Rhythm and Cognition: Investigating perception and response.

'It may be objected that the perception of rhythm by a child does not necessitate its execution on the part of the child himself.' *Emile Jaques-Dalcroze.*

Rhythm, as defined by the Oxford English Dictionary is *'*movement marked by the regulated succession of strong or weak elements ', it 'is defined as the pattern of intervals in a stimulus.' (Grahn, 2012, pg 586) and is 'concerned with the description and understanding of their duration and durational patternings' Oxford Music Online (London, online). This essay aims to investigate rhythm, as a steady and regular occurrence of impulse or beat, and the cognitive, neurological and physical processes a musician with a learning disability uses in order to convert rhythmical perception into rhythmical response. It aims to broadly investigate the impact of rhythmical concepts and methods of perception and response for individuals with learning disabilities, and investigate the application of these concepts in practice.

Perceiving rhythm; feeling the pulse in music, uses a closely connected neurological pathway and set of cognitive processes to making the beat, creating a physical, visual or audible, independent rhythmical response. Auditory perception, which takes places in the auditory cortex, positioned just above the ear responds to the auditory stimulus of the music, these 'perceptions are responses in the mind of the listener.' (Sethares, 2007,pg. 79). In order for the brain to identify a sense of beat or pattern with in the auditory stimulus or music and create a sense of rhythmic perception it relies heavily on constant interaction between memory, engagement and expectation. To form a perception of the beat in context with real time, thus giving it rhythmical value, the short term memory must recall the previous beat; in order to do this the listener must be actively engaged and remain engaged as they anticipate the arrival of the next beat. 'When people listen to music, they generate temporal expectations (a form of covert, internal synchronization)' (Repp, 2005, pg. 969) and it is this expectation which enables the perception of rhythm within an auditory stimuli.

Perception and response to rhythm embedded within a musical stimulus is shown to engage the pre-motor and motor cortex within the brain. 'Neuropsychological and neuroimaging studies have shown that the motor regions of the brain contribute to both perception and production of rhythms' (Chen, J. Penhune,V. and Zatorre,R. 2007, pg 550)**.** Several motor functional brain regions are also activated during rhythm perception, including the motor cortex reception, which is the brains initial response to the auditory stimulus, the basal ganglia, motor cortex and the dorsal premotor cortex. These areas of the brain are also

engaged when creating a rhythmical response. However there are numerous neurological and cognitive processes which occur before the responsive action, on which we base someones rhythmicity, can be executed. Cognitive limitations, spatial organisation and timings in motor control and movement often lead to what initially appear to be non-rhythmical responses and as a result the presumption that the listener has a lack of rhythmical perception.

When activated by a musical stimulus the auditory and dorsal premotor cortex works in partnership through the cerebellum to create a response. This response in turn stimulates the motor cortex, motor neurons and neurotransmitters to deliver this to the muscles which display the physical action. It is only however when these physical actions are performed reliably and continually at consistently placed intervals, of which the frequency is anticipated, do we perceive a rhythmical response. Musicians with learning disabilities may often have characteristics attributed to their disability which compromise the development of some or many of the processes needed in order to produce this reliability. These compromises may appear at different stages of the perceptive and responsive process and include problems with sustained active engagement and memory, compromising the initial perception of a rhythmical stimulus within the music; or in the development of the cognitive and fine motor control needed to produce a consistent audio or visual physical response.

'Music is an intrinsic part of all of us: pulse and rhythm are found in our heartbeat, our breathing and our movement' Nordoff-Robbins Centre[1], suggesting rhythmic perception is a skill all individuals possess. Heart beat and breathing are internal processes which place rhythm as the fundamental element of their success therefore these basic and intrinsic rhythmical stimuli are often used as a way of explaining the beat or 'heartbeat' in methods such as Kodály[2]. This implies that we are consciously able to manipulate the tempo of these processes as a rhythmical response; however the rhythmical qualities of both breathing and heartbeat are controlled by the *medulla oblongata.* This is located in the centre of the brain and there is little conscious control over manipulating the rhythms of these processes as to create a rhythmical response, and any manipulation of breathing patterns cannot be done so for an extended period of time. It is therefore impossible to justify an individuals ability to perceive and respond rhythmically when relating it solely to these internal rhythmic sources. Natural rhythms in pace, gait and rocking or other self-simulative actions attributed to people on the autistic spectrum disorder, *stimming*, are however controlled by the primary motor cortex, of which more awareness of control and influence is apparent. These natural

[1] Nordoff-Robins Centre- a leading centre for music therapy based on the pioneering work of Paul Nordoff and Clive Robbins.

[2] Kodály- an approach to music education developed in Hungary by Zoltán Kodály.

rhythms, which use the motor cortex, the same brain activity used in creating a rhythmical response to music, are more malleable to extrinsic influence, 'a regular gait furnishes us with a perfect model of measure and division of time into equal portions' (Dalcroze, 2000, pg. 38). It may be presumed that if students are able to display these outputs rhythmically the chance of externally influencing these natural rhythms to create rhythmical responses to a musical stimulus is higher.

'What is special about humans is not their capacity to move rhythmically but their ability to entrain their movements to an external timekeeper, such as beating a drum' (Wallin, 2000, pg.12). Using a persons' natural rhythm found in pace, gait or *stimming*[3] as the basis of the temporal structure for musical stimulus allows a greater sense of entrainment to be achieved. Entrainment, 'the process in which the rhythms displayed by two or more phenomena become synchronised' (Bluedorn, 2002) is a concept that can be applied to a rhythmical response to a musical stimulus. 'The process of synchronizing our internal rhythmic processes to external regular or periodic, cues (often the "beats") in stimuli' (Grahm, 2012, pg 586) allow individual natural rhythm to synchronise with the temporal rhythm of the music, and thus creating the sense of being rhythmical and rhythmically synchronised, or 'in time'. Research suggests that using musical stimuli which is closely related to the natural rhythm of this listener allows for more successful entrainment. Expecting the listener to entrain to music which is considerably slower or dramatically faster than their natural rhythm alienates them from rhythmic perception, so compromising any rhythmical response. Sethares (2007) states that a rhythm is perceived when the successive gap between clicks or impulses is between '100 milliseconds and three seconds', beats or stimuli which are more frequent than this are perceived as one continual sound, and those less frequent are void of any 'perception of duration.' It could be assumed therefore that within the time scale of rhythmically perceivable stimuli the successfulness of rhythmical perception varies and this is dependent on its closeness to the 'internal clock' of the listener. When looking specifically at perception and response of students with learning disabilities, considering *stimming* as the primary natural rhythmic focus of an individual on the autistic spectrum Rider and Eagle conclude that 'perseverative rocking behaviours of children are entrained best to musical tempi which are near, but not precisely the same as, the rocking state.'

The concept of entrainment, as mentioned above, is however dependant on the initial development of motor control independent of influence; if motor control of the foot has not

[3] *Stimming*- self-stimulatory behaviour. In a person with autism, *stimming* usually refers to specific behaviours such as flapping, rocking, spinning.

been developed independently then spontaneous 'foot-tapping' or entrainment will not occur, likewise with any other part of the body controlled by the motor cortex:

> Neurobehavioral mechanisms involved in adult entrainment are no indication of an endogenous predisposition for auditory-motor coupling. Previous developmental studies show that the ability to entrain to the beat emerges only around preschool age (4–8). Even then, the ability seems modest: it tends to be fraught with inaccuracies up until school age, it requires prompting by an experimenter, and it has been reported to occur for a restricted motor range only, usually finger and hand movements. From this evidence, one could understandably conclude that the skill for coordinating movement to music and other metrically regular sounds is, primarily, an acquired behaviour. (Eerola and Zentner. 2010.pg 4.)

The process and success of entrainment therefore is subject to the students' development in motor control, it also relies heavily on entraining with a tempo closely related to the natural rhythms of the listener, listeners with learning disabilities where motor range is less developed may be unable to physically entrain to the music, and so appear unsynchronised. As a result students listening to very slow or very fast music may appear to lack rhythmical perception even if motor control has been developed, these 'movement skills…can be enhanced by an approach focusing on inner rhythms.' (Benari, 1995, pg. 53) and awareness of temporal relations.

Dalcroze argues however that initial perception of musical rhythms cannot be achieved independent of physical response. Looking further into the relationship of rhythm perception and response and the connection between the two one can consider the Dalcroze Method, developed by Emile Jaques-Dalcroze and first published in 1921 though deemed to be 'even more relevant now than when it was first published.' George Caird, Principal Birmingham Conservatoire, 2000. Dalcroze suggests that 'rhythm is movement' and 'musical consciousness is the result of physical experience.' The concepts of the teaching suggest that rhythmical physical actions and muscular awareness must be learnt independently to the musical stimuli before a perception of rhythm can be developed. Although devised with the neurotypical musician in mind the principles of Dalcroze are widely used with students and listeners with learning disabilities, the fundamental concepts of its teachings aim to 'create more intimate relations between mental and nervous processes' (Dalcroze, 2000, pg.64). 'It is rare, in these days to find a person whose mental and bodily processes are perfectly harmonised. Relations between the imaginative and the executive faculties are too often compromised by lack of freedom in the nerve currents' (Dalcroze, 2000, pg. 61). However, this method supports the argument that unless a 'clear and distinct consciousness of measured and rhythmic muscular movements' (Dalcroze, 2000, pg.39) had been

established then independent rhythmical perception is not evident. Applying this concept to listeners with learning disabilities, who often present delays and compromises in motor development, suggests that the lack of accuracy often displayed in movement, caused by neurological processing and cognitive challenges, over-rides any perception of rhythm and individual may internally process and perceive.

Down's syndrome, a condition caused by chromosome abnormalities, has up to '300 distinguishing characteristics…and almost always learning difficulties' (Farrell, 2003, pg. 52). These characteristics often include delayed development in motor control and fine motor control, co-ordination and balance. 'Although there is only one study reporting on the motor progress of older children with Down's syndrome, the delay in motor skill development in earlier childhood is often evident in development of fine-motor skills in older children and adults with Down's syndrome' (online, Accessed [11/04/13]).

Bethany, a fifteen year old, physically able student with Down's syndrome, shows awareness and response to rhythm; however the inconsistency in her response to rhythmical stimuli often makes Bethany appear out of time with the music, unaware of its presence or unrhythmical. Through application and investigation of the above mentioned methods, including entrainment, Dalcroze and awareness of Bethanys' motor control and co-ordination this essay aims to investigate Bethanys' inconsistency in rhythmical response and the obstacles faced in changing rhythmical awareness into rhythmical action. After observing Bethany, for a period of approximately ten weeks, during her weekly attendance at a music group for students with learning disabilities, it was clearly evident that there were no distinct physical limitations to hinder Bethanys' rhythmical responses.

On initial observation of Bethany the group are singing a welcome song, which includes the names of all the group members, students are expected to sing the words of the song and show the beat, ♩=65, by tapping both full palms onto their thighs from a seated position.

This tempo is slower than Bethanys' walking pace, however still well within her rhythmically perceivable range. At the beginning of the song Bethanys' movements appear to be rhythmical and consistent in their tempi, however the speed of movement is not synchronised to the external rhythmic source, the song and its rhythmical stimuli. Bethanys' movements fall slightly late, or behind the temporal rhythm of the music, but continue to be independently regular until the group sings her name.

At this point the reliability of Bethanys' movements is no longer evident; it is clear she is distracted and as a result the co-ordination of her actions is compromised. Initially observing

these movements it may seem that the lack of synchronised movements meant that entrainment was not achieved as Bethany does not 'move in synchrony with its beat.' (Eerola and Zentner, 2010, online) however Bethanys' rhythmical responses are produced at the consistent tempo of ♩=66, clearly connected to, and influenced by the ♩=65 tempo of the piece. It is evident from observation that once distracted by her name Bethany is no longer able to perceive the rhythm within the music, or feel the beat, it appears that her brain is not actively engaged by the rhythmical stimuli and so the perception of rhythms which 'influence and are influenced by our attention' (Sethares, 2007, pg. 78) is lost and as a result there is no connection between the music and Bethanys' response.

Previous to this however her movements are rhythmical but unsynchronised with the external influence; this may be due to the multi requirements of the task, Bethany is expected to perceive speech, sing and move rhythmically. Unlike the processing of a neuro-typical brain, or general model, speech perception for individuals with Down's syndrome is processed and organised on the right side of the brain, Fig.1 (Chua, Elliott, Weeks, 1996, pg. 27). This division of brain activity and engagement often leads to a compromised response, 'persons with Down syndrome have particular difficulty performing a variety of tasks that require both the perception of speech and the production of complex oral or manual movements.' (Chua, Elliott, Weeks, 1996, pg. 27). Thus asking Bethany to listen to the song, speech perception; beat the rhythm and sing, both complex controlled motor requirements, leads to the output, or rhythmical response being compromised. This is particularly applicable when considering Bethanys' need to understand when it was her turn to be 'welcomed' within the song, a process which requires extreme and prolonged speech perception, as Bethany's turn taking did not fall until the middle of the activity.

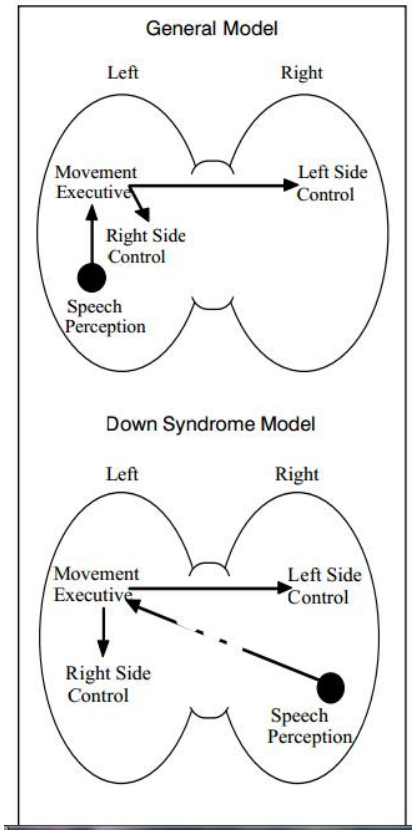

Fig.1: A model of the functional cerebral organisation in persons with Down syndrome.

Removing the complexity of multi-response requirements, a second observation of Bethany responding to pre-recorded material, *The World in Union,* still presents challenges in her rhythmical response. The same action, tapping both full palms onto her thighs from a seated

position is the required way of presenting a rhythmical response to the music, however there is no need for speech perception or verbal response. The tempo of the music is slightly faster than the previous stimuli ♩=70 however Bethanys actions fall, out of synchrony with this at ♩=87. As investigated above it is considered that 'teenagers and adults with Down syndrome may be slower to perform movements in some situations, possibly reflecting slower information processing in the central nervous system' (online, Accessed [12/03/13]). Bethanys' rhythmical response does not synchronise with the tempo of the music and is in fact a faster response thus displaying none of the delayed processing speed associated with the motor control and speed of execution of a person with Down's syndrome. One may question therefore whether Bethanys' actions are a response to influence at all, it appears her actions are not reactions but self-initiated action. It appears that Bethany is unable to entrain her movements with the music, and despite being in full concentration and seeming actively engaged Bethanys' perception of the rhythmic stimuli seems non-apparent. On observation it appears that her movements are dictated by her natural and internal rhythms which function at a faster pace than the tempo of the music and so the entrainment process is unsuccessful as Bethany shows little awareness of the extrinsic pulse. The co-ordination and execution of the movement is accurate and precise however once again it is not a response to the rhythmical stimuli as the primary stage of rhythmical perception of it does not appear to have been established.

On observations where obvious rhythmic perception and awareness of the musical stimuli has been established Bethanys' response is completely synchronised with the temporal rhythm of the music. In one notable case Bethany is required to shake an instrument along to the pulse of the music, and she does so keeping perfectly synchronised timing. It is imperative to mention however the size of Bethanys' movement in performing this action; shaking the instrument, which could be done in a simple hand-wrist movement, as if shaking hands with someone, is developed in to a whole arm, entire upper body response. Bethany moves her right elbow joint from flexion to extension, up and down, from a fully extended arm above her head to a closed arm by her side. The motor control of this broad, less fine-motor action seems to be a well-established and learnt movement for Bethany. The movement seems a very natural pendulum like action, and does not confine itself to movement of the hand alone. In the successful execution of this rhythmical response Bethany displays many of the fundamental teachings of Dalcroze in which 'the whole body should be set in rhythmic motion' the movement appears to 'possess absolute freedom of

limb' (Dalcroze, 2000, pg. 42) and be at a completely natural and constant tempo for the energy level in which the action is performed.

Throughout the observation process the size of action used to display rhythmic response appeared a key element in the success of the execution of movement in relation to extrinsic temporal influence. When using larger movements Bethanys' rhythmical response to the music is more 'in time'. It would be fair to assume that the motor control and cognitive processes of these motor actions are more established independently of the music so, when influenced through entrainment, produce responses that are a truer reflection of Bethanys' rhythmical perception. It is only when the actions performed as a response require smaller movement and finer motor control, which lack the pendulum like natural movement and gravitational influence suggested in the Dacroze technique, does Bethanys' response become unrepresentative of her perception. These finer motor controlled movements have yet to be developed as familiar consistent muscular movements for Bethany and so are still hesitant and unrhythmical in performance, as their neurological processes and cognition are still developing. Bethany, like any fifteen year old, is often distracted and unengaged with the music, her attention to rhythm is constantly compromised by the dual need for speech perception and movement executive. 'Rhythmic movement is the visible manifestation of rhythmic consciousness' (Dalcroze, 2000, pg. 42). When unaware of the rhythmical stimuli for reasons of distraction or compromised attention Bethanys' responses appear uninfluenced by extrinsic rhythms, and frequently her actions fall into her natural internal temporal rhythm, well-co-ordinated and rhythmical but completely disassociated with the tempo of the external source. When aware and engaged Bethany performs larger actions with more rhythmical fluency and accuracy, Bethanys' personal strength in responsive actions is contained in whole upper body and full arm movements and this is shown consistently throughout the observations.

Therefore it appears, after investigation and observation, reasons that make a musician rhythmical and those that make them appear rhythmical, are two independent factors which are closely connected. Why and where the obstacles appear in the cognitive and physical processes which stop a rhythmical response and whether they can be addressed is subject to understanding and accommodating the individual and their specific needs. Active engagement and awareness of the musical stimuli are imperative to an individuals' perception of rhythm regardless of ability. If the listener is not engaged or actively aware of the music they will be unable to perceive its temporal rhythm and any responses will be uninfluenced by this and thus not synchronised. Entrainment, as a concept, can only be evident in actions where motor control has already been established and neurological

pathways developed, the auditory stimuli is highly unlikely to engage a motor receptor and create a response, rhythmically reflective of an individuals' perception, in an undeveloped cognitive process. In individuals where motor control or fine-motor control is developed and awareness of the musical stimuli is present the entrainment process is more likely to occur when musical stimuli is closely related to, but not identical to the tempi of the individuals natural rhythms. When working with students on the autistic spectrum, using entrainment as a way of changing the speed of *stimming* actions, consideration of the natural tempi of the stimming movement is imperative to its success. Rhythmical responses of listeners with Down's syndrome which are influenced by speech perception, cues which are placed lyrically, will often be a compromised representation of their actual rhythmical perception ability. Using responses which require larger body movements, free of tension and subject to gravitational influence; movements which are developed and familiar cognitive processes for the listener regardless of ability and do not present physical challenges are more likely to allow for a truer rhythmic representation of an individuals' rhythmical perception.

Bibliography:

Benari, N. (1995) *Inner Rhythm. Dance Training for the Deaf.* United Kingdom: Harwood Academic Publishers.

Berger, J and Turow, G (ed.) (2011) *Music, Science and the Rhythmic Brain.* Oxford: Routledge

Boucher,J. Jackson, S and Treharne,D. (1997) 'Rhythm and language in children with moderate learning difficulties.' in *European Journal of Disorders of Communication* vol. 32, pg. 99-108 London: Royal College of Speech & Language Therapists.

Brett,M and Grahn,J. (2007) 'Rhythm and Beat Perception in Motor Areas of the Brain' in *Journal of Cognitive Neuroscience* Vol. 19 (5) pg.893-906.

Buckley,S. (ed.)(2006) 'Music, music therapy, musical abilities and the role of music in the lives of children and adults with Down syndrome.' in *Down Syndrome News and Update* Vol. 5 (2);pg. 53-53. Available at http://www.down-syndrome.org/essays/359/essays-359.pdf [Accessed 30/11/12].

Chen, J. Penhune,V.and Zatorre,R. (2007) 'When the brain plays music: auditory–motor interactions in music perception and production' in *Nature Reviews Neuroscience* Vol. 8. pg. 547-558. Available at http://psych.concordia.ca/fac/penhune/publications/Zatorre%20Chen%20%26%20Penhune%202007.pdf [Accessed 25/03/13].

Chen, J. Penhune,V.and Zatorre,R. (2009) 'The role of the Auditory and the Premotor Cortex in Sensorimotor Transformations.' in Dalla Bella, S. Krauss, N. Overy, K. Pantev, C. Snyder,

J. Tervaniemi, M. Tillman,B. Schlaug, G. (eds.) *The Neurosciences and Music III: Disorders and Plasticity*. New Jersey, USA: Wiley- Blackwell.

Chua R, Weeks DJ, Elliott D.(1996) 'A functional systems approach to understanding verbal-motor integration in individuals with Down syndrome.' in *Down Syndrome Research and Practice*. pg.25-36 Available at http://www.down-syndrome.org/reviews/60/?page=1 [Accessed 03/12/12].

Clayton,M, Sager,R. and Will,U (2004) 'In Time: The concept of entrainment and its significance for ethnomusicology' in *ESEM CounterPoint,* Vol.1, pg.1-45 Available online http://ethnomusicology.osu.edu/EMW/Will/InTimeWithTheMusic.pdf [Accessed 29/11/12].

Dalcroze, E. (2000) *Rhythm and Music in Education. Revised edition*. Kent, England: The Dalcroze Society.

Eerola,T and Zentner, M. (2010) 'Rhythmic engagement with music in infancy' in *Proceeding of the National Academy of Sciences of the United States of America.* Avaliable online http://www.pnas.org/content/early/2010/03/08/1000121107.full.pdf+html [Accessed 10/04/13].

Gold, C. Wigram,T (2006) 'Music therapy in the assessment and treatment of autistic spectrum disorder: clinical application and research evidence' in *Child: Care, Health and Development.* pg. 535-542. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2214.2006.00615.x/full [Accessed 30/11/12].

Grahn, J.(2012) 'Neural Mechanisms of Rhythm Perception: Current Findings and Future Perspectives' in *Topics in Cognitive Science* Vol. 4, pg. 585-606 Massachusetts, USA: Cognitive Science Society Inc.

Hampson, P and Phelan, B. (1996) 'Multiple Components of the Perception of Musical Sequences: A Cognitive Neuroscience Analysis and Some Implications for Auditory Imagery' in *Music Perception: An Interdisciplinary Journal.* Vol.13 No.4. pg. 517-561. Available at http://www.jstor.org/stable/40285701 [Accessed 25.03.13].

Kang. N. Latash, M. and Patterson, D. (2002) 'Finger coordination in persons with Down syndrome: atypical patterns of coordination and the effects of practice' in *Experimental Brain Research,* Vol. 146, Issue 3, pg.345-355. Available at http://link.springer.com/article/10.1007%2Fs00221-002-1189-3?LI=true [Accessed 30/11/12].

Jensen, E. (2000) *Music with the Brain in Mind.* San Diego, USA: The Brain Store Inc.

London,J. (n.d, online) 'Pulse' in *Oxford Music Online.* Available at http://www.oxfordmusiconline.com/subscriber/article/grove/music/45964?q=pulse&search=quick&pos=1&_start=1#firsthit [Accessed 01/12/12].

London, J. (n.d online) 'Rhythm' in *Oxford Music Online.* Available at http://www.oxfordmusiconline.com/subscriber/article/grove/music/45963?q=rhythm&search=quick&pos=1&_start=1#firsthit [Accessed 01/12/12].

Maeda, F., Mazziotta, J. & Iacoboni, M. (2002). 'Transcranial magnetic stimulation studies of the human mirror neuron system' in *International Congress Series,* Vol.1232, pg. 889-894.

Unknown (Online) *Motor development for individuals with Down syndrome – An overview*. Available at http://www.downsyndrome.org/information/motor/overview/Default.aspx?page=3#s2_development_of_motor_skills_Down_syndrome. [Accessed 13/04/13].

Poppel, E and Wittmann M. (2000) 'Temporal mechanisms of the brain as fundamentals of communication- with special reference to music perception and performance' in *Musicae Scientiae*, pg. 13-22 Munchen, Germany: ESCOM European Society for the Cognitive Sciences of Music.

Povel, D. (1984) 'A Theoretical Framework for Rhythm Perception' in *Psychological Research* Vol.45 pg.315-337.

Repp, B. (2005) 'Sensorimotor synchronization: A review of the tapping literature' in *Physconomic Bulletin and Review* vol.12 (6). pg. 969-992. Available at http://www.haskins.yale.edu/Reprints/HL1413.pdf. [Accessed 25/03/13].

Sacks, O. (2007) *Musicophilia: Tales of Music and the Brain.* United Kingdom: Picador Publishing.

Sergares, W. (2007) *Rhythm and Transforms.* Madison, USA: Springer.

Thaut, M. (2007) *Rhythm, music and the Brain: Scientific Foundations and Clinical Applications.* Oxford: Taylor & Francis.

Vanderspar, E. (1984) *Dalcroze Handbook: Principles and Guidelines for Teaching Eurhythmics.* London: Roehampton Institute.

Wood, M. (1993) *Music for People with Learning Disabilities.* London: Souvenir Press.