Two studies investigating the value of DJing for contemporary music education

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Tiivistelmä – Abstract

This research investigated the importance of cognitive skills learned through DJing and perspectives on the potential value of DJing for music education through two studies. The first was a qualitative investigation into contemporary perspectives on the potential value of DJing for music education. Participants were asked three questions in order to establish their perceptions concerning the cultural relevance of DJing regarding the skills that might be learned through DJing and how DJing might be incorporated into formal music education curriculums. Perspectives emerged that showed a majority of participants believed that DJs learn valuable musical skills, DJing had equal relevance with other musical forms and a high degree of contemporary relevance, and agreed that DJing lessons should be offered. These results merited further investigation into the cognitive/perceptual skills/abilities developed through DJing. The second study quantitatively investigated the cognitive abilities derived from formal and informal music learning. This study focussed on sensorimotor synchronization (SMS) in order to test the extent of cognitive abilities relating to rhythm perception among these participant groups. The SMS study therefore tested comparative SMS ability between the participant groups by having them tap along with various auditory sequences under conditions of increasing distraction in order to see if any significant differences occurred in the timing of their tapped responses. Results suggested that DJs asynchronies proved to be the least variable out of the participant groups, showing that their error correction responses (ECRs) were more stable than the other two groups even if their (negative) mean asynchronies (NMAs) were not as small as the classical performers' asynchronies. DJs were also the least susceptible to "phase attraction" out of the three participant groups. It is hoped that these results might stimulate a greater inclusion of informal learning practises into the contemporary music classroom, and further investigation of the cognitive skills and abilities that are being developed by informally trained musicians in response to advances in (music) technology. Future research will assess the views of a wide sample group of formal music educators in order to establish how DJing might be integrated into a school curriculum.

Asiasanat – Keywords

DJing, sensorimotor synchronization (SMS), distraction, music education.

Säilytyspaikka – Depository	
Muita tietoja – Additional information	

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Introduction

1.1 General introduction

A primary aim of this research is to establish the importance of cognitive skills learned through DJing to contemporary and future music education, empirically establishing the potential value of this informal practice for music education. This thesis describes two studies: the first aimed to qualitatively investigate contemporary perspectives on the potential value of DJing for music education, and the second quantitatively investigating the cognitive abilities derived from informally learning how to DJ through testing sensorimotor synchronization (SMS) under distraction.

Sensorimotor synchronization (SMS), or the "coordination of rhythmic movement with rhythmic sensory stimuli" (Repp, 2006: 55) is the fundamental cognitive ability that allows humans to engage in nearly all aspects of musical performance, and extends to all forms of synchronized movement across species (Jäncke, 2006; Repp & Su, 2013; Toiviainen & Snyder, 2003). The quantitative experiment delineated in Chapter 3 of this thesis has been designed to test the extent of SMS among our participant groups, comparing sensorimotor synchronization ability between formally trained and informally trained professional musicians, namely string players and DJs, with non-musicians as the control group. This research hopes to address the following research questions:

- What is developed through DJing with regards to quantifiable cognitive/perceptual abilities (i.e. sensorimotor synchronization) and how do these abilities compare with professional formally trained musicians and a control-group consisting of non-musicians?

This experiment is designed to quantitatively establish participant groups' respective sensorimotor synchronization (SMS) abilities in a series of "normal" auditory conditions (i.e. without distraction), then to compare these results with their respective SMS abilities under conditions of auditory distraction, thereby testing the extent of this ability in a more ecologically valid context.

A glossary of terms relevant to the study of sensorimotor synchronization (SMS) is provided in Appendix F of this thesis.

1.2 DJing in context

> DJs track down greatness in music and squeeze it together[…] a DJ condenses the work and talent of hundreds of musicians into a single concentrated performance. DJs bring all the right things together – that's why we love them so much. (Broughton & Brewster, 2002. p. 12)

DJs in their contemporary state evolved from two wellsprings. One source can be traced to the radio announcers that were responsible for cuing the records on music programs, referred to colloquially as *disk jockeys*. Disk jockeys held considerable cultural power as they influenced the music that was aired, in evidence in the *payola* scandals that led to the criminalization of undisclosed payments given to influence the content of broadcast programs in 1960 (Coase, 1979). Disk jockeys like Dick Clark and Alan Freed became extremely famous as they were seen as key figures in exposing the American youth to previously tabooed music, specifically of African-American origin, which was viewed as having little commercial value by the music industry of their time (Shuker, 2005). The second origin of DJing is early experimental music written by the composer Hindemith, who is considered to have composed the first music specifically for the gramophone (his *grammophonplatten-eigene Stücke*) in 1930, utilizing pitch/speed augmentation and sampling (layering two or more pre-recorded sounds simultaneously) in a recorded musical work for the first time (Katz, 2012).

To give a brief overview of a contemporary DJ's instrument: as illustrated in Figure 1, a traditional DJ's equipment generally consists of two turntables. Over the past decade, technology has greatly influenced DJ practices, progressing from traditional vinyl approaches to new DJing systems such as Digitial Vinyl Systems (DVS), CDJs, and purely Digital Systems. In the year 2000, the music technology company Native Instruments released Traktor Studio, which is a software package for DJing that comes with a controller interface that combines all of the necessary technical components of a vinyl DJs equipment (dummy turntable platters and mixer). The Traktor software offers advanced digital functionality. By combining all the equipment into a single, cheap unit, has made DJing a far less expensive enterprise and highly accessible to prospective learners. What has occurred is a split in DJ technique as certain aspects of vinyl DJing have been made all but redundant through the introduction of this new technology (many vinyl DJs have adapted their skills to this digital format for the sake of convenience, while young learners begin with controllers and never learn how to DJ with vinyl). For example, the manual process of "beatmatching", where two vinyls are brought into synchrony through physical manipulation and restraining of the vinyl platter and a foundational aspect of a DJs art, can be done automatically with this digital technology by the pressing of a (Synch) button (Greasley & Prior, 2013). Furthermore, a continuous waveform visualization of the audio signals of samples being used in the performance/mix is available at all times in the application window, making it far easier to synchronize two samples, initially a manual process. In addition, the latest versions of this software include colour-coded visualisations, the colour of which indicates the frequency range of that part of the waveform, making it easier to identify specific regions; sample identification has therefore come a long way from the sticky-tape and colour markers that vinyl DJs use to indicate the locations of desired samples on the record surface.

Figure 1

A DJ's equipment. Used with permission of Greasley & Prior.

Contemporary DJs still provide an almost continuous stream of music with the addition of a technique called *mixing*, which requires that two or more turntables be simultaneously used so that the end of one record can overlap seamlessly with the beginning of the next (Butler, 2006). This technique is greatly expanded in the modern DJ and turntablist, and involves several sub-components including *cuing*, *beatmatching*, *blending*, *phrase matching* and *rhythm matching* (Broughton & Brewster, 2002), techniques which will be described more fully later in the thesis. Other than sampling pre-recorded music, DJing can also be a virtuoso performance art in which record player turntables are used as a musical instrument, which is referred to as *turntablism* (Chapman, 2012). Vandemast-Bell (2013, p. 243) describes turntablism as "resisting the intended purpose of the turntable as an autonomous playback device". In this regard, turntablists utilize a technique referred to as *scratching* (in which the record is quite literally scratched) in order to interact with, negotiate and deconstruct the sampled music (Vandemast-Bell, 2013).

DJing occurs predominantly in two musical contexts: electronic dance music (EDM) and hip-hop (Butler, 2006). EDM includes a wide array of beat-based sub-genres (techno, house, trance, garage, drum n' bass, to name but a few), but the origins of turntablism as an art-form are to be found in hip-hop (Poschardt, 2002). In hip-hop performances, the DJ provides music over which a vocalist raps, predominantly making use of *breakbeats* (sampled drum and percussion patterns/loops) (Butler, 2006), and performs scratch solos on the turntables. DJ Kool Herc is attributed with discovering the interesting effects of overtly percussive sections of music (i.e. breakbeats) on disco dancers whilst working as a DJ in the discos of the early 1970s, which led to his technique of only playing breakbeats in succession and removing the intervening material, which was later adopted by others (Smith, 2000). More recently, studies in the psychology of music have quantified the effect of the bass drum on human dance movement (Van Dyck et al., 2013), empirically supporting DJ Kool Herc's hypothesis. DJing has also found its way into popular music genres in a variety of ways; for example, famous bands such as Portished, Incubus, Linkin Park and Slipknot all feature(d) live DJs as permanent band members.

1.3 Background to the study

Although there seems to be consensus in DJ tutor books as to how to go about learning to DJ (e.g. Broughton & Brewster, 2002), how DJs informally acquire these skills has not yet been investigated. Studies of informal learning such as those carried out by Green (2002) and described in her book *How Popular Musicians Learn* have avoided DJs as a participant group because the developmental processes of musicians in synthesized/sampled fields of music production are not easily identified. For example, Green claimed that musicians in "synthesized/sampled" music genres "do not go about acquiring their musical skills and knowledge in the same ways as each other" (2002: 10). However, Smith's (2007) investigation of "collective creation" among two professional hip-hop turntable teams points towards an agreed consensus as to the methods employed during DJing, suggesting that even if Green is correct in assuming that musicians working with "synthesized/sampled" music are non-homogenous in their means of knowledge and skill-acquisition, there is still at the very least a homogeny of approach among DJs that makes collaboration possible.

A brief overview of the small quantity of current academic literature on DJing as a musical practice shows that the exploration of this phenomenon is in its infancy within the discipline of music psychology. In a study by Söderman and Folkestad (2004), the creative processes underlying the composition of a hip-hop group (including a DJ) in Sweden has been documented and includes references to the compositional processes underlying DJing as described by the "beatmaker" (in this case, synonymous with DJ) of the group. However, this brief description of practices based on an interview with one individual was neither exhaustive nor generalizable to DJs as a whole. An interesting but highly theoretical analysis of the semiotic content of DJ performance (specifically reggae and club DJing) has been provided by Bakker and Bakker (2006) in which an attempt to use a semiotic framework to interpret the meaning of DJing, a framework within which he interprets all aspects of the club as part of a sign system. However, this research makes claims about what DJs do without any empirical grounding (questionnaires, interviews). A recent addition to the academic literature on DJs is an article by Vandemast-Bell (2013) who is a DJ and academic. In this article Bell used himself as the subject and discusses the manner in which live DJ performance involves tactile manipulation of sound through physical means, as well as "real-time composition". He is responding to the prevalent conception that a DJ is just someone that plays other people's music. Although his work provides an important context for this research, it is limited because it is based on the personal experience of an expert as opposed to objective data or scientific observations (Jabusch, 2006). Further context for this research is provided by a study by Greasley and Prior (2013) in which they investigated the concept of musical shape in relation to DJing through phenomenological analysis of interviews with three professional DJs, adding substantially to academic literature on the subject of DJing.

In order to compare sensorimotor synchronization (SMS) ability between formally and informally trained professional musicians, it was necessary to select a representative population from each group. The formally trained group consisted of professional string players, chosen because of the degree to which they regularly entrain rhythmically with external sources (Repp, 2005; Repp & Su, 2012) in both the auditory and visual domains, without the direct use of some form of tapping with their dominant hand. For this reason, formally trained drummers and pianists were excluded from the participant group because tapping with their dominant hand is an intrinsic part of their art and provides a distinct motoric advantage in SMS tasks over other types of musicians (Krause et al., 2010a, 2010b; Fuji et al., 2011). Despite a lack of actual tapping with their dominant hand (which usually holds the bow), an ensemble musician in an orchestra synchronously entrains with the visual cues provided by a conductor as well as the auditory cues provided by the multitude of other instruments in their sonic environment through the perceptual/cognitive mechanism of *feedback control* (Jäncke, 2006). This mechanism is described by Jäncke as a “comparison of one’s own performance with the auditory templates from the rest of the orchestra” (2006: 26). In the execution of this process they must filter out the misleading sounds of those less capable of entraining due to differences in skill level, distractions and other factors, and focus on their own auditory stream as well as other auditory streams they perceive to be consistent with the conductor’s timing-related gestures (Luck & Toiviainen, 2006).

DJs were chosen to represent informal musical practitioners because of the contemporary prevalence of DJing as a performance art and the degree of professionalism that DJs attain without any formal musical training (Greasley & Prior, 2013). As has been described, the practical development of SMS occurs during musical performances when timing discrepancies brought about by distractions, differences in skill level between players and other factors are perceived and corrected by the performer. This ability to isolate and eliminate noticeable asynchronies successfully is especially relevant to the fundamental DJing technique of “beatmatching”, in which one beat must be strictly adhered to whilst matching the other (asynchronous) beat during a performance in order for two tracks to be appropriately “mixed” (i.e. played simultaneously). Although there are technically no other performers in a conventional DJ setup (though Smith’s research has begun to investigate collaborative processes among hip-hop “turntable teams”) (Smith, 2007; 2013), the coordination and entrainment of two rhythmic sources in phase is the essential part of DJ performance that is thought to develop SMS ability, a central hypothesis of the quantitative study reported in this thesis. Furthermore, in a DJ performance, the DJ regularly “cues” one record by physically restraining the vinyl and then releasing it for a timed entry that coincides with the record that is already playing. Cuing also has a specific motor movement associated with it: initially, the record is pulled back to a point preceding the desired beat onset, and then the platter is manually rotated in time to the tempo with which it will be matched. When the record is released, the first beat of the introduced record will coincide exactly with that of the record that is already audible. Inability to cue and beatmatch properly has adverse consequences for the performer and listener alike. If the two records are perceived as being “out” (of synchrony) in a DJing context, this would be much the same as two ensemble musicians playing out of synchrony in a classical performance. Furthermore, DJs are continually aiming to maintain synchrony in a performance by eliminating asynchrony between the beat of the music that is already playing, and the samples they overlay and "mix" into the sonic environment, which is at the heart of what DJs do: intertextual layering of different audio samples to produce new and interesting combinations and aesthetic relationships (Bradby, 1993; Kistner, 2006).

For one that hopes to know what DJs really do and why they do it, the only option currently available is to turn to YouTube or the wealth of populist books on the subject (Broughton & Brewster, 2002; Brewster & Broughton, 2010; Katz, 2012; Poschardt, 2002). The equivalent of this in music psychology research might be to go to a concert, or examine piano tutor books and teachers' anecdotes in order to establish a well-rounded picture of what a pianist does and why, rather than investigating the musician him/herself; the limitations inherent in this sort of approach may be obvious. Therefore, it is hoped that this research will add something valuable to music psychology by investigating DJs directly, establishing what cognitive skills DJing techniques develop, and investigating the learning processes whereby the DJ sample group has acquired these skills.

2. Qualitative investigation: perspectives on the value of DJing for music education

This qualitative investigation was intended to pinpoint contemporary perspectives on the value of DJing for music education. It was hoped that equally sized groups of classical performers, DJs and non-musicians would give a well-rounded view of the subject and provide ground for or negate the necessity for further investigation. This investigation is contextualized within debates relevant to music education, which will now be briefly reviewed.

2.1 Background: DJing and contemporary music education in the U.K.

Educational bodies in the United Kingdom are becoming increasingly interested in the capacity for informal learning practices to inspire personal and creative growth in the music classroom (Green, 2002, 2009; McQueen & Hallam, 2010). Interest in the potential for DJing to develop critical creative skills in children has already been established in the work of Crow (2006). In the United Kingdom, there is a growing inclusion of informal learning methods in music education (Green, 2002, 2009; Hallam & Creech, 2010). Through the emergence of "information and communication technology" (ICT) in schools, the use and study of music technology to develop critical computer skills has meant that new instruments and music-making technology has found its way in classrooms, outside of the sorts of contexts that have hitherto been associated with music and learning (Hallam & Rogers, 2010; Himonides & Purves, 2010). Music technology encompasses too broad a range of instruments, multimedia interfaces, applications and creative workstations for an exhaustive list to be given here. What is important is that the old methods of music education, those associated with formal training, are not necessarily applicable to the educational contexts in which musical skills are now developed (Himonides & Purves, 2010), and equally as inapplicable to new music styles and new instruments (Green, 2002; 2009). These sources indicate that influential music educators, at least in the United Kingdom, seem well aware that music education needs to adapt to new technology and informal learning approaches in order to be a part of the future of music education.

Within music education discourse, informal learning practices are finding increasing inclusion into school syllabi (Cain, 2013) in what has been termed "informal pedagogy" (Price & D'Amore, 2007), in an attempt to ground music education in a more "learner-centred way" and combat the flagging interest in formal music training in schools (McQueen & Hallam, 2010). For example, on its website, the Musical Futures informal learning approach describes itself as a "movement to reshape music education driven by teachers for teachers" and currently involves 28 schools in the United Kingdom and over 700 secondary-school teachers (McQueen & Hallam, 2010). This move reflects a more socially conscious awareness of how learning occurs outside institutions in the contemporary era, which has been modulated by the influx of technology suspected to be at the heart of this shift in modes of teaching and learning (Thomas & Brown, 2011). In 2009, Green's influential book entitled "Music, informal pedagogy and the school: A new classroom pedagogy" described her attempt to introduce learning practices of informal musical learning into a classroom environment, an area in which she has done much pioneering work (Green, 2002; 2006; 2009). In such a context the teacher's role is to guide behaviour and tasks, and thereafter observe without too much intervention or participation (Green, 2009). Green argues that despite the inclusion of popular music into curriculums, little has been done to incorporate the informal learning practices of popular musicians, something which her work addresses (Green, 2002; 2006; 2009) and that has gained momentum within music education as a whole (Cain, 2013). Cain comments that the success of Green’s project at seven schools in Northern England is suggestive of teachers’ appreciation of the flexibility of this new pedagogical style, and that their willingness to change to a more flexible style indicates a questioning of more formal teaching styles (Cain, 2013).

2.2 Methods

All of the participants from which collected data was collected (classical performers, DJs and non-musicians) were required to fill in a questionnaire (see Appendix C) designed to establish their perspectives on DJing and the value of DJing for music education. These questions were meant to approach some of the core misconceptions and issues that are commonly perceived to be associated with DJing; whether or not DJs are perceived to be musicians for example.

2.2.1 Details of the sample

The “perspectives on DJing” questionnaire were completed by all participants; 7 string player participants aged between 18 and 60 (mean age=26.56, SD=13.78), and 7 non-musicians aged between 20 and 37 (mean age=25.43, SD=4.89) and 7 professional DJ participants aged between 25 and 43 (mean age=35.71, SD=5.33), all of whom will remain anonymous for the purposes of this study in accordance with the ethics guidelines for this research (see Appendix A). The “perspectives on DJing” questionnaire was intended to give a view of contemporary perspectives on DJing within our sample groups, providing exploratory data with which to highlight themes that may be further investigated in future studies.

2.2.2 Process of analysis

As contemporary perspectives on DJing and informal learning techniques are both relatively underexplored areas within music psychology (with the exception of the examples of informal learning literature discussed previously in this chapter), a thematic analysis of questionnaire data was required in order to isolate relevant themes. A thematic analysis incorporates the following phases, as described by Braun and Clarke (2006):

1. Familiarizing oneself with the data: includes possible reading or transcription of the data, establishing first observations.
2. Coding: systematic categorization of interesting features that might be relevant to the research aims.

3. Establishing themes: systematic categorization of coded features.
4. Mapping the analysis: thematic review and checking if themes relate to the data set as a whole.
5. Producing the report: final analysis and “selection of vivid, compelling extract examples” (Braun & Clarke, 2006: 35) which are then viewed in light of the literature and original research questions.

Figure 2 below provides a schematic of the broad themes and questions.

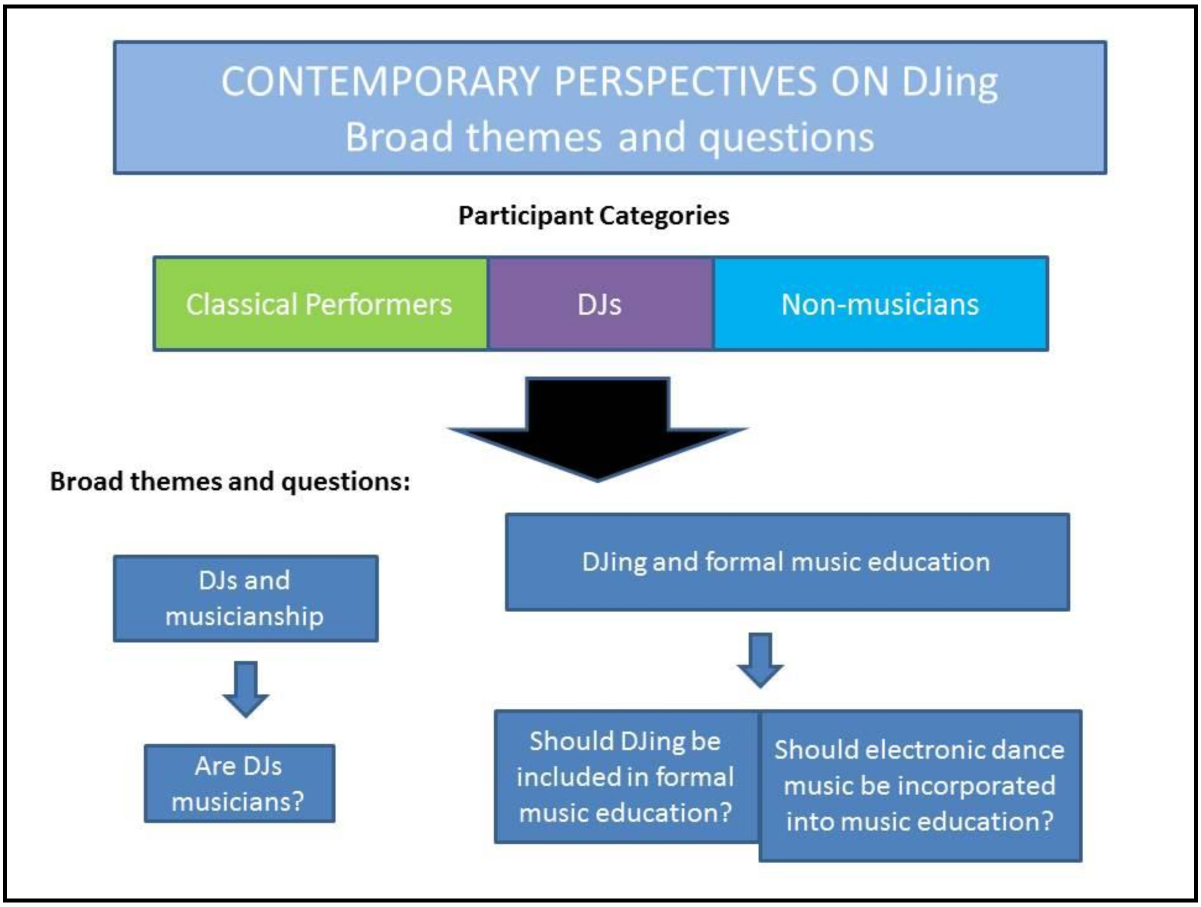


Figure 2

Perspectives on DJing: Broad themes and questions.

2.3 Results and discussion

The figure below illustrates the thematic map drawn from the “perspectives on DJing” questionnaires; an analytic strategy applied separately to each participant category to establish the different groups' perspectives. Differences and similarities of those perspectives were then compared.

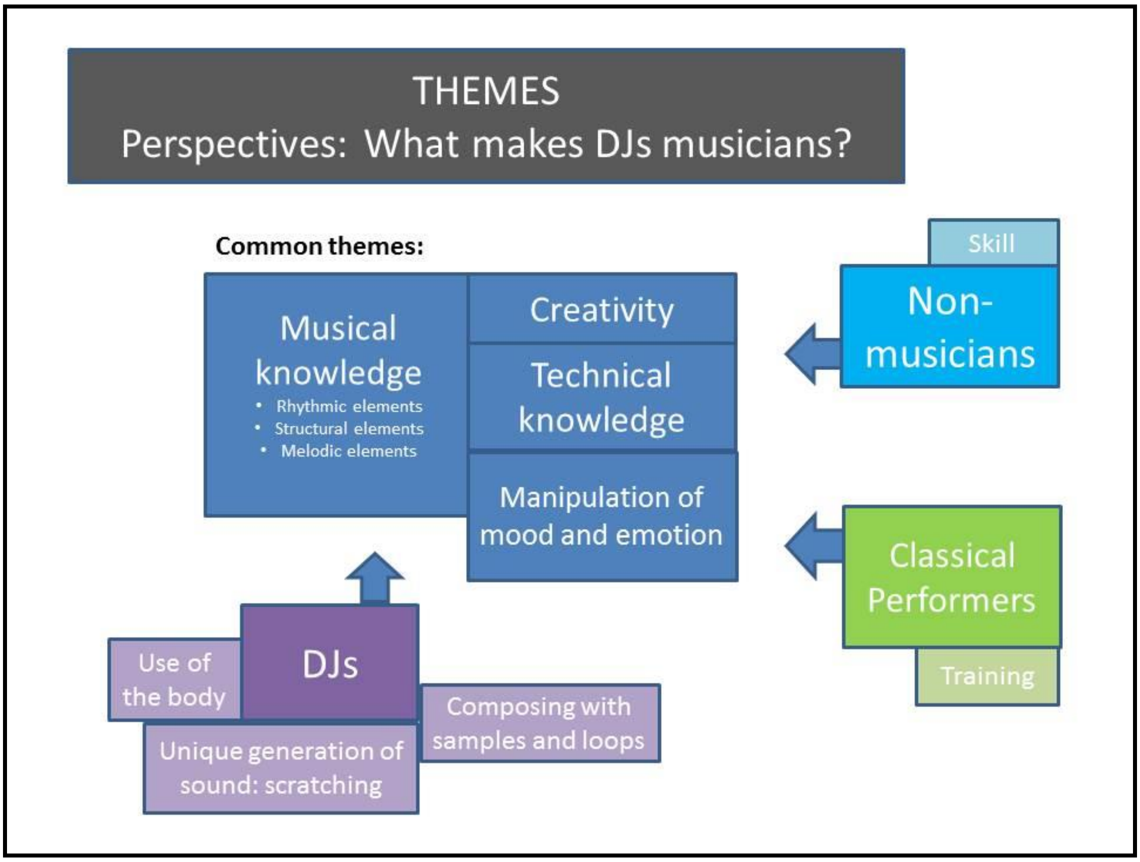


Figure 3

Thematic map of "Are DJs musicians?" themes.

2.3.1 Results: contemporary perspectives on DJs and musicianship

An initial problem encountered in this research related to categorization of DJs as informally trained *musicians*, as their official status as musicians was unclear. A musician is someone that plays an instrument; to what extent can the turntables and mixer be considered an instrument is unclear. Therefore, part of this study hoped to establish perspectives on whether or not DJs are considered to be musicians, and why people considered them to be so. 20 out of 21 participants claimed that DJs can be considered as musicians. By systematically examining the data relating to our participants' categorization of aspects essential to being considered a musician, four broad themes were established that were mentioned at least once in all three participant groups: manipulation of mood and emotion, musical knowledge, technical knowledge and creativity. An overview of the shared and category-specific themes relating to this question are illustrated in Figure 3. Some participants expounded on the musical knowledge employed by DJs that justified their definition as musicians, including rhythmic, melodic and structural elements as being essential to DJ practices. One classical string player felt that training was an additional necessity when defining a musician, while non-musicians similarly thought that skill was essential. In a different but related question, one classical musician stated that DJs have to "master technology in a way similar to learning an instrument". A particularly defensive DJ participant eloquently expressed that "Creating new music/a new song by combining pre-existing songs or using electronic sounds is no different to music created by the combination of different physical instruments or voices." However, this is more descriptive of the DJ as a composer rather than a musician (i.e. someone that plays a musical instrument).

One DJ participant voiced doubts, claiming that DJs (*not* turntablists) are low on the spectrum of musicians. However, he also stated that "If they aren't musicians – who play music – what could you classify them as?" Only one (non-musician) participant openly stated disagreement that DJs are musicians, stating that "there is some skill involved and required, but that's the same for driving a car."

It is concluded for the purposes of this thesis that DJs/turntablists are musicians if they physically mediate the sounds that are heard through various techniques (mixing and scratching for example).

2.3.2 Results: perspectives on the value of DJing for music education

In this part of the study, contemporary perspectives on the value of DJing for music education were investigated. As our participant groups held equal numbers of formally and informally trained musicians, there was cause to believe that both groups would have developed ideas on this subject, therefore this part of the study was expected to reveal interesting and possibly conflicting results between the groups. Furthermore, as two of our DJ participants were also DJing instructors at a local DJ school and were very active in local school s at the time of the study, where they were using the teaching of DJing skills for various educational purposes (partly funded by Leeds City Council for certain projects), it was also expected that their opinions on this matter would be highly developed and that their answers may provide substantial arguments for inclusion of DJing in school music curriculums.

21 participants were asked the following three questions in order to establish their perceptions concerning the cultural relevance of DJing with regards to the skills that might be learned through DJing and how DJing might be incorporated into formal music education curriculums. The exact questions were as follows:

1. Do you think that DJs learn valuable musical skills through what they do?
2. Do you think that DJing has cultural relevance on a par with classical music tradition?
3. Do you think that DJing lessons should be offered alongside traditional music lessons as part of a formal music education?

In response to the question "Do you think that DJs learn valuable musical skills through what they do?" all participants unanimously agreed that skills were learned and almost all participants had insightful things to say. Table 1 on the following page groups the musical skills mentioned by participants into thematic categories. Only the category of "mixing" is DJ-specific; all other categories apply generally to music education. Categories were colour coded to assist in the thematic analysis that produced these results, and the colour key is provided in Appendix D.

One participant, an experienced DJ instructor and professional DJ, wrote very eloquently on musical skills learned through DJing:

> The most basic skill all DJs who mix have to learn is how to count to a pulse, how to recognise the first beat of a bar and phrase, and how to match the tempo of a song to the tempo of another song. Advanced musical skills occur when a DJ recognises the harmonic, rhythmic or textural effect of mixing two sounds together. Scratch DJs learn at least the equivalent amount of musical skills as percussion players as both use tactile methods to add musical elements to compositions. True "turntablists" use mixing, beat matching and scratching (i.e. all the elements of DJing) to produce entirely new compositions. These "turntablist" compositions utilise melodies, beats and basslines from other recordings but rework them into brand new pieces which are clearly separate from the original. There can be no doubt that these DJs have learnt valuable musical skills to do so.

Another DJing instructor wrote:

> Some may think it is just about pressing a button or to look good but there is a lot in involved in DJing; counting beats and bars, understanding structure and timing, learning about the key of a piece of music, musicianship, performance, music technology and creativity.

Musical skill	Times mentioned
Rhythmic perception	7
Harmonic perception	5
Musical structure	4
Music technology	4
Music performance	4
Stylistic knowledge	4
Instrumental skills	3
Mixing	3
Music production	3

Table 1

Categories of musical skills learned through DJing.

Across all participant groups, rhythm perception was the most noted category of musical skill learned by DJing, perhaps as a result of the beat-based nature of the music generally played through this creative medium and the fundamental necessity of beatmatching. This result was in line with the proposition of this thesis as a whole and substantiated the quantitative investigation of rhythmic perception in the following chapter. *Mixing* requires that harmonies as well as beats match, which might explain why skills relating to the category of harmonic perception were mentioned second-most by participants. Skills relating to musical structure, technology, performance and stylistic knowledge were all mentioned an equal number of times and considered to be the joint third-most important aspect of DJing in this analysis. In addition to a wide genre-based knowledge of available repertoire, DJs are required to understand the structure of bars, phrases and overall pieces in order to produce their mixes, while their knowledge of music technology and musical performance are obvious components of their art. Instrumental skills, mixing and music production were all mentioned three times. The instrumental skills learned by DJs are central to the quantitative experiment described in this thesis (*cf*. Chapter 3), the results of which confirm the importance of this aspect of DJing, whilst mixing and music production (synonymous, in this case, with composition) are essential to understanding the important distinction between disk jockeys and DJs/turntablists described in the first DJ instructor’s quote above.

In the second question, participants were also asked whether DJing had a cultural relevance on a par with classical music tradition. Out of the 21 participants, 9 stated that DJing had greater contemporary relevance than classical music, 8 stated that DJing had equal relevance to classical music, and four claimed that DJing was not as relevant as classical music. All classical musician participants claimed that DJing was more or equally as relevant than classical music, whilst all of those claiming DJing is less culturally relevant were non-musicians and DJs. This was a surprising result as it was expected that each group would defend their position (classical music for classical musicians and DJing for DJs) and non-musicians' opinions would gravitate towards their stylistc preferences (which were also noted as part of the study by correlating their responses with a list of each participant's top five favourite songs/albums), but results suggested that this was not the case.

The final question was intended to establish if people felt that DJing lessons should be offered alongside traditional music lessons as part of a formal music education. Approximately 62% of participants stated that DJing lessons should be offered, 14% claimed that they should be optional, 14% claimed that they did not know, and 10% stated that DJing lessons should not be offered alongside traditional music lessons (both of whom were non-musicians). A non-musician participant stated that DJing is "more of a hobby and if you get good you could go professional but I don't think it's really an educational thing." One DJ's argument claimed that learning to DJ is as valid as studying the violin or piano. One DJ instructor argued that the two supposedly disparate learning approaches could be mutually beneficial:

> Most young people today gain their first access to music through pop culture and DJing is a large part of that. If we insist that all young people who show an interest in music need to learn a traditional instrument first, then we will fail to encourage musicianship in the majority. If we do offer DJ education we help naturally musical young people discover music in a manner which they feel comfortable with. This in turn helps us signpost them onto more traditional instruments if they so wish.

Finally, one DJ noted the functional value of DJing skills by mentioning that "DJing has a place in the music industry; therefore, you are equipping people with skills to work."

2.4 Discussion

The intention of this qualitative investigation was to establish contemporary perspectives on the value of DJing for music education. Results showed that the majority of participants from all three groups shared the view that DJs could be considered to be musicians by definition, and also voiced agreement that DJing might be valuable for music education. These views provided substantiation for a quantitative investigation into the skills that DJs develop through their musicianship, which is described in the following chapter. Further qualitative research could assess the views of a wider sample group of formal music educators in order to establish how this might be integrated into a school curriculum. Interviewing DJing instructors may also yield data as to how an educational methodology for DJing lessons might be implemented.

3. Quantitative experiment: sensorimotor synchronization abilities in professional string players and DJs

3.1 Overview: sensorimotor synchronization

Sensorimotor synchronization (SMS) involves the entrainment of physical movement with an external rhythmic source, and has most often been studied by measuring participants' tapping responses to external metronomes under a variety of conditions (*cf.* Repp, 2005; Repp & Su, 2013 for an overview of SMS liteRepp & Su, 2013rature). There are many contexts in which this sort of behaviour may occur in ecologically valid contexts, but a rhythmical musical setting remains the most obvious and prevalent environment in which this cognitive-motor skill is applied, specifically with the function of aiding synchronization between players in collaborative musical activities (Jäncke, 2006; Repp, 2005). Rhythm has been defined in the Oxford Dictionary as "a strong, regular repeated pattern of movement or sound", and also as "the systematic arrangement of musical sounds, according to duration and periodical stress" (Pearsall et al., 2008). Rhythm perception involves principles of pattern recognition in music that are perceived through auditory processes relating to Gestalt laws (such as the laws of proximity, similarity, continuity) within a musical context (Jones, 2008). These explanations of rhythm imply that *a rhythm* is established through a pattern of regular occurrence, the regularity of which conditions and affects listeners' expectations during music listening; expectations which are arguably at the core of our emotional experience of music (Huron, 2006).

The underlying perceptual and cognitive-motor processes governing synchronization adjustment (minimisation of asynchrony) in human subjects are collectively referred to as *error correction* in SMS literature (Repp & Su, 2013), which includes *phase correction* and *period correction* (Repp & Moseley, 2012; Repp & Su, 2013). Phase correction consists of the automatic process of adjusting of the phase of subsequent taps relative to the phase of the stimulus onsets (Repp & Moseley, 2012), and in this way, synchronization is established through continuous sensory feedback (Engbert et al., 2002). This is referred to as the *phase correction response* (PCR) (Repp, 2003a). Period correction is a voluntary error correction action and consists of the subject comparing the perceived inter-onset interval (IOI) of the stimulus with the period of their "inner timekeeper" (internal sense of the beat) and correcting the inter-response intervals (IRIs) of their taps accordingly (Repp & Su, 2013). An SMS glossary is provided in Appendix F and includes summaries of all relevant SMS terminology.

Tapping along to an isochronous (regularly occurring) beat is a relatively easy task for most people. There is evidence that correcting and maintaining movements in time with an external isochronous auditory beat is automatic, governed by the mechanism of phase correction described above (Repp, 2002) and requiring no conscious attention to the task and no higher level executive function, as shown by the fact that older adults can fairly accurately synchronize with an isochronous metronome but are worse than young adults at synchronizing with complex rhythms and noisy metronomes (Krampe et al., 2001; Elliott et al., 2011). SMS studies have discovered that there are significant differences in timing accuracy between different populations and under a variety of different conditions that test the extent of this ability within and across modalities (Aschersleben, 2002; Elliott et al., 2011; Fuji et al., 2011; Krampe et al., 2001; Krause et al., 2010a, 2010b; Repp, 1999, 2003b). Figure 4 depicts the measurement of asynchrony of participants' taps in relation to a target metronome. Musicians have been shown to be highly advantaged in this task (Aschersleben, 2002; Repp, 1999, 2003b) and some musicians more than others (Krause et al., 2010a, 2010b; Fuji et al., 2011), provoking questions as to how SMS ability relates to the motor system, cognitive processes like attention and perception, and how is it developed within different learning contexts (e.g. formal and informal training).

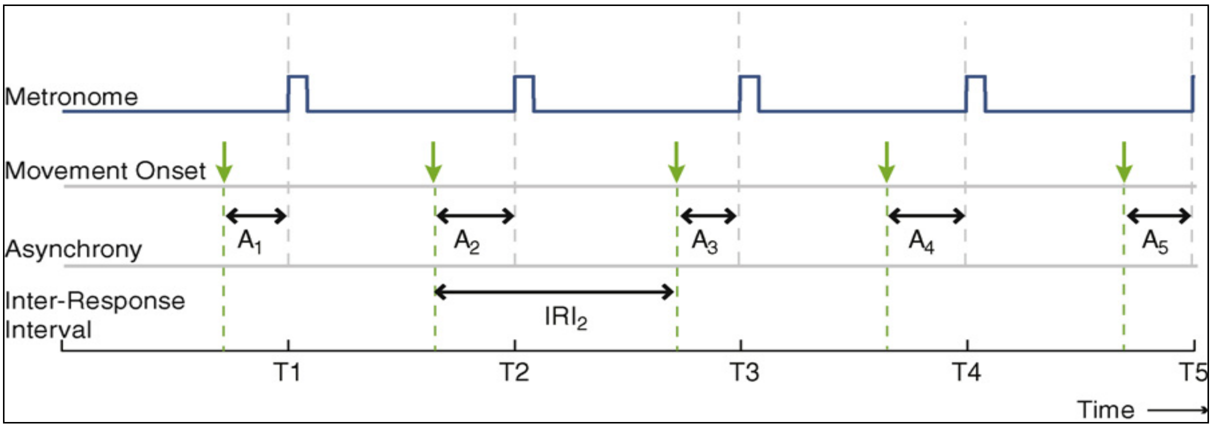


Figure 4

Measurement of tapped response movement onsets in relation to a target metronome provides an asynchrony measurement critical to establishing SMS ability. Figure adapted from Elliott et al.

3.1.1 SMS and musicians

As stated, musicians' superiority over non-musicians at minimising asynchrony during general tapping tasks is well established in the literature (e.g. Aschersleben, 2002; Fuji et al., 2011; Krause et al., 2010a, 2010b; Repp, 1999, 2003b), but an ecologically valid musical setting does not simply require such a straightforward application of SMS ability. In an ecologically valid musical context, continual adjustment of timing takes place in order for performers to convey the expressive intentions of the music and maintain interpersonal coordination with other performers through the cognitive processes of prediction and adaption (Konvalinka, 2010; Nowicki et al., 2013). A central tenet of this thesis is that in an ecologically valid performance setting, SMS adaptability has to be maintained despite unexpected internal and external distractions that direct attention away from the target source. It was decided that a distractor-based experimental paradigm is the most applicable for testing this complex phenomenon in musicians, who are expected to perform more accurately under conditions of distraction than the control group of non-musicians.

In past studies, musicians' superior SMS ability has been shown through a measurable lack of asynchrony during tapping tasks when compared with non-musicians, indicating that SMS ability is modulated by musical training (Aschersleben, 2002; Fuji et al., 2011; Krause et al., 2010a, 2010b; Repp, 1999, 2003b). Evidence from the neuroscience of music concludes that pianists show distinct motoric advantages over non-musicians in both performance in SMS, tasks and learning of new SMS tasks due to differences in the efficiency of neurological functioning in motor areas (Hund-Georgiadis & von Cramon, 1999; Krings et al., 2000; Münte et al., 2002). In studies utilizing a wider array of musician types, musicians showed a negative mean asynchrony (NMA) (anticipation of the target metronome beat onset) of -14ms whilst musically untrained people showed a NMA of -40 to -50ms (Aschersleben, 2002). Musically untrained people have been shown to be an appropriate control group for SMS studies because their asynchronies tend to be approximately 10ms larger than amateur musicians (Aschersleben, 1994), and even greater when compared with music students (Aschersleben, 2002). Another measure of interest is the variability (i.e. consistency of synchrony with the beat) of tapping responses among different participant populations. In addition to being more accurate, musicians have been shown to be less variable in their tapping responses than non-musicians in a variety of studies (Fuji et al., 2011; Krause et al., 2010b; Madison, 2000; Repp, 2010; Repp & Doggett, 2007).

3.1.2 SMS ability under auditory distraction

The current experiment investigates the effects of distractor cues on SMS performance among formally trained musicians (professional ensemble performers) and informally trained musicians (professional disk jockeys/DJs), using musically untrained people as a control group. To restate: this thesis posits that an ideal test of the extent of SMS ability would be to look at differences in SMS performance within specific participant groups and under distracting conditions because these distractions form part of an ecologically valid musical setting under which music is usually performed. This paradigm will now be described in more detail.

Although much of the research on auditory attention in cognitive psychology more broadly is centred on the dichotic listening task (Anderson, 2000), in this experiment stimuli are presented to participants simultaneously to both ears which is more in line with the distractor cues paradigm established by Repp (2003a). Within a distractor cues paradigm, periodic distractors are used to test the extent of participants' sensorimotor synchronization because they have shown to effectively produce distractions distraction (Repp, 2003a). Participants are required to synchronize their taps as accurately as possible with an isochronous target sequence whilst a simultaneous isochronous distractor metronome sequence (the "distractor") diverts attention away from the target sequence (Repp, 2005). In the two distractor conditions used by Repp (2003a) and replicated in this experiment, *phase distractors* and *tempo distractors* were used. Phase distractors fall on subdivisions of the beat, avoiding an antiphase condition because its exact subdivision of the pulse is hypothesized to increase timing accuracy rather than hinder it due to it effectively creating a new isochronous beat albeit twice the tempo (Repp, 2003a). Tempo distractors are set to periodically occur at a continuously different tempo to the target sequence (e.g. target metronome set at 500ms and tempo distractor at 340ms) and thus create a continually waxing and waning phase relationship with the target. In the experiment described in this chapter, the stimuli consisted of two auditory metronomes of differing pitch and tempi that were presented simultaneously to the participants under conditions of difference in phase and tempo of the distractor metronomes. Participants were required to tap along with the target metronome pulse and ignore the distractors. By affecting SMS generally, a distractor cues paradigm measures the effect the distractors have on the phase correction response (PCR), the automatic process which mediates tapped responses. Distractor cues disrupt participants' PCRs by exerting the effect of *phase attraction*, causing participants' PCRs to gravitate towards the onset phase of the distractor metronome and away from the target phase onset, a phenomenon which participants have shown difficulty in resisting (Repp, 2002). According to the absence of literature, this has not yet been tested on musicians.

In this experiment, participants' synchronization abilities were measured in relation to a target sequence and two types of periodic distractor sequences (phase and tempo distractors respectively). The experimental variables were the relative phase/tempo differences between the distractor and the target sequence. Dependent variables were the variability of tapped responses and the mean asynchrony of the taps. In SMS research, asynchrony is calculated by measuring the mean and standard deviation of the distance of participants' tap onsets relative to the metronome beat onset (Elliott, 2009; Repp & Su, 2013), and variability is measured in order to calculate the consistency of the taps (inter-response intervals or IRIs). Variability was measured in three ways: 1) "the standard errors of the average relative asynchronies, which reflect differences among participants", "the average between-trials standard deviations of the raw asynchronies", and "the average within-trial standard deviation of the asynchronies" (Repp, 2003a: 296). In the second part of the experiment, the independent variable was manipulated to produce distraction using phase and tempo distractors, in order to see if the distractors influenced the asynchrony and variability of tapped responses, referred to by Repp as *phase attraction*. The degree of phase attraction exerted on participants by the distractors was measured through calculating the change in mean asynchrony as a function of the distractor offset (Repp, 2003a). The overall aim was to measure differences in rhythm synchrony accuracy between participant groups.

3.2 Hypotheses

The central hypothesis of this SMS experiment is that informally trained professional musicians, DJs in this context, will perform better than non-musicians in a task in which they must selectively attend and synchronise movements to a specific beat, both without interference from other sources and under distracting conditions. DJs' performance is expected to approach that of ensemble musicians because of their expertise in the essential DJing technique of "beatmatching", which involves "getting two records to play at the same tempo" (Broughton & Brewster, 2002). Therefore, it is expected that musicians' ability to control and adjust phase and tempo of a beat will be advantageous in the distractor metronome paradigm. It is also hypothesized that DJs will also be susceptible to the NMA in the same way as formally trained musicians and non-musicians, but their results will be more similar to the musicians than those without musical training, especially under distractor conditions. In distractor conditions, it is further hypothesized that tempo distractors will affect tapping asynchronies among all groups more than phase distractors because of their greater irregularity.

To briefly summarize the central hypotheses stated by this thesis, the data collected will be used to test the hypotheses that:

- Professional DJs are less asynchronous in their tapping responses than non-musicians and performed as well as professional musicians, under conditions of no distraction and distraction with tempo and phase distractors.
- Tempo distractors, because of their greater irregularity, will affect tapping asynchronies among all groups more effectively than phase distractors.
- Professional DJs are not as susceptible to phase attraction as non-musicians in distractor conditions, and even outperform professional musicians on account of their perfection of this aspect of SMS ability whilst beatmatching.

The null hypotheses of this research are as follows:

- Experimental conditions have no effect on the populations within groups;
- There is no significant difference in asynchrony and variability between groups.

3.3 Methods

3.3.1 Recruitment process

Three methods of recruitment were used to approach prospective DJ participants: professional DJ contacts of the supervisor (a DJ herself) were utilized, then DJing instructors in the Leeds area were sourced through internet searches and contacted, and thereafter social media was used to establish contact with the DJ friends of prior participants. As this experiment was conducted at the University of Leeds' School of Music, the professional string player participants were recruited from the various orchestras and musician populations that are associated with the university. However, as wide an array of ages was drawn from as possible, so that our sample population did not entirely consist of university students. Our non-musician sample was selected randomly from university administrative staff and friends. In order to recruit supplementary non-musicians and students, a recruitment email was sent to various university lists.

3.3.2 Details of the sample

Data collection for this study occurred over a four-month period. Equally-sized sample groups consisted of 7 professional DJ participants aged between 25 and 43 (mean age=35.71, SD=5.33), 7 string player participants aged between 18 and 60 (mean age=26.56, SD=13.78), and our control group consisted of 7 non-musicians aged between 20 and 37 (mean age=25.43, SD=4.89).

3.3.3 Materials

A musical training questionnaire (Appendix B) was used to determine the respective extents of our participants' musical training so as to make sure that our participants properly fit the respective categories of our study (professional string player, professional DJ and non-musician). Thereafter, participants' tapping responses were recorded using a pressure sensor and a DAQ (data acquisition device) and a laptop running MatTAP Toolbox for Matlab, a toolbox specifically designed for the capturing and statistical analysis of synchronization timing (Elliott et al., 2009). Figure 5 illustrates the experimental setup.

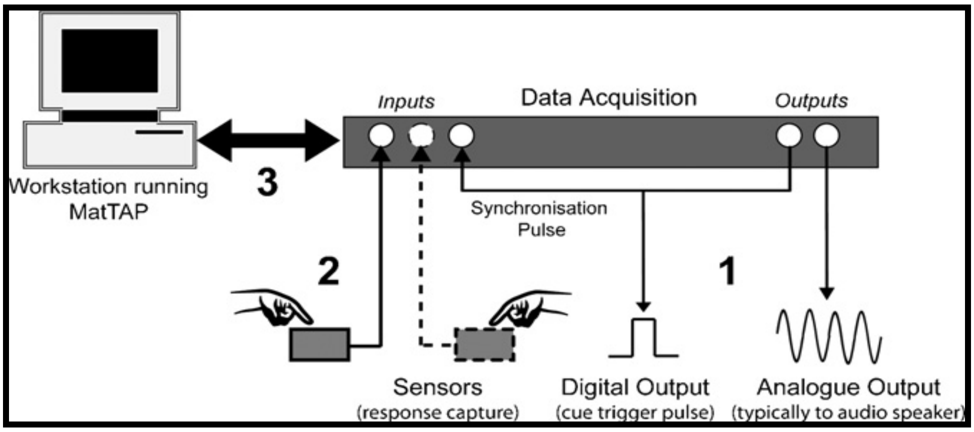


Figure 5

Experimental setup of equipment used in this study. Figure used with the permission of Elliott et al., 2009.

MatTAP software and equipment developed by researchers at the University of Birmingham were used to measure participants' inter-response intervals (IRIs) and asynchronies relative to the interonset invervals (IOIs) of the target and distractor metronomes. This software affords an extremely high degree temporal resolution with almost no jitter (Elliott et al., 2009). The MatTAP GUI (see Figure 6) allows the user to specify the settings (pitch, duration, inter-stimulus interval/ISI) of a target metronome and also of up to two additional metronomes that can be set to different tempos and degrees of offset in relation to the target metronome. For a series of experiments, MatTAP can also be automatically activated using a pre-prepared parameter script in which the settings are specified in an Excel spreadsheet beforehand and loaded into the GUI as an Excel .csv file. The conditions stipulated in this parameter script were randomized for each participant in our experiment to avoid order effects.

3.3.4 Experimental conditions

The experiment consisted of a total of 23 experimental conditions (7 baseline, 8 phase distractor and 8 tempo distractor), each with 3 trials per condition, making a total of 69 trials per participant, each trial lasting approximately 30 seconds. The instructions for this experiment are describe in Box 1 on the following page. In the baseline conditions (BL) of this experiment, the auditory stimulus consisted of a simple metronome pulse 30ms long.

Baseline Conditions 1-7 were established in order to measure participants' asynchrony mean and variance under normal conditions, i.e. without distraction.

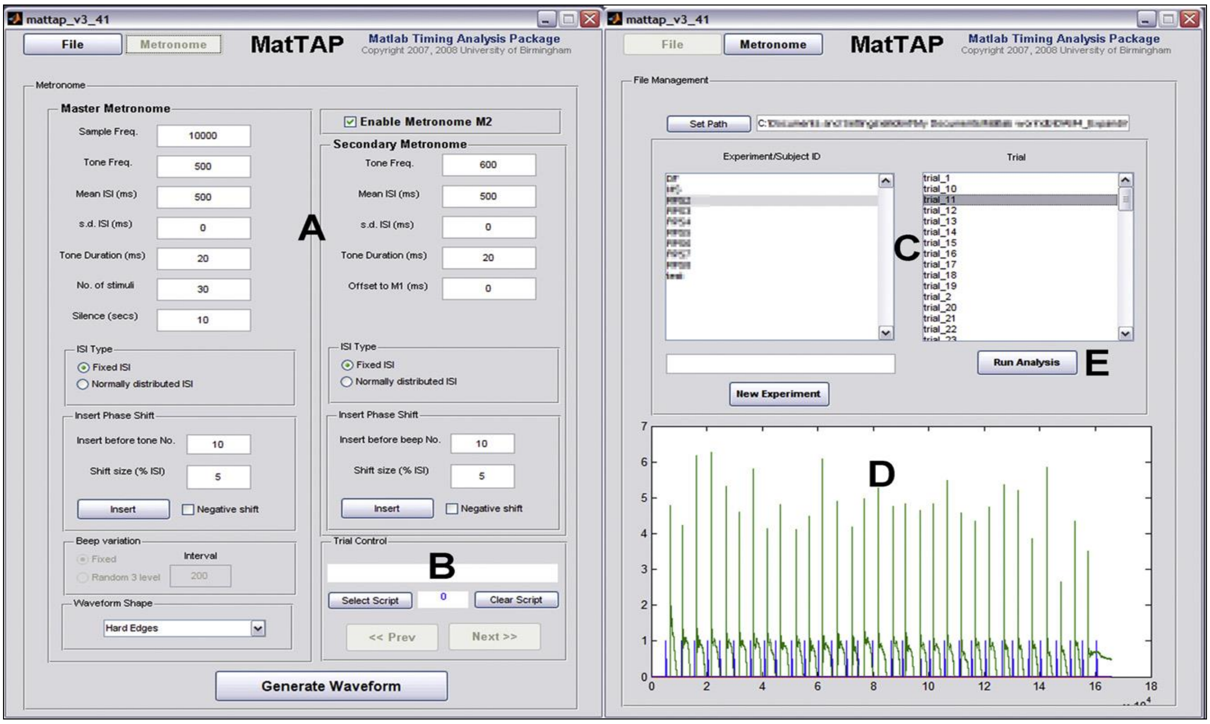


Figure 6

MatTAP GUI. Used with permission of Elliott et al., 2009.

In the following experiment there are 2 conditions that will be presented to you in a random order: **Condition 1**: You will hear a single metronome and be expected to tap along with it as synchronously as possible (i.e. at the same time) **Condition 2**: You will hear a single metronome for 5 beats (the Target Metronome) after which a second conflicting metronome (the Distractor Metronome) will be heard. Your task will *always* be to tap along with the first metronome you hear from the first beat that becomes audible. Please tap firmly in the centre of the sensor provided. Both metronomes will be distinguishable from one another by a significant difference in pitch. The Distractor Metronome should be ignored as best as you can. Please note the aim of the Distractor Metronome is to distract, so please do not be disheartened; just fixate your attention on the Target Metronome (the one that sounds first) and *do your best*! Once the trial starts, you can press the pause button at any in an emergency, but it will be best to work as quickly through the conditions as possible. Introducing breaks into the experiment may compromise the data and also will make the experiment take much longer.

Box 1

Participant instruction sheet

These conditions established participants' tapping responses to 6 different tempi: 340ms (BL1), 420ms (BL2), 580ms (BD3), 660ms (BL4), 750ms (BL5) and 500ms (BL6/TD5 and BL7/PD5). In the distractor conditions of this experiment, the auditory stimuli consisted of a simple target metronome with an interonset-interval (IOI) of 500ms in all trials, and in addition, a single periodic phase distractor (PD) or tempo distractor (TD) metronome was introduced after the initial 5 target tones of the target metronome. In accordance with parameters established in Repp's foundational distractor cue experiments (2003a), phase distractors 1-9, represented by ▲ ("temporal displacement of the distractor tones relative to the target tones") (p. 295), occurred at -160ms (PD1), -80ms (PD2), -40ms (PD3), -20ms (PD4), 0ms (PD5, which was technically a baseline condition, referred to as BL6 in the rest of the thesis), +20ms (PD6), +40ms (PD7), +80ms (PD8), and +160ms (PD9). Tempo Distractors 1-9 occurred at 340ms (TD1), 420ms (TD2), 460ms (TD3), 480ms (TD4), 500ms (TD5, which was technically a baseline condition, referred to as BL7 in the rest of the thesis), 520ms (TD6), 540ms (TD7), 580ms (TD8) and 660ms (TD9.

Both target, phase and tempo distractor metronomes were consistently periodic. The target metronome per trial maintained a pitch of 440Hz, while distractor metronomes of both distractor conditions were maintained at 700Hz. Pitch differences have been previously found to have no noticeable effect on synchronization in distractor cues experiments (Repp, 2003a), however, in the target and distractor metronomes were nonetheless differentiated by pitch to facilitate auditory stream segregation, which best replicated the pitch differences that occur under ecologically valid musical settings. Therefore differing pitches within the range of normal human hearing were arbitrarily chosen. Tables 2, 3 and 4 below show the exact MatTAP specifications for each condition.

	Tone Frequency	**Inter Stimulus Interval (ISI)**	**Baseline (BL) Condition Tempo**	**Number of stimuli**	**Tone Duration**
Target Metronome (TM)	440Hz	500ms	BL1: 340ms BL2: 420ms BL3: 580ms BL4: 660ms BL5: 750ms BL6: TD5 BL7: PD5	30	30ms

Table 2
Baseline (BL) trials and conditions 1-7 MatTAP settings

	Tone Frequency	Inter Stimulus Interval (ISI)	Offset	Number of stimuli	Tone Duration
Target Metronome (TM)	440Hz	500ms	N/A	30	30ms
Phase Distractor (PD) Metronome	700Hz	500ms	PD1: -160ms PD2: -80ms PD3: -40ms PD4: -20ms PD5: 0ms PD6: +20ms PD7: +40ms PD8: +80ms PD9: +160ms	25	30ms

Table 3
Phase Distractor (PD) trials and conditions 1-9 MatTAP settings

	Tone Frequency	Inter Stimulus Interval (ISI)	Phase shift magnitude (length of phase shift as a percentage of mean ISI)	Number of stimuli	Tone Duration
Target Metronome (TM)	440Hz	500ms	N/A	30	20ms
Tempo Distractor (PD) Metronome	700Hz	TD1: 340ms TD2: 420ms TD3: 460ms TD4: 480ms TD5: 500ms TD6: 520ms TD7: 540ms TD8: 580ms TD9: 660ms	TD1: 735ms TD2: 595ms TD3: 543ms TD4: 521ms TD5: 500ms TD6: 481ms TD7: 463ms TD8: 431ms TD9: 379ms	TD1: 36 TD2: 29 TD3: 27 TD4: 26 TD5: 25 TD6: 24 TD7: 23 TD8: 21 TD9: 18	20ms

Table 4
Tempo Distractor (TD) trials and conditions 1-9 MatTAP settings

3.3.5 Analytical procedure

The analytical procedure began with establishing SMS accuracy for each participant for each condition and trial by calculating the mean and standard deviation of asynchronies in relation to the target metronome for each participant (N = 30) for 3 conditions (3x5 Baseline Conditions, 3x9 Phase Distractor Conditions, and 3x9 Tempo Distractor). This was calculated in Matlab in the MatTAP Toolbox (Elliott, 2009) by averaging asynchronies in each individual trial over taps 9-29, excluding first 8 taps because cumulative effect of distraction only apparent after first few taps) across the 3 trials for all conditions. The mean and standard deviation of participants' inter-response intervals (IRIs) for each trial were also calculated for taps 9-29. Once this was accomplished, the overall mean and standard deviation for each separate condition was also calculated, i.e. combined means of all 3 trials for each condition. These calculations were essential for the next step of the analysis in which descriptive statistics were used to substantiate suspected differences in the data and ANOVA was conducted to assess between-group comparisons.

3.4 Analysis

3.4.1 Analysis of baseline (BL) conditions

3.4.1.1 Assumptions and hypotheses

Repp and Su (2013) state that under normal conditions in which a participant is required to tap along with a simple auditory metronome, a large majority of participants display the effects of the negative mean asynchrony (NMA), meaning that their tapped responses tend to consistently anticipate the metronome onset (see Chapter 2.2). With regards to our participant groups, the following hypotheses are drawn from this assumption:

1. Non musicians (NMs) will display the greatest negative mean asynchrony, whilst classical performers (CPs) and DJs will have smaller negative mean asynchronies, i.e. their tapped responses falling relatively closer to the metronome onset. This effect would indicate a more highly developed error correction response (ECR), developed through informal and formal musical training respectively.
2. CPs' and DJs' asynchronies will be less variable, showing that their ECR is more stable than NMs.

3.4.1.2 Measurement process

The data used in this part of the experiment were as follows: BL conditions 1-5, BL6/PD5 (equivalent to BL6 because the distractor was set to 0ms) and BL7/TD5 (equivalent to BL7 because the distractor was set to 0ms) for all participants; x3 trials per condition = 69 trials x 21 participants.

The following steps were used in order to obtain the various measurements described in the results and discussion:

1. Calculate (in Excel) the negative mean asynchrony (NMA) and standard deviation of NMAs for each separate trial and condition, for each participant of BL condition trials (e.g. Participant 1, BL condition 1 NMA: trial 1 = –10.29, trial 2 = –14.50, trial 3 = –26.82).
2. Calculate (in Excel) the mean NMA and mean SD for all three trials that make up each condition (e.g. Participant 1 mean NMA and SD of three BL1 trials: NMA = –17.20ms, SD = 16.40). Input these calculations into SPSS.
3. Separate participants into groups in SPSS and find the within-group mean NMAs and mean SDs. Run ANOVA to compare NMAs and SDs between groups in order to validate Hypotheses 1-3.

3.4.1.3 Results and discussion

Appendix E displays the descriptive statistics with regards to participants NMAs derived from an ANOVA run in accordance with Step 3. Baseline condition NMAs for conditions BL2 ($F(2,18) = 3.07$, MS = 1518.99, $p = 0.071$), BL4 (F(2,18), MS = 2749.14, $p = 0.085$) and BL6/TD5 (F(2,18), MS = 1939.02, $p = 0.066$) show non-significant results (i.e. $p > 0.05$) while BL 7 (PD5) showed a statistically significant result (F(2,18), MS = 2750.75, $p = 0.045$), suggesting that there might be valid differences between groups. To summarize, ANOVA showed that most between-group differences in negative mean asynchronies were not statistically significant except for one condition (BL7/TD5), which found significant asynchronies. Figure 7 illustrates the between-group differences more clearly in some of the baseline trials, validating Hypothesis 1: NMs will show the greatest NMA in most baseline conditions, while DJs and CPs would have smaller NMAs, indicating a more highly developed error correction response (ECR), developed through informal and formal musical training respectively. The unconvincing level of statistical significance described in the results of the ANOVA may be due to the small size of the sample populations used in this experiment.

Appendix E displays the descriptive statistics relating to participants standard deviation of asynchronies (SDasy) derived from an ANOVA run in accordance with Step 3. None of the SDasy conditions produced statistically significant differences between groups variability of asynchrony in baseline conditions. However, the between-group means of the SDasy were clearly very different from one-another, and in many trials followed a similar pattern, with CPs and DJs showing the least variability in their asynchronies, suggesting that Hypothesis 2 (CPs' and DJs' asynchronies will be less variable) was well-founded and that these two groups ECRs are more stable than NMs regardless of the lack of significant differences.

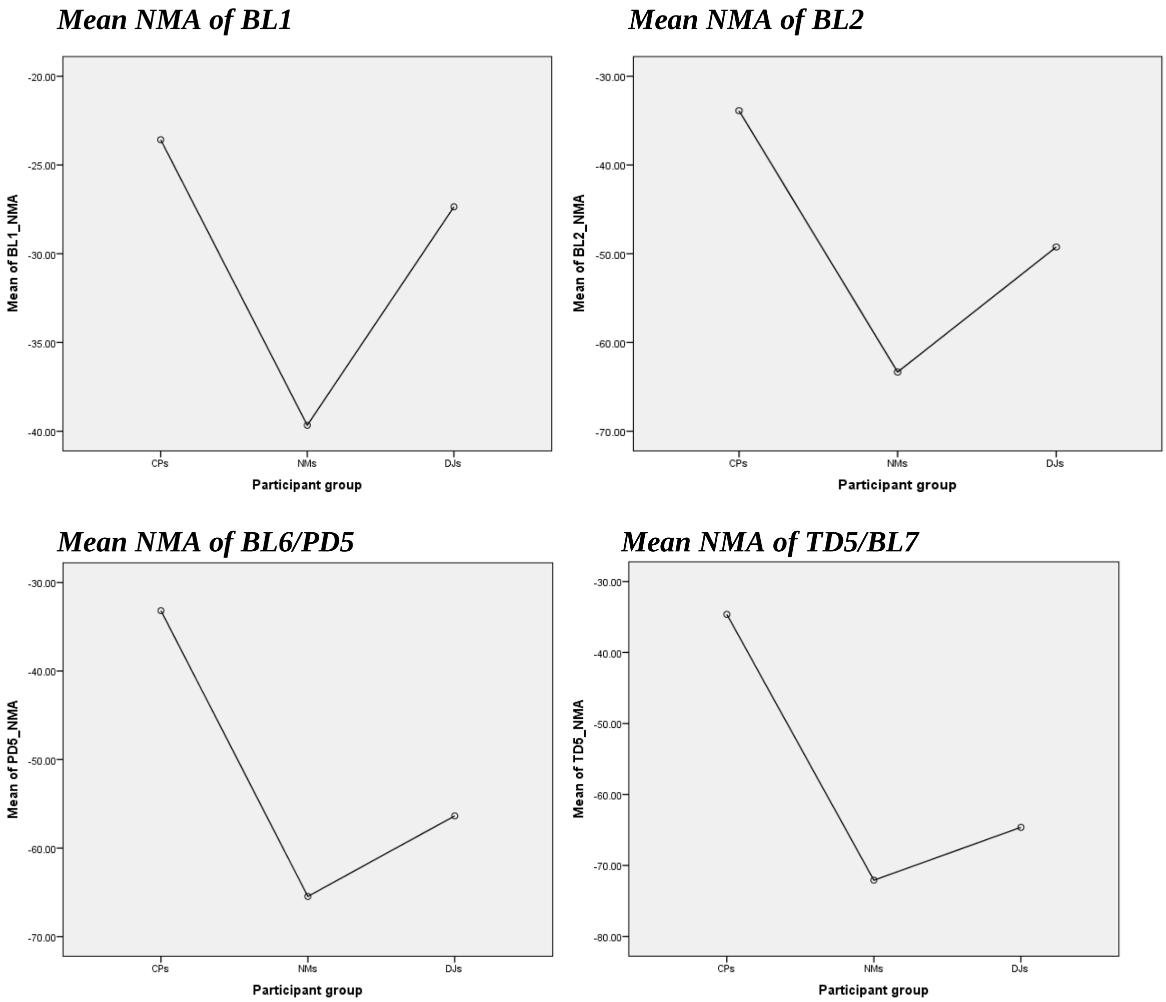
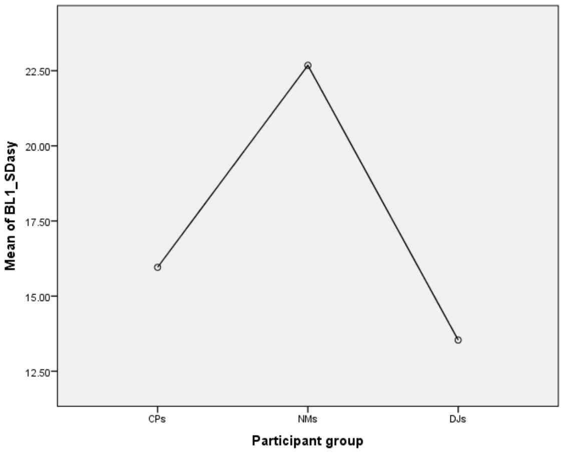


Figure 7

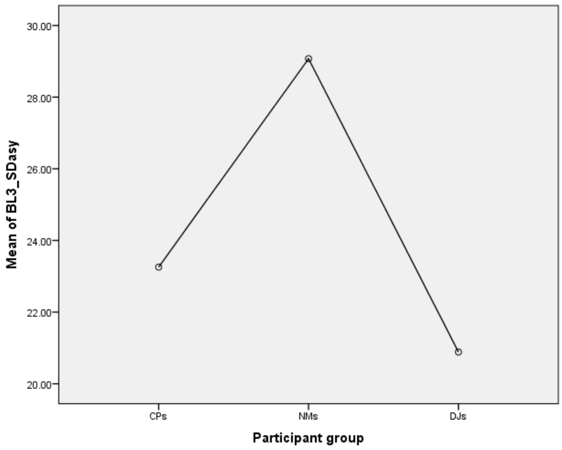
Between-group comparisons of selected BL trial NMAs

Figure 8 a) and b) show plots and histograms illustrating describing the between-group mean differences in SD of inter-response intervals in BL trials, further illustrating that DJs were the least variable in their tapped responses. Surprisingly, as indicated by Figure 8 a), CPs were the most variable in BL trials, even more so than NMs, however, this trend was not visible when all trials were averaged, as illustrated in Figure 8 b).

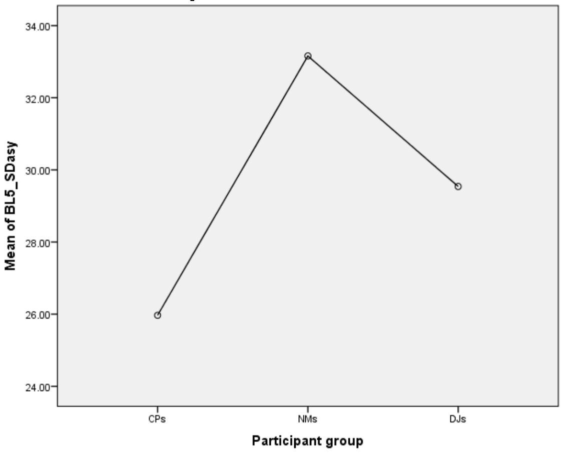
SD NMA of BL1



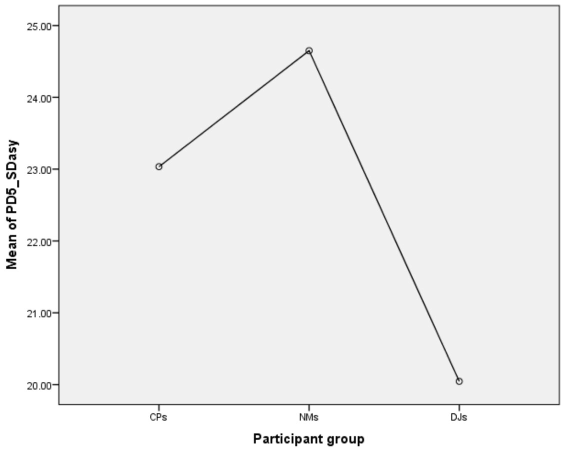
SD NMA of BL3



SD NMA of BL5



SD NMA of BL6/PD5



SD NMA of BL7/TD5

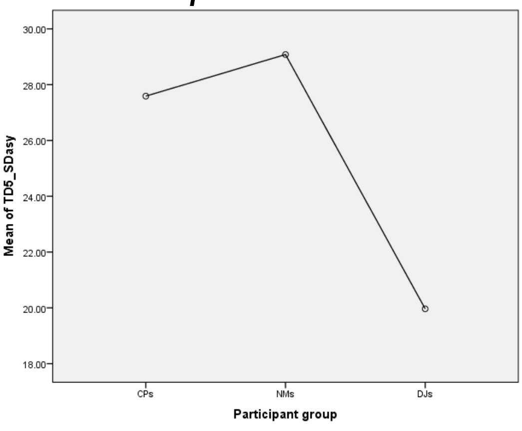


Figure 8a

Between-group comparisons of selected BL trial SD of NMAs

SD of BL IRIs

SD of IRIs over all conditions

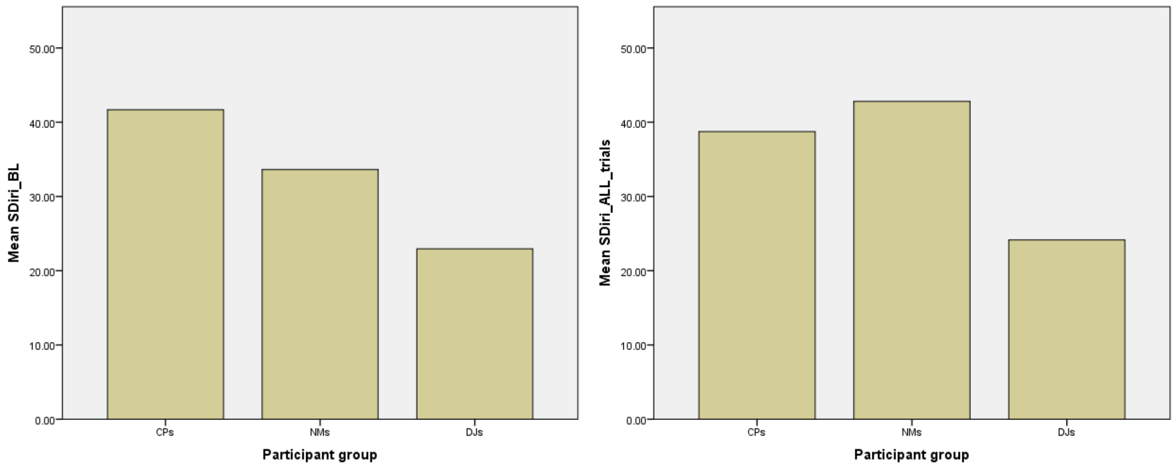


Figure 8b
Between-group differences in SD of IRIs between BL and over all conditions

3.3.2 Analysis of phase distractor (PD) conditions

3.3.2.1 Assumptions and hypotheses

Repp (2003) states that if the phase distractor (PD) is within a range of 20% of the target metronome's (TM's) IOIs (in this case, 20% of 500ms is 100ms), then the effect of phase attraction is at its height, but once it crosses this threshold, the effects of phase attraction become less noticeable. The effect of phase attraction on SMS is that the participants' tapped responses (i.e. asynchronies) are drawn in the direction of the distractor. With regards to our conditions and participant groups, the following hypotheses are drawn from this statement, which will then be tested through an examination of the data:

1. In trials where the PD *precedes* the TM within a threshold of approximately 20% of the TM IOI, i.e. trials PD1 and PD2 with offsets of -80ms and -160ms (which represent 16% and 32% of the TM IOI respectively), the relationship between non-musicians' asynchronies and the PD tone will be closer than what they would have been in relation to the TM in a baseline condition (i.e. measured in relation to their BL mean asynchrony) as a result of the effects of cumulative phase attraction in the direction of the PD metronome beat. The overall effect is that their NMA will be greater than it had been in BL conditions, showing the effects of phase attraction.
2. In trials where the PD comes *after* the TM within a threshold of approximately 20% of the TM IOI, i.e. trials PD8 and PD9 of +80ms and +160ms (which represent 16% and 32% of the TM IOI respectively), non-musicians' asynchronies will be closer to the

TM tone, i.e. their NMA will be smaller in relation to the TM. The overall effect is that their NMA mean will be *less* asynchronous than it would have been in the BL conditions as a result of phase attraction in the direction of the PD tone.

3. In CP and DJs, asynchronies from the TM will be similar in BL and PD conditions, even when the PD is within the 20% threshold, showing less effects of phase attraction. The overall effect is that their NMAs for PD and BL conditions will be approximately the same.

3.3.2.2 Measurement process

The data used in this part of the experiment is as follows: PD1, 2, 8, 9 and BL mean NMA over all BL trials. The following steps were adhered to in order to obtain the various measurements described in the results and discussion:

1. Take BL mean (over all conditions) as a point of reference in relation to which the IRIs in PD conditions will be measured.
2. Find PD NMA for: a) PD1 (x3 trials per condition= mean of 3 trials) and PD2 (x3 trials per condition= mean of 3 trials) and b) PD8 (x3 trials per condition= mean of 3 trials) and PD9 (x3 trials per condition= mean of 3 trials).
3. Calculate the difference between the answer to step 1 and step 2 a) and b) in order to obtain the effect of phase attraction in that particular trial.

3.3.2.3 Results and discussion

Table 5 on the following page describes the different participant groups' respective NMAs in the baseline conditions in relation to their NMAs in the relevant PD conditions (1, 2, 8, 9). Hypothesis 1 stated that if PD1, 2 NMAs > BL NMAs (i.e. the NMA is bigger in the direction of the distractor for all NMAs for PD1, 2 trials). The results indicate that only non-musicians showed the effects of phase attraction on their taps in the PD1 condition, showing a large increase in NMA of -32.32ms, while classical performers and DJs showed a slight decrease in NMAs in relation to their respective baseline condition NMAs. In the PD2 condition, CPs NMAs increased by 3.25ms, DJs by 1.44ms, while NMs showed the most marked effect of phase attraction as their NMA increased by 42.74ms, effectively almost doubling their NMA in these trials. These results confirm that phase attraction had a larger effect on the non-musicians in the PD1 and 2 trials, and that DJs' performance was on a par with CPs, showing little effect of phase attraction on the respective musician groups; again, despite the lack of statistical significance due to small sample sizes.

Participant group	Condition	Mean	SD
Classical Performers	BL (all conditions)	-31.62	10.04
	PD1	-23.70	16.62
	PD2	-34.86	21.98
	PD8	-0.72	32.80
	PD9	1.29	51.30
DJs	BL (all conditions)	-53.00	23.50
	PD1	-50.63	38.68
	PD2	-54.44	66.19
	PD8	-41.79	19.92
	PD9	-25.25	15.33
Non-musicians	BL all conditions	-53.96	23.58
	PD1	-86.29	54.34
	PD2	-96.71	36.72
	PD8	-23.09	49.32
	PD9	-9.54	25.58

Table 5
Comparison between NMAs in BL and PD1, 2, 8, and 9

The second hypothesis suggested that PD8, 9 NMAs should be ≤ BL NMAs in the direction of the distractor for all NMAs for conditions PD8 and PD9. The results for PD8 and PD9 suggested that all three participant groups showed the effects of phase attraction in both trials, indicated by a marked decrease in the NMAs of PD8 and 9. In the PD8 and 9 conditions, CPs showed a mean asynchrony decrease of 30.9ms and 32.9ms in the direction of the distractor, leading to a positive asynchrony in the PD9 condition. Non-musicians showed large decreases in NMA, 30.87ms and 44.43ms in relation to the baseline NMA, while DJs showed the smallest effect of phase attraction with decreases of 11.21ms and 27.76ms. Finally, it was hypothesized that PD1, 2, 8, 9 trials NMAs would be approximately equal to the BL NMA for CP and DJ groups, indicating that they were less susceptible to phase attraction than NMs. Nearly all conditions showed the effects of phase attraction regardless of participant group, so this hypothesis could not be confirmed. The change in DJs NMAs for PD conditions 1, 2, 8 and 9 in relation to the BL NMAs showed that DJs were the least susceptible to phase attraction out of the three participant groups.

3.3.3 Analysis of tempo distractor (TD) conditions

3.3.3.1 Assumptions and hypothesis

In tempo distractor conditions, the phase relationship between the tempo distractor (TD) metronome and the target metronome (TM) is continually changing. As Repp states (2013: 291) "this paradigm tests participants' ability to maintain synchrony with the target sequence in the presence of a systematically waxing and waning (and periodically reversed) phase attraction exerted by the distractor tones", resulting in "periodic modulations of the asynchronies." This lead to the following hypothesis regarding our participant groups in TD conditions: periodic modulations of their inter-response intervals (IRIs) resulting from the phase attraction exerted by distractor tones will be more pronounced in NMs, while CPs and DJs will show smaller variability in their IRIs for TD trials.

3.3.3.2 Measurement process

The data used in this part of the experiment is as follows: BL1-7, TD 1-4 and TD 6-9. To briefly restate: TD5 is omitted because this is technically our BL7 as the interonset-interval (IOI) of the TD is the same as the TM in this trial (i.e. 500ms). The following steps were adhered to in order to obtain the various measurements described in the results and discussion:

1. Calculate the SD of IRIs for TD1-4 and 6-9 for each individual participant and find the mean SD IRI for each trial.
2. Calculate the mean SDasy for each TD condition (mean of 3 trials=1 condition) and compare SDasy of the TD trials with the SDasy of the BL trials.

3.3.3.3 Results and discussion

Results (Table 6 on the following page) indicated that the mean SDasy for TD1-4, 6-7 increased for all participants in relation to each group's baseline conditions SDasy mean, suggesting that periodic modulations of asynchrony increased in TD conditions for all participant groups. In TD conditions, CPs' SDasy mean increased by from 25.28 in the BL conditions to 36.66 in the TD conditions, while non-musicians' and DJs' SDasy mean increased from 27.01 to 37.67 and 20.99 to 33.25. As non-musicians' variability of asynchrony decreased the least out of all participant groups in these trials, the hypothesis with regards to the TD conditions was not substantiated.

Participant group	Condition	Mean
Classical Performers	BL all conditions SDasy	25.28
	TD all conditions SDasy	36.66
Non-musicians	BL all conditions SDasy	27.01
	TD all conditions SDasy	37.67
DJs	BL all conditions SDasy	20.99
	TD all conditions SDasy	33.25

Table 6
Comparison of BL SDasy and TD SDasy

3.4 Discussion

The aim of this quantitative investigation was to establish the degree of sensorimotor synchronization ability developed through formal and informal learning respectively. To this end, professional string players, non-musicians and professional DJs were tested to explore between-group differences. Baseline conditions were used to establish their general SMS abilities under normal conditions, then under increasingly distracting conditions, using both phase distractors and tempo distractors in a total of 23 conditions. Each randomized condition was repeated three times giving a total of 69 trials per participant in the experiment as a whole.

Differences could be inferred from the data under baseline conditions, but due to small sample-sizes, these differences only approached significance in the subsequent ANOVA. However, a similar pattern could be seen in many of the trials, suggesting that classical performers (CPs) showed the smallest negative mean asynchronies (NMAs), while DJs and non-musicians (NMs) had similar asynchrony means, with DJs showing a slightly smaller NMA than NMs. DJs' asynchronies proved to be the least variable out of the participant groups, showing that their ECRs were more stable than the other two groups even though their NMAs were not as small as the CPs'.

This experiment also tested SMS ability under two conditions of distraction, phase distraction (PD) and tempo distraction (TDs) respectively. In the phase distractor conditions, the cumulative effects of phase distractors on the rhythmic perception of participants led to phase attraction of taps in the direction of the distractor sequence for all participant groups. Results suggested that DJs were the least susceptible to phase attraction out of the three participant groups. In tempo distractor conditions, similar increases in periodic modulations of asynchrony were noted for all participant groups, with non-musicians surprisingly showing the least effect on the variability of their tapped responses in these conditions.

These results suggest that DJs develop cognitive/perceptual skills through DJing, that those skills can be measured through sensorimotor synchronization experiments, and that in some respects those skills approach those of formally trained musicians. It is hoped that these results might stimulate further investigation of the cognitive skills and abilities that are being developed in response to advances in technology, and a greater inclusion of informal learning practices into the contemporary music classroom. Finally, it is indirectly asserted in this thesis that success at a sensorimotor synchronization task involving distraction must also directly involve the cognitive faculty that stops one from becoming distracted, i.e. attention, and that this type of research has a wider bearing on cognition research with regards to attention as a result.

4. General discussions, limitations and suggestions for further research

4.1 General discussion

The primary aim of this research was to establish the importance of cognitive skills learned through DJing, and perspectives on the potential value of DJing for music education. This thesis described two studies. The first study aimed to qualitatively investigate contemporary perspectives on the potential value of DJing for music education. Once perspectives on this potential value had been qualitatively established, the second study quantitatively investigated the cognitive abilities derived from informally learning how to DJ. Sensorimotor synchronization (SMS) under distraction was investigated quantitatively as it was considered to be a way of accurately measuring the extent of cognitive abilities relating to rhythm perception; rhythm perception was the first area it was decided would be valuable to explore between-group differences between classical performers and DJs.

In order to establish contemporary perspectives on the potential value of DJing for music education in the first study, 21 DJ, classical performer and non-musician participants were asked three questions in order to establish their perceptions concerning the cultural relevance of DJing, the skills that might be learned through DJing and how DJing might be incorporated into formal music education curriculums. Perspectives emerged that showed participants in all three categories felt that DJs learn valuable musical skills through this creative medium; skills that are not only specific to DJing but to music education generally, including rhythm perception, harmonic perception, instrumental skills, knowledge of musical structure, performance skills and stylistic knowledge. A majority of participants agreed that DJing had equal relevance with other musical forms (e.g. classical music) and that DJing had a high degree of contemporary relevance, especially in popular culture, relevance that was not shared by other more formal musical idioms under consideration. On the whole, non-musicians were the most sceptical of the value of DJing in society and education. The final question was intended to establish if people felt that DJing lessons should be offered alongside traditional music lessons as part of a formal music education, and again, a majority (62%) of participants stated that DJing lessons should be offered and out of the remainder, a minority claimed that they should be optional (14%). These results merited further investigation into the cognitive/perceptual skills/abilities developed through DJing in order to establish the degree of sensorimotor synchronization (SMS) ability developed through formal and informal learning respectively. By investigating these abilities, empirical substantiation for the incorporation of DJing into the music classroom in addition to those provided by the perceptions of our participants was hopefully established.

The SMS study therefore tested SMS ability among professional string playing classical performers, non-musicians and professional DJs by having them tap along with various auditory sequences under increasing distraction in order to see if any significant differences occurred in their tapped responses. Under normal/baseline (BL) conditions it was found that differences could be inferred from the data, but due to small sample-sizes, these differences only approached significance in the subsequent ANOVA despite the emergence of patterns in many of the trials that suggested differences. Overall, DJs asynchronies proved to be the least variable out of the participant groups, showing that their error correction responses (ECRs) were more stable than the other two groups even if their (negative) mean asynchronies (NMAs) were not as small as the classical performers'. This experiment tested SMS ability under two conditions of distraction, phase distraction (PD) and tempo distraction (TDs) respectively. In the PD conditions, the cumulative effects of phase distractors on the rhythmic perception of participants led to phase attraction of taps in the direction of the distractor sequence for all participant groups. Results suggested that DJs were the least susceptible to phase attraction out of the three participant groups. In TD conditions, similar increases in periodic modulations of asynchrony were noted for all participant groups, and it was concluded that there were no significant differences between groups for this condition. These results suggest that DJs may develop cognitive/perceptual skills through DJing and that sensorimotor synchronization experiments may be a successful way of investigating these skills, but that the experimental conditions need to be re-evaluated, particularly those relating to the TD condition.

It is hoped that these results might stimulate a greater inclusion of informal learning practises into the contemporary music classroom, and further investigation of the cognitive skills and abilities that are being developed by informally trained musicians in response to advances in (music) technology.

4.2 Limitations of the studies

Limitations relating to the study concerning perspectives on the value of DJing for music education were mainly due to the conjectural nature of those perspectives. The random sample of DJs, classically trained performers and non-musicians were not always equipped to articulate their views on the subject, and in some cases their responses did not address the questions directly, or their views were not particularly developed.

Furthermore, reliable accounts were difficult to establish with regards to levels of formal *and* informal training in the absence of longitudinal studies that would necessarily span long periods of time. Due to the exhaustive nature of such a study, this research was consequently forced to rely on self-report and certain markers of achievement (e.g. formal examinations or measures of professional experience). Issues that arose in quantifying levels of musical training and professionalism were as follows:

- Degrees of professionalism (eg. is someone that performs regularly for money more professional than someone that performs less regularly?),
- Degree to which formally trained musicians adopt informal training strategies to learn a number of other instruments which they are familiar with but not expert in, as well as applying informally learned techniques to their formally learned art, and
- Degree to which non-musicians were informally trained in music.

In the second study, this research was further limited by the fact that sensorimotor synchronization studies require a great many trials in which participants have to sit and tap. This study was comparatively short, running just short of half an hour, but the majority of our participants showed obvious signs of boredom within the first 10 minutes. Problems with the auditory stimuli were also reported. For example, the metronomes were fairly high-pitched (TM=440Hz, PD=700Hz, TD=700Hz) and in one case a participant complained that it had aggravated her tinnitus. Pitches were arbitrarily chosen on the grounds that Repp (2003) concluded that the pitch of the stimuli has no effect on SMS performance, but future studies might consider which pitches are the least aggravating for participants.

The fundamental problem encountered in this study was due to the small sample group sizes, which made it difficult to infer statistical significance from our results despite clear differences in some of the measures, and visible differences when the data was graphically visualised.

4.3 Suggestions for further research

As well as measuring of SMS ability, the results obtained in this study may also suggest that further investigation into the differences in auditory attention between these diverse participant groups is warranted, thereby adding to research concerned with the degree to which formal musical training and informal musical practices enhances this cognitive faculty. It is possible that this research might also be applicable to the study of cognition more generally as SMS ability is linked with the cognitive faculty of perception because of the direct (and often automatic) evocation of motor actions in response to what is heard/perceived; it is therefore established in the literature that musical abilities are linked with cognitive fields like perception, attention, memory and visuospatial functions (Jäncke, 2006). For example, like natural musical practices, SMS tasks invariably require the underlying cognitive faculty of auditory attention, and even more so, it is hypothesized, within a distractor cues paradigm. Recent research has already found that training is capable of improving attention (Soveri et al., 2013), and particularly that musical training affects selective auditory attention (Strait et al., 2010; Strait & Kraus, 2011). An interesting development on this research would be to look at the different types of attention that are developed within the context of DJing such as selective/focused attention ("cocktail party phenomenon"), sustained attention, and divided attention. Attention across modalities might also be explored in order to test the overall performance of the respective populations an extra-musical distractor task is introduced (e.g. silent reading), which could establish whether general attention-related faculties and not only auditory attention is developed through musical practices; however, it is not the argument of this thesis that musical training should have to justify itself according to its extra-musical outcomes, in agreement with Rauscher (2009). Other possible studies that would further investigate the cognitive skills developed through DJing could include an adaptive timing study in which phase perturbations/shifts occurring in the target sequence could be used to investigate phase correction responses (measured through phase shifts below point of JND - =/- 10% of the IOI) (Repp 2010) and period correction (measured through the use of phase shifts above point of JND) (Mates, 1994; Schulze et al., 2005) under distraction.

Future research might also assess the views of a wide sample group of formal music educators in order to establish how DJing might be integrated into a school curriculum. Interviewing DJing instructors may also yield data as to how a “formal” educational methodology for DJing lessons might be implemented.

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Appendices List

Appendix A – Ethical review form

UNIVERSITY OF LEEDS RESEARCH ETHICS COMMITTEE APPLICATION FORM 1

UNIVERSITY OF LEEDS

Please read each question carefully, taking note of instructions and completing all parts. If a question is not applicable please indicate so. The superscripted numbers (eg8) refer to sections of the guidance notes, available at www.leeds.ac.uk/ethics. Where a question asks for information which you have previously provided in answer to another question, please just refer to your earlier answer rather than repeating information.

Research ethics training courses: http://ris.leeds.ac.uk/EthicsTraining

To help us process your application enter the following reference numbers, if known and if applicable:

Ethics reference number:	
Student number and/ or grant reference:	

PART A: Summary

A.1 Which Faculty Research Ethics Committee would you like to consider this application?2

- (●) Arts and PVAC (PVAR)
- ( ) Biological Sciences (BIOSCI)
- ( ) ESSL/ Environment/ LUBS (AREA)
- ( ) MaPS and Engineering (MEEC)
- ( ) Medicine and Health (Please specify a subcommittee):
- ( ) Leeds Dental Institute (DREC)
- ( ) School of Healthcare (SHREC)
- ( ) School of Medicine (SoMREC)
- ( ) Institute of Psychological Sciences (IPSREC)

A.2 Title of the research3

Effects of distractor cues on sensorimotor synchronization in DJs

A.3 Principal investigator's contact details4	
Name (Title, first name, surname)	Dr. Alinka Greasley
Position	Lecturer in Music Psychology and Admissions Tutor
Department/ School/ Institute	School of Music
Faculty	PVAC

Work address (including postcode)	School of Music University of Leeds Leeds LS2 9JT UK
Telephone number	+44 (0)113 343 4560
University of Leeds email address	a.e.greasley@leeds.ac.uk

A.4 Purpose of the research:5 (Tick as appropriate)

- [x] Research
- [ ] Educational qualification: Please specify: ________________________
- [ ] Educational Research & Evaluation6
- [ ] Medical Audit or Health Service Evaluation7
- [ ] Other

A.5 Select from the list below to describe your research: (You may select more than one)

- [x] Research on or with human participants
- [ ] Research with has potential significant environmental impact.8 If yes, please give details:

____

- [x] Research working with data of human participants
- [x] New data collected by questionnaires/interviews
- [ ] New data collected by qualitative methods
- [x] New data collected from observing individuals or populations
- [ ] Research working with aggregated or population data
- [ ] Research using already published data or data in the public domain
- [ ] Research working with human tissue samples9

A.6 Will the research involve any of the following:10 (You may select more than one) If your research involves any of the following an application must be made to the National Research Ethics Service (NRES) via IRAS www.myresearchproject.org.uk as NHS ethical approval will be required. There is no need to complete any more of this form. Contact governance-ethics@leeds.ac.uk for advice. ☐ Patients and users of the NHS (including NHS patients treated in the private sector)11 ☐ Individuals identified as potential participants because of their status as relatives or carers of patients and users of the NHS ☐ Research involving adults in Scotland, Wales or England who lack the capacity to consent for themselves12 ☐ A prison or a young offender institution in England and Wales (and is health related)14 ☐ Clinical trial of a medicinal product or medical device15 ☐ Access to data, organs or other bodily material of past and present NHS patients9 ☐ Use of human tissue (including non-NHS sources) where the collection is not covered by a Human Tissue Authority licence9 ☐ Foetal material and IVF involving NHS patients ☐ The recently deceased under NHS care ☑ None of the above You must inform the Research Ethics Administrator of your NRES number and approval date once approval has been obtained.
If the University of Leeds is not the Lead Institution, or approval has been granted elsewhere (e.g. NHS) then you should contact the local Research Ethics Committee for guidance. The UoL Ethics Committee need to be assured that any relevant local ethical issues have been addressed.

A.7 Will the research involve NHS staff recruited as potential research participants (by virtue of their professional role) or NHS premises/ facilities? ☐ Yes ☑ No
If yes, ethical approval must be sought from the University of Leeds. Please note that NHS R&D approval is needed in addition: www.myresearchproject.org.uk. Contact governance-ethics@leeds.ac.uk for advice.

A.8 Will the participants be from any of the following groups? (Tick as appropriate)

- [ ] Children under 1616
- [ ] Adults with learning disabilities12
- [ ] Adults with other forms of mental incapacity or mental illness
- [ ] Adults in emergency situations
- [ ] Prisoners or young offenders14
- [x] Those who could be considered to have a particularly dependent relationship with the investigator, eg members of staff, students17
- [ ] Other vulnerable groups
- [ ] No participants from any of the above groups

Please justify the inclusion of the above groups, explaining why the research cannot be conducted on non vulnerable groups.

We are including this group of participants because part of the design involves recruiting musically trained individuals. Asking members of the School of Music –both staff and students – will provide us with a larger potential pool of musically trained individuals, including professional performers.

It is the researcher's responsibility to check whether a DBS check is required and to obtain one if it is needed. See also http://www.homeoffice.gov.uk/agencies-public-bodies/dbs and http://store.leeds.ac.uk/browse/extra_info.asp?modid=1&prodid=2162&deptid=34&compid=1&prodvarid=0&catid=243.

A.9 Give a short summary of the research18

This section must be completed in language comprehensible to the lay person. Do not simply reproduce or refer to the protocol, although the protocol can also be submitted to provide any technical information that you think the ethics committee may require. This section should cover the main parts of the proposal.

The ability to move in time to a simple beat or rhythm is a skill humans can perform easily, often without conscious attention to the task. Formal training undertaken by professional musicians results in a heightened ability to synchronise movements to a beat, demonstrated by lower variability in movement timing and reduced timing errors (asynchronies). Musical skill can be considered to cover a wide range of genres. The increasing complexity in skills demonstrated by professional DJs means there is a strong argument that they should be classified as 'professional musicians' however DJs typically follow a more informal route of training. This study assesses the performance of informally trained DJs during a movement synchronisation task compared with formally trained professional musicians and non-musicians. Participants will be asked to fill out a questionnaire about their levels of musical training, and then asked to take part in a series of experiments in which they will be asked to tap their finger in time to an auditory metronome. To increase task complexity, distractor metronomes (auditory and visual) will also be presented. The distractors will vary in tempo and phase relative to the target metronome to test the limits of the participants' ability to attend to and synchronise with the target rhythmic source. It is hypothesised that DJs and string ensemble players will show similarly accurate performance, with minimal asynchrony and variability; both outperforming non-musicians. In our analysis, we will compare movement timing variability and timing errors among the three groups. The study goes beyond previous investigations of

sensorimotor synchronisation among musical populations through its focus on an underrepresented group, DJs. It enables exploration of the perceptual and attentional abilities developed through informal musical practices which are the source of cognitive-motor skills in musical synchronisation.

A.10 What are the main ethical issues with the research and how will these be addressed?19 Indicate any issues on which you would welcome advice from the ethics committee. All aspects of this research will be carried out in accordance with the Ethical Guidelines provided by the University of Leeds (UREC) and in accordance with the British Psychological Society's (2006) Ethical Principles for Conducting Research with Human Participants (which includes a consideration of deception, consent and debriefing, risk, right to withdraw, and confidentiality). There are no physical or psychological risks associated with taking part in the research. The sample will not be drawn from clinical or vulnerable participant populations. The main ethical consideration is ensuring that participants do not feel pressured into taking part in the study. Students and staff members in the School of Music could be described as 'compromised subjects', given that the two researchers comprise a member of staff (AG) and a research assistant (DM) in the School. To combat this, it will be made clear during recruitment that their participation is entirely voluntary; that they are under no obligation to take part. An additional ethical consideration is that the experiments will be conducted in two separate locations: in the School of Music at the University of Leeds and in the SyMon (sensorimotor synchronisation) Laboratory in the School of Psychology at the University of Birmingham. Ethical review will be sought from the University of Birmingham Research Ethics Committee. Given that all researchers are governed by the same ethical principles (British Psychological Society's Guidelines for Ethical Conduct and Practice, 2009), the same levels of attention to detail regarding issues such as anonymity, confidentiality and briefing/consent will be adhered to in both locations.

PART B: About the research team

B.1 To be completed by students only20	
Qualification working towards (eg Masters, PhD)	
Supervisor's name (Title, first name, surname)	
Department/ School/ Institute	
Faculty	
Work address (including postcode)	
Supervisor's telephone number	
Supervisor's email address	
Module name and number (if applicable)	

B.2 Other members of the research team (eg co-investigators, co-supervisors) 21

Name (Title, first name, surname)	Douglas MacCutcheon
Position	Visiting research assistant
Department/ School/ Institute	School of Music
Faculty	PVAC
Work address (including postcode)	
Telephone number	+44 (0)783 150 8956
Email address	d.maccutcheon@leeds.ac.uk

Name (Title, first name, surname)	Mark Elliott
Position	Research fellow
Department/ School/ Institute	School of Psychology
Faculty	Psychology
Work address (including postcode)	University of Birmingham Edgbaston Birmingham B15 2TT UK
Telephone number	+44 (0)121 414 7260
Email address	m.t.elliott@bham.ac.uk

Part C: The research

C.1 What are the aims of the study?22 (Must be in language comprehensible to a lay person.)

The aims of the study are to quantify the differences in rhythmic synchronization ability between informally trained musicians (DJs), formally trained musicians (professional string players), and non-musicians.

C.2 Describe the design of the research. Qualitative methods as well as quantitative methods should be included. (Must be in language comprehensible to a lay person.)

The design consists of a questionnaire to measure levels of musical training, and a series of experiments to measure sensorimotor synchronisation accuracy under different conditions (e.g. without distractor, with auditory distrator, with auditory and visual distrators).

Questionnaire
Participants will complete a survey regarding their levels of musical training in order to assign them to different groups.

Experiments
Participants will be requested to tap their finger in time to an auditory metronome. To increase task complexity, auditory and visual distractor metronomes will also be presented. The distractors vary in tempo and phase relative to the target metronome to test the limits of the participants' ability to attend to and synchronise only with the target rhythmic source under unimodal and bimodal conditions.

Interviews
DJs in the research will be asked whether they are willing to take part in a semi-structured interview regarding their informal learning practices to contextualise the development of their perceptual and attentional skills more broadly.

C.3 What will participants be asked to do in the study?23 (e.g. number of visits, time, travel required, interviews)

Questionnaire
Participants will be required to complete the questionnaire, which will take approximately 10 minutes.

Experiments
Participants will be asked to come into one of the research locations (either the School of Music, Leeds or the School of Psychology, Birmingham) for two one-hour sessions.

Interviews
Those in the DJ group (but not the other groups) who are willing to be interviewed will be interviewed for one hour about their learning approaches.

C.4 Does the research involve an international collaborator or research conducted overseas:24
(Tick as appropriate)

☐ Yes ☑ No

If yes, describe any ethical review procedures that you will need to comply with in that country:

Describe the measures you have taken to comply with these:

Include copies of any ethical approval letters/ certificates with your application.

C.5 Proposed study dates and duration
Research start date (DD/MM/YY): 1/09/2013_________ Research end date (DD/MM/YY): 30/04/2013______

Fieldwork start date (DD/MM/YY): 30/11/2013________   Fieldwork end date (DD/MM/YY): 01/04/2013______

C.6. Where will the research be undertaken? (i.e. in the street, on UoL premises, in schools)25

University of Leeds, School of Music
University of Birmingham, School of Psychology

RECRUITMENT & CONSENT PROCESSES

How participants are recruited is important to ensure that they are not induced or coerced into participation. The way participants are identified may have a bearing on whether the results can be generalised. Explain each point and give details for subgroups separately if appropriate.
C.7 How will potential participants in the study be:
(i) identified?

Professional musicians will be identified through the School of Music. DJs will be identified by the principal investigator, with whom they are personally acquainted, and via snowball sampling (i.e. getting the DJ participant to recruit fellow DJs). Non musicians will be identified by sending group emails to university emailing lists.

(ii) approached?

Participants will be approached via email and telephone (in cases of telephone, the aims of the study will be outlined verbally, but this will be followed up with an email detailing the aims of the study to allow participants sufficient time to decide whether they wish to take part).

(iii) recruited?26

Participants will be approached via email and telephone. They will be provided with details of the aims of the study, and details of the commitment expected. Participants will be given time to decide whether they wish to take part.

C.8 Will you be excluding any groups of people, and if so what is the rationale for that?27
Excluding certain groups of people, intentionally or unintentionally may be unethical in some circumstances. It may be wholly appropriate to exclude groups of people in other cases

Participants will need to possess normally functioning sensorimotor ability (motor coordination) to take part in this study, or results will not be generalizable. People with hearing loss will be unable to participate because of the centrality of the auditory stimuli in this investigation. People with excessive eye problems will not be able to participate because of the centrality of visual stimuli in this investigation. Participants will be asked on the questionnaire whether they have any motor, auditory or visual impairments.

C.9 How many participants will be recruited and how was the number decided upon?28
It is important to ensure that enough participants are recruited to be able to answer the aims of the research.

30 in total: 10 of each participant group will be recruited.

Remember to include all advertising material (posters, emails etc) as part of your application

C10 Will the research involve any element of deception?29
If yes, please describe why this is necessary and whether participants will be informed at the end of the study.

No, participants will be made aware of the aims of the study as we want them to perform to the best of their ability in the sensorimotor synchronisation tasks.

C.11 Will informed consent be obtained from the research participants?30

☑ Yes ☐ No

If yes, give details of how it will be done. Give details of any particular steps to provide information (in addition to a written information sheet) e.g. videos, interactive material. If you are not going to be obtaining informed consent you will need to justify this.

Participants will sign a written consent form after they have read the participant information sheet, and been given sufficient time to decide whether they want to take part.

If participants are to be recruited from any of potentially vulnerable groups, give details of extra steps taken to assure their protection. Describe any arrangements to be made for obtaining consent from a legal representative.

Copies of any written consent form, written information and all other explanatory material should accompany this application. The information sheet should make explicit that participants can withdraw from the research at any time, if the research design permits.
Sample information sheets and consent forms are available from the University ethical review webpage at http://ris.leeds.ac.uk/InvolvingResearchParticipants.

C.12 Describe whether participants will be able to withdraw from the study, and up to what point (eg if data is to be anonymised). If withdrawal is not possible, explain why not.

Withdrawal from the questionnaire and experiment will be possible at any point before the completion of data collection (April 2013). Withdrawal of interview data may take place up until the end of April, as results will be disseminated in May. Participants will be informed of their right to withdraw their data up until these points.

C.13 How long will the participant have to decide whether to take part in the research?31
It may be appropriate to recruit participants on the spot for low risk research; however consideration is usually necessary for riskier projects.

Participants will be given one week to decide whether to take part in the research.

C.14 What arrangements have been made for participants who might not adequately understand verbal explanations or written information, or who have special communication needs?32 (e.g. translation, use of interpreters etc. It is important that groups of people are not excluded due to language barriers or disabilities, where assistance can be given.)

It is unlikely that issues will arise in relation to participants' ability to understand written instructions on the questionnaire given that they will be recruited via email, which requires the ability to read and respond to verbal information on-line. If participants have perceptual (e.g. hearing, vision) impairments, they will be excluded from the research.

C.15 Will individual or group interviews/ questionnaires discuss any topics or issues that might be sensitive, embarrassing or upsetting, or is it possible that criminal or other disclosures requiring action could take place during the study (e.g. during interviews or group discussions)?33 The information sheet should explain under what circumstances action may be taken.

☐ Yes ☑ No If yes, give details of procedures in place to deal with these issues.

The information sought from participants in the current study does not require discussion of topics of a sensitive, embarrassing or upsetting nature.

C.16 Will individual research participants receive any payments, fees, reimbursement of expenses or any other incentives or benefits for taking part in this research?34

☐ Yes ☑ No

If Yes, please describe the amount, number and size of incentives and on what basis this was decided.

There are no payments, fees, reimbursement of expenses or any other incentives or benefits for taking part in the research other than contributing to further understanding of sensorimotor synchronisation among musical populations.

RISKS OF THE STUDY

C.17 What are the potential benefits and/ or risks for research participants?35

There are no specific benefits or risks associated with participation in the current research. Participants will be informed of their anonymity, confidentiality of data, and right to withdraw from the research in line with BPS guidelines.

C.18 Does the research involve any risks to the researchers themselves, or people not directly involved in the research? Eg lone working36

☐ Yes ☑ No

If yes, please describe: ____

Is a risk assessment necessary for this research?

☐ Yes ☑ No If yes, please include a copy of your risk assessment form with your application.

NB: Risk assessments are a University requirement for all fieldwork taking place off campus. For guidance contact your Faculty Health and Safety Manager or visit http://www.leeds.ac.uk/safety/fieldwork/index.htm.

DATA ISSUES

C.19 Will the research involve any of the following activities at any stage (including identification of potential research participants)? (Tick as appropriate)

- ☐ Examination of personal records by those who would not normally have access
- ☐ Access to research data on individuals by people from outside the research team
- ☑ Electronic transfer of data
- ☐ Sharing data with other organisations
- ☐ Exporting data outside the European Union
- ☑ Use of personal addresses, postcodes, faxes, e-mails or telephone numbers
- ☑ Publication of direct quotations from respondents
- ☐ Publication of data that might allow identification of individuals to be identified
- ☐ Use of audio/visual recording devices
- ☐ FLASH memory or other portable storage devices

Storage of personal data on or including any of the following:

- ☐ Manual files
- ☑ Home or other personal computers
- ☐ Private company computers
- ☑ Laptop computers

C.20. How will the research team ensure confidentiality and security of personal data? E.g. anonymisation procedures, secure storage and coding of data.37 Refer to http://ris.leeds.ac.uk/ResearchDataManagement for advice

The use of personal details such as email addresses and phone numbers is unavoidable in order to contact potential participants. However this information will not be shared or released beyond the principal researcher and team. Assurance of this will be offered to all potential participants.

As one of the methods of investigation is interview, direct quotes may be included in the write-up of the results. However participant contribution will be anonymous and identifiable only to the principal researcher (AG) and associated team members (DM and ME). Audio recordings made will be stored only on the university M: drive (password protected) and transcriptions and citation of participant quotes will be anonymous.

C.21 For how long will data from the study be stored? Please explain why this length of time has been chosen.38

RCUK guidance states that data should normally be preserved and accessible for ten years, but for some projects it may be 20 years or longer.

Students: It would be reasonable to retain data for at least 2 years after publication or three years after the end of data collection, whichever is longer.

10__ years, _________ months

CONFLICTS OF INTEREST

C.22 Will any of the researchers or their institutions receive any other benefits or incentives for taking part in this research over and above normal salary or the costs of undertaking the research?39

☐ Yes ☑ No

If yes, indicate how much and on what basis this has been decided

____

C.23 Is there scope for any other conflict of interest?40 For example will the research funder have control of publication of research findings?

☐ Yes ☑ No If yes, please explain

____

C.24 Does the research involve external funding? (Tick as appropriate)

☐ Yes ☑ No If yes, what is the source of this funding?

____

PART D: Declarations

Declaration by Chief Investigators

The information in this form is accurate to the best of my knowledge and belief and I take full responsibility for it.
I undertake to abide by the University's ethical and health & safety guidelines, and the ethical principles underlying good practice guidelines appropriate to my discipline.
If the research is approved I undertake to adhere to the study protocol, the terms of this application and any conditions set out by the Research Ethics Committee.
I undertake to seek an ethical opinion from the REC before implementing substantial amendments to the protocol.
I undertake to submit progress reports if required.
I am aware of my responsibility to be up to date and comply with the requirements of the law and relevant guidelines relating to security and confidentiality of patient or other personal data, including the need to register when necessary with the appropriate Data Protection Officer.
I understand that research records/ data may be subject to inspection for audit purposes if required in future.
I understand that personal data about me as a researcher in this application will be held by the relevant RECs and that this will be managed according to the principles established in the Data Protection Act.
I understand that the Ethics Committee may choose to audit this project at any point after approval.

Sharing information for training purposes: Optional – please tick as appropriate:

☑ I would be content for members of other Research Ethics Committees to have access to the information in the application in confidence for training purposes. All personal identifiers and references to researchers, funders and research units would be removed.

Principal Investigator

Signature of Principal Investigator: ....

Print name: ....Dr Alinka Greasley....................... Date: 29th October 2013...

Supervisor of student research: I have read, edited and agree with the form above.

Supervisor's signature: .... (This needs to be an actual signature rather than just typed. Electronic signatures are acceptable)

Print name: .... Date: (dd/mm/yyyy): ....

Appendix B – Musical training questionnaire

Musical Training Questionnaire

We are conducting research into people's respective levels of musical training and the synchronization abilities that evolve as a result of this training. If you decide to take part in this research you will be asked some general questions about your musical training and background. The responses that you provide on this questionnaire are confidential: this means that they will not be seen by anyone other than the researchers.

____

I ____________________________ [full name] consent to take part in this research.

Signature _____________________   Date_________________

____

SECTION 1: BACKGROUND INFORMATION

1. Your age: _____ years

2. Your gender: _____   male   _____female

3. Nationality:___________

4. Ethnicity:

White: British (English)
White: British (Scottish)
White: British (Welsh)
White: Irish
Mixed : White & Black Carribean
Mixed :White & Black African
Mixed : White & Black Asian
Asian/Asian British : Indian
Asian/Asian British : Pakistani
Asian/Asian British : Bangladeshi
Black/Black British : Carribean
Black/Black British : African
Chinese
Other Ethnic (Please Specify)____________________________________

5. In what city and country do you usually live? (e.g. London, UK)

6. Do you have any visual, auditory, or other sensory impairments (e.g. tinnitus, noise-induced hearing-loss)? (please describe)

7. Please indicate the highest academic qualification you are currently studying for or have completed:

No Qualification
GCSEs/O-Levels
A-Levels/Diploma/Baccalaureate/any other final school exam
Undergraduate degree (e.g. BA/BMUS/BSc)
Postgraduate degree (e.g. MA/MPhil/MMus)
PhD/DPhil/any other doctorate
Postdoctoral qualification
Other (Please Specify)

8. What is the subject area(s) of your highest academic qualification?

9. Are you currently a student?
Yes _______ No _______

10. Are you currently in employment?
Yes _______ No _______

11. Please describe your current vocational title(s) (e.g. chemistry student, musicologist, nurse, unemployed):

SECTION 2: MUSICAL TRAINING

12. Have you ever...? (please tick all that apply)

HYEA Learned one or more instruments
HYEB Had singing lessons
HYEC Improvised music
HYED Composed music
HYEE Conducted music
HYEF Played in a musical ensemble (e.g. chamber music, orchestra, choir)
HYEG Mixed on decks (DJing)
HYEX None of the above

13. Please indicate the highest level of music education you have (or are currently completing):

No training	0
GCSE music	1
A-Level music	2
ABRSM Grade 8 or equivalent	3
Undergraduate-level diploma/Degree	4
Postgraduate-level diploma/Degree	5
Doctorate in Music/Doctorate in Musical Arts/Any other	6
Other (please specify)	

14. Which of the following statements most accurately describes you?

I have never played an instrument (incl. voice)	0
I used to play and instrument (or sing) years ago	1
I currently play one instrument (or sing) to a moderate level	2
I currently play one instrument (or sing) to a high level (e.g. Grade8)	3
I play several instruments (incl. voice) to a moderate level	4
I play several instruments (incl. voice) to a high level (e.g. Grade 8)	5

15. If applicable, at what age did you start playing/learning music?

16. Would you describe yourself as a "professional musician" or "amateur musician"?
Professional _______ Amateur _______

17. Have you performed music in exchange for money within the last 12 months?
Yes _______ No _______

18. If you answered "Yes" to the previous question, then please describe the performance context (e.g. wedding, solo performance, club):

19. Approximately how often are you paid to perform music?

Less than once a year	0
Once a year	1
Once every 6 months	2
Once every 2 or 3 months	3
Once a month or more	4
Once a week	5

20. Are you right-handed, left-handed, or ambidextrous (equal facility with both hands)? (please tick the appropriate answer)
Right-handed______ Left-handed______ Ambidextrous______

21. Please approximate how many hours you have practiced daily over the past month:

22. Have you ever experienced any problems with fine motor control? (please describe)

Appendix C – Participant information sheet

UNIVERSITY OF LEEDS

You are being invited to take part in a research project.

Before you decide it is important that you understand what the research is for and how you will be involved in the project. Please take as much time as you need to understand the following information and feel free to discuss it with others if this would help. Ask us if you are unsure about anything or if you need any more information.

Think carefully and **take time** to decide whether or not you wish to take part.

What is the purpose of this research?

This research investigates rhythmic accuracy and motor coordination in non-musicians, musicians and DJs.

Why have we chosen you?

You are a non-musician, a professional string player with formal musical training, or a DJ.

How long will this research last and what is your role?

This project will last until 30th April 2014. You will only be needed for data collection which consists of:

- Two sessions of one hour on two separate days for all participants.
- DJs participants will be required to take part in a recorded verbal interview of up to one hour concerning their learning habits.

At no point shall the recordings be used for audio purpose and they will be disposed of in April 2016, two years after the project has ended. No other use will be made of them and no else will be allowed access to the original recordings. We may use direct comments in our research but with no reference to your name. If at any point during the recordings you wish for me not to use some of your comments, then you can notify us and that is completely fine. Responses will be anonymous. Interviews will take place at the School of Music, University of Leeds, or where ever you feel most comfortable.

What are the benefits of this research?

There are no direct benefits for participants, but you will be aiding in a deeper scientific understanding of movement and synchronization.

Will the information be confidential?

All the information that is collected will be strictly confidential and participants will not be able to be identified in any reports or publications. The final research will be finalised in summer 2014. Data may be used for future research but all data will remain confidential.

This is your copy to keep and you will also be given a consent form if you decide to participate. Thank you for your time.

Appendix D – Thematic analysis example

Category colour key:

Rhythmic perception

Harmonic perception

Musical structure

Music technology

Music performance

Instrumental skills

Mixing

Music production

Stylistic knowledge

<u>CPs (selected answers):</u>

2: “They have to structure their music, listen to a wide variety of music, master technology in a way similar to learning an instrument and still have to create balance, understand rhythm, metre and harmony.”

3: They learn music technology and music production, a “big part of music”

4: “As they learn about beat, rhythm and the relationships between genres and tracks, which is a large part of what is imporatant about music.”

5: “Very strong grasp of rhythm and balance. Awareness of key (although not necessarily tuning) and performance skills.

6: Mixing songs together must develop musicality.

14: Rhythmic coordination.

<u>NMs (selected answers):</u>

7: They learn how to blend and mix music.

12: Develops logic as opposed to creativity.

16: “Depends on how they use the technology at their disposal; if they rely too much on the technology and too little on their ears then no.”

DJs (selected answers):

9: “Scratching and mixing gives you ideas of rhythm. Modern DJs learn harmonic mixing and key clash, performing DJs learn performance character and presentation while playing to a crowd as practicalities like problem solving (sound checks) and adapting to difficult scenarios (e.g. working with inferior equipment).

10: “A selector will learn how to order music in order to make people want to dance. A DJ will learn timing and to be able to hear more than one rhythm at once, and also rhythms within rhythms.”

13: “All Djs who have ever successfully gained an income have definitely learnt a lot about entertaining, wether they also learnt any valuable musical skills is a harder question. I believe those mix DJs who have learnt musical skills can be heard to have done so in the poly-rhythms, textures and harmonies they create during their mixes. Without musical skill and a proficient musical ear, these DJs would fail. The most basic skill all DJs who mix have to learn is how to count to a pulse, how to recognise the first beat of a bar and phrase, and how to match the tempo of a song to the tempo of another song. Advanced musical skills occur when a DJ recognises the harmonic, rhythmic or textural effect of mixing two sounds together. In some cases the effect is not desired so a musical DJ knows to remove the undesired element by using eq, effects or by not playing certain parts of a song. Scratch DJs learn at least the equivalent amount of musical skills as percussion players as both use tactile methods to add musical elements to compositions. The additions made by scratch DJs must be in time and harmonically effective within the genre of music being produced. As many DJs are somewhere on a spectrum between being a “mix” dj or a “scratch” DJ it is very hard to categorise DJs' musical abilities without looking at each individual in depth. True “turntablists” use mixing, beat matching and scratching (i.e. all the elements of Djing) to produce entirely new compositions. These “turntablist” compositions utilise melodies, beats and basslines from other recordings but rework them into brand new pieces which are clearly separate from the original. There can be no doubt that these DJs have learnt valuable musical skills to do so”

15: Yes. They learn performance skills and knowledge of genre.

19: Yes. Understanding tempo, pitch and musical structure.

Appendix E – ANOVA tables

Baseline (BL) conditions NMA ANOVA results

		Sum of Squares	df	Mean Square	Sig.
BL1_NMA	Between Groups (N-1 for df)	991.013	2	495.506	.162
	Within Groups (N*amount of groups-1)	4421.420	18	245.634	
	Total	5412.432	20		
BL2_NMA	Between Groups	3037.987	2	1518.994	.071
	Within Groups	8915.745	18	495.319	
	Total	11953.732	20		
BL3_NMA	Between Groups	1544.041	2	772.021	.305
	Within Groups	10935.933	18	607.552	
	Total	12479.974	20		
BL4_NMA	Between Groups	5498.348	2	2749.174	.085
	Within Groups	17471.081	18	970.616	
	Total	22969.429	20		
BL5_NMA	Between Groups	1387.574	2	693.787	.504
	Within Groups	17531.581	18	973.977	
	Total	18919.156	20		
PD5_NMA	Between Groups	3878.034	2	1939.017	.066
	Within Groups	11020.947	18	612.275	
	Total	14898.981	20		
TD5_NMA	Between Groups	5501.501	2	2750.750	.045
	Within Groups	13409.375	18	744.965	
	Total	18910.876	20		

Baseline (BL) conditions SDasy ANOVA results

		Sum of Squares	df	Mean Square	Sig.
BL1_SDasy	Between Groups	313.930	2	156.965	.259
	Within Groups	1941.219	18	107.846	
	Total	2255.149	20		
BL2_SDasy	Between Groups	8.948	2	4.474	.954
	Within Groups	1705.262	18	94.737	
	Total	1714.210	20		
BL3_SDasy	Between Groups	248.399	2	124.199	.542
	Within Groups	3527.164	18	195.954	
	Total	3775.562	20		
BL4_SDasy	Between Groups	1337.921	2	668.960	.195

	Within Groups	6715.123	18	373.062	
	Total	8053.044	20		
	Between Groups	180.986	2	90.493	.300
BL5_SDasy	Within Groups	1264.100	18	70.228	
	Total	1445.085	20		
	Between Groups	76.399	2	38.199	.661
PD5_SDasy	Within Groups	1620.152	18	90.008	
	Total	1696.551	20		
	Between Groups	334.680	2	167.340	.340
TD5_SDasy	Within Groups	2626.167	18	145.898	
	Total	2960.847	20		

Appendix F – SMS Glossary

Anti-phase taps: Tapping out of phase with external stimuli

Asynchronies: synchronization errors

Distractor sequence: Isochronous sequence occurring simultaneously with target sequence to distract attention away from target sequence, causing *phase attraction*

Error correction: Participants' correction of synchronization error in SMS tasks, 2 corrective processes: Phase correction (including Phase resetting) and Period correction

Interpersonal synchronization: Adapting through error correction (PCR and period correction) to a continually and unexpectedly perturbed (shifting) external stimuli, such as another person during ensemble playing (an isochronous beat is used in SMS tests)

In-phase tapping: Tapping along with the external stimuli

Internal timekeeper period: Internal (imagined/felt) sense of IOIs during SMS tasks

Inter-onset interval (IOI): Interval between beat onsets in external rhythm, independent variable

Inter-response interval (IRI): same as ITI.

Inter-stimulus interval (ISI): Same as the IOI

Inter-tap interval (ITI): Interval between taps

Isochronous: Occurring at the same time, occupying equal time

Nonisochronous: Occurring at different times, occupying unequal times

Negative Mean Asynchrony (NMA): All people show tendency to anticipate the beat during SMS tapping tasks

Phase Correction Response (PCR): A measure of how participants correct errors in tapping tasks, quantified as the shift of the immediately following tap from its expected time-point

Period correction: Intentional correction of tap based on perceived IOI-duration/ asynchronies/ internal timekeeper model

Phase attraction: when sequence events are phase-shifted slightly, particpants' taps quickly adapt to the new phase despite it being below the perceptual detection threshold

Phase correction: Automatic correction of tap based on perceived asynchronies

Phase perturbations: Introducing unpredictable phase shifts or event onset shifts into the stimulus in order to measure the PCR (and consequently the phase correction parameter)

Phase shift: Unpredictable shifts of phase in the stimuli. phase shift (PS), essentially the shortening or lengthening of a single interval in a (typically isochronous) pacing sequence, with the consequence that all subsequent sequence events are either advanced or delayed

SDasy: Standard Deviation Asynchrony

Sensorimotor Synchronization (SMS): coordination of rhythmic movement to an external rhythm

Synchrony: Simultaneous action, development, or occurrence