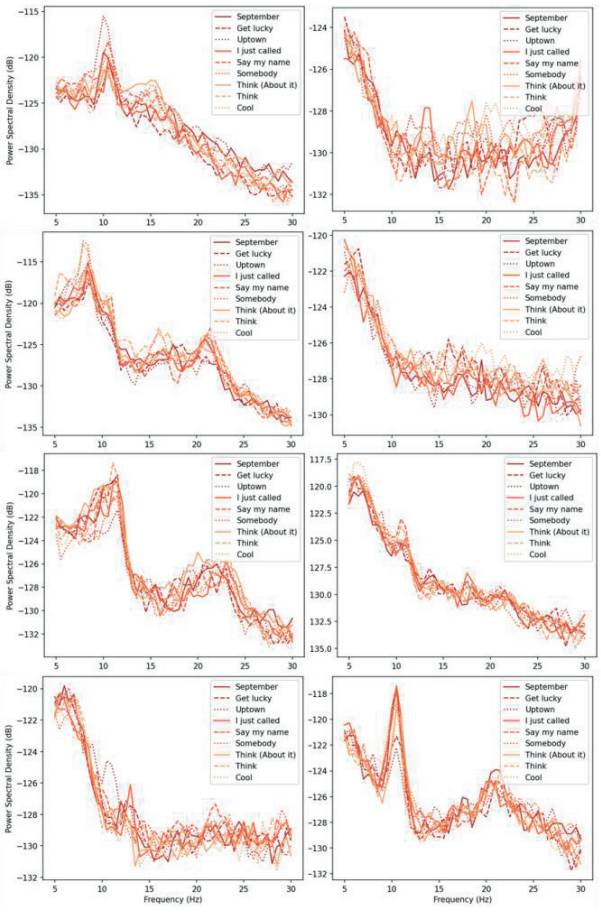

Figure 3. Power spectral density respresentation of the stimuli of individual participants

Discussion

Overall, the results of the current study might be considered similar to null findings of Nijhuis and colleagues' research (2022), indicating no influence of different levels of groove stimuli on mu oscillations. However, additional data and other analytical investigations might be required before pursuing such a conclusion. Therfore, we propose the following limitations and potential adjustments to be considered for future research.

First, the lack of evidence for the hypothesis could be due to stimuli selection. As seen in Figure 1, some of the participants gave high ratings to low groove stimuli too. A set of stimuli that differ clearly in terms of groove ratings might be crucial. Second, previous literature revealed that high groove music influences postural sway (Ross et al., 2016). Thus, quantifying body movements during a passive listening task (such as via simultaneous motion capture measurement) migh be necessary to control for movement of participants. Third, similar to the study by Ross and colleagues (2022), a localising analysis could be carried out in order to ensure the source of mu oscillations are auditory and motor related brain regions. For this, a change in experimental design might be needed to detect motor and auditory brain regions in each participant. Furthermore, it is known that there are individual differences in neuronal responses across participants (Croce et al., 2020) as well as in terms of the music that participants want to move to (Duman et al., 2022). Therefore, future research could consider carrying out the analysis on an individual level rather than grand averaged group analysis. Finally, groove is described as a personal experience (Duman et al., 2021) which relates to several factors (Senn, Bechtold, et al., 2019). In addition to this, there is a consideration of different kinds of groove experiences in the groove literature (Keil, 1995; Bechtold & Witek, 2021; Duman et al., 2021). Thus, future research could consider the possibility of different groove experiences across participants depending on selected stimuli. In conclusion, careful experimental designs are crucial while investigating processing of naturalistic groove stimuli in the brain.

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