Just Noticeable Difference and Tempo Change

Kim Thomas
University of Central Oklahoma

Abstract

Rapid perception of change in environmental energy is important to survival. This study applies Weber's law to perception of tempo change using sound to simulate environmental energy shifts in a response time paradigm. Two independent variables; beginning tempo and direction of change each have 2 levels; slow (43 bpm) and fast (75 bpm) and increasing or decreasing tempo, respectively. Participants were exposed to 4 listening conditions; slow-up, slow-down, fast-up and fast-down; in 2 blocks of 24 trials-48 total. Participants indicated a perceived change by clicking a wireless mouse. They verbally reported whether the perceived change was an increase or decrease. The measures recorded were the change in beats per minute (bpm) before detection. Results between beginning conditions were significantly different (p < .000) while the ratios remained stable, confirming Weber's Law in the perception of tempo change.

Sound is the least controllable of all stimuli. We can attempt to avoid or muffle it but the entire human body is perceptive of even the slightest rhythm (Jaynes, 1976). Tempo is sensed even in the absence of the sense of hearing. Wigram (1995) speaks of a deaf-mute named Parson Sutermeister of Berne. While he was not born deaf, he lost his hearing and speech soon after birth due to cerebral meningitis at age 4. At the age of 59, he discovered his ability to enjoy music. He described it this way:

> My main receiving station is my back. The sound penetrates here and flows through the whole trunk of my body, which feels like a hollow vessel struck rhythmically, resounding now louder, now softer, depending on the intensity of the music. But there is not the slightest sensation in my head and hands – the head is the least sensitive. (p. 17)

Sutermeister's discovery of music changed his life.

Music organizes movements of the body (Storr, 1992). The use of music as a tool to synchronize the mind and body has been widely documented. Each musical note represents a precise frequency at a precise point in time for a specific duration. Music takes the human mind on a sequential, ordered journey. Music is used daily to teach children language (alphabet song), to time hand washing (Happy Birthday 2x) and for a multitude of other lessons to help people learn simple tasks. In humans, there are two interrelated responses to tempo, first, the perception of the tempo and, second, the subsequent physical response (Lundin, 1953).

Storr (1992) tells of an autistic boy who had trouble tying his shoes until the task was put to song. Rhythm helped him organize his movements and on his second try with the song, he learned to tie his shoes. Music has also caused less than therapeutic effects on the human. Storr (1992) talks about another patient who experienced epileptic attacks brought on by listening to *Valse de Fleurs* by Tchaikovsky; it caused the patient to experience emotional distress, convulsive movements, frothing at the lips, and cyanosis. Recording the patient's brain activity with an electro-encephalogram while the patient experienced an episodic fit confirmed the organic nature of the attack. Although the phenomenon is rare, it indicates the extreme effect music has on the brain (Storr, 1992).

Temporal integration matures by 3-6 months in human infants. Babies have demonstrated the ability to remember tempo over long periods of time (Trainor, Wu, & Tsang, 2004). Baruch and Drake (1997) showed habituation to tempo change in 2-4 month-old infants. They surmised this indicated babies were integrating temporal events. Habituation was much less for the slower tempi. Baruch and Drake interpreted the inability of infants to perceive slower tempi as the inability to separate groups.

The environment is in constant motion. Everything that moves creates sound, which travels through the atmosphere at 344 meters per second (12 miles per minute), no matter what the frequency (Leonard, 1978).

Swinging from tree to tree there is no time for slow cognition (Mathews, Roussel, Cockran, Cook, & Dunaway, 2000). The faster the environment becomes, the more important implicit learning becomes.

Kim Thomas, Department of Psychology, University of Central Oklahoma. This paper was presented at the 25th annual meeting of the Oklahoma Psychological Society in Edmond, Oklahoma. Correspondence regarding this manuscript may be directed to Kim Thomas, Department of Psychology, University of Central Oklahoma, Edmond, Oklahoma, USA 73034, kthomas13@ucok.edu.

If a sound is perceived as threatening a different reaction occurs than if perceived as non-threatening.

Research indicates emotions travel a different system of neural paths through the limbic system. The limbic system allows emotional signals to avoid conscious control (Ornstein, 1991). If involved in an emotionally charged situation, the probability of survival would increase if no conscious thought were necessary to escape. Prey pausing to think about a response would supply the predator just enough time to succeed. Emotions elicit feelings that correspond to bodily signals. The circuitry of the limbic system, primarily the amygdala and anterior cingulate, produce the emotions that direct our behavior. Damasio (1995) points out that happiness, sadness, anger, fear, and disgust – primary universal emotions – correspond to bodily responses. When we have feelings of emotion, we allocate substantial attention to the parts of the body responsible for the response.. Although individual history and culture affects the threshold of stimuli it takes to change the amount of perceived information, ultimately, the environment shapes emotions (Damasio, 1995).

Chronic mental stress related to over-stimulation and over-processing in the neocortex level of the brain, limbic system, and hypothalamus leads to overproduction of some chemicals, peptides, neurotransmitters, and causes the disability of some cells. The result is a weaker body and higher probability of infection or disease (Damasio, 1995). The reticular activating system controls physical arousal. This system connects the sense organs, brainstem, limbic system, and frontal lobes together. If any one of these parts of the system is aroused, the rest of the arousal circuit activates due to the intricate connections. The brain is efficient at filtering incoming stimuli so that negotiating the environment is not overwhelming (Ratey, 2001).

Recent studies indicate that environmental noise affects fetuses' in utero (Abrams, Griffiths, Huang, Sain, Langford, & Gerhardt, 1998). Prenatal exposure to the environment begins shaping a fetus from conception. Newborns do not act as passive listeners after birth. Rather, prenatal experience appears to cause postnatal reinforcement. Hearing processes occur earlier in the brain than all other senses (Ratey, 2001). The human ear appears only days after conception and is fully-grown and operational by the fifth month of pregnancy. The first operational sensory organ, the human motor system, is born already under the control of the vestibular labyrinth emanating from the neural tube formed during the first trimester. The vestibular integrator controls the body's motor and sensory responses usually outside of conscious control. The cochlea measures infinitesimal movement and the vestibule measures movement of greater amplitude. Both, the cochlea and the vestibule, are made of the same materials organized in very different but complimentary ways (Tomatis, 1987). Throughout development, the labyrinth is increasingly able to analyze bodily movement. It analyzes the movements of others by unconsciously analyzing the invisible sound waves moving away from them.

DeCasper and Spence (1986) noted that recordings taken from inside of the uterus during pregnancy indicate that both speech sounds and heartbeat sounds of the mother are audible. Third trimester fetuses' are responsive to sound and prefer their mothers' voice to other females. DeCasper and Spence also found fetuses preferred female voices to male voices and the intrauterine sounds of the heartbeat over male voices. Their research indicated that although fetuses prefer the voice of their mother to other females, they do not prefer the fathers' voice to that of a male stranger. Fetuses not only learned about the sounds but also remembered something about the acoustic cues (DeCasper & Spence, 1986).

Scientists use sheep in fetal studies of sound because of their similarity to humans in body weight and abdominal dimensions. Researchers reported that these studies, recordings inside and outside of the uterus, captured vocal information more accurately than information on spatial location or stimulus formation all of which are characteristically associated with loss of higher frequencies. Studies now show that frequencies below 300 Hz pass through the mother's body to the fetus with no measurable change. Filtering affects what stimuli the fetus receives and is important to identifying in utero vocal cues (Abrams et al., 1998).

Acoustic change is an important cue for the perception of all auditory motion (Seifritz, et al.,2002). Stride frequency of an approaching predator is one example of a rapidly changing environmental tempo that results in an auditory cue requiring timely reaction. Prey's inability to perceive or attend to external motion, when milliseconds matter, will quickly result in death. Common opinion is that processing short intervals in the millisecond range *does not require* cognitive intervention while they do in the seconds and longer period range (Näätänen, Syssoeva, & Takegata, 2004).

Time and tempo both describe sequential relations. The word "tempo" describes the characteristic rate of a piece of music (Dictionary.com, 2007) and arises from the measured duration of musical notes (Coren, Ward, & Enns, 2004). Succession and duration are the fundamental aspects of time (Fraisse, 1963). Since both time and tempo describe a measure of passing time, for the purpose of this paper, the term "tempo" is interchangeable with the "time".

Time estimation is involved in the coordination of all movement and all physical interaction with the environment (Carrasco, Redolat, & Simón, 1998). All social, physical, and psychological interactions involve tempo perception and time estimation. While an animal is safer as response time to environmental stimuli decreases (gets faster), the inverse is true as well. A slow response to the environment may quickly lead to death by predator. The "psychological present" defines the simultaneity within which humans perceive change. It is the order in which stimuli arrive and the intervals between them. Perception of change is the integration of successive stimuli, which participants perceive as one coherent piece of information. One obvious example of this is the rhythms of sentences in speech (Fraisse, 1963). Temporal drift is the gradual change over time of statistical properties of one continuous sequence of sound. It plays an important role in human perception because it signals a change in the velocity of moving or falling objects as well as the stride frequency of animate objects (Madison, 2004). The ability to perceive change in tempo would increase the fitness of any animal. One selective advantage conferred by a faster detection would be increased safety from looming threats.

Neural firing is on a time scale in the order of tens of milliseconds. Within one second, a human brain reacting to its environment produces millions of firing patterns distributed throughout the brain (Damasio, 1995). If tempo perception first occurs below conscious awareness, as research indicates, then testing the "just noticeable difference" (JND) of tempo drift may pinpoint how much change is necessary before perception. JND compared across individuals could help to determine if the same natural laws governing other perceptive organs also govern the organs of tempo perception.

Structure sets the scene for behavior (Lackman, 1972). The hearing structure can limit the ability of an animal to process the sounds of a looming threat. Perception of tempo change is also crucial for understanding language, which consists of its own rhythms and inflections (Tomatis, 1987). Some autistic children cannot distinguish differences between speech sounds. The ambient noise distracts their focus from words (Ratey, 2001). Since the skin grows directly from within the neural tube, along with the rest of the central nervous system, the skin's surface is intricately involved in perception. The skin, principally the face, anterior part of thorax and abdomen, the insides of arms, palms of hands, inside of thighs and legs, and soles of feet, are all very dense with sensory receptors (Tomatis, 1987). Very low frequencies (below 60 Hz) are heard more through the skin than with the ears (Leonard, 1978). Neural patterns most important for survival are contained within the deepest circuits of the brain stem and hypothalamus, so, even the smallest problem with perception can lead to major changes in a person's psychological life (Damasio, 1995; Ratey, 2001). According to some studies, this ability to detect change may remain stable across time (Dahl & Granqvist, 2003).

Two types of nerve cells, parvocellular (slow transfer) and magnocellular (fast transfer), make up pathways of information transfer to the mediate geniculate bodies of the thalamus. Some who lack magnocellular pathways may have problems discriminating fast sounds and be dyslexic. The superior olivary nucleus compares the information from each ear and determines spatial location based on the assumption that the ear sensing the louder sound will be the closest to it. The human medulla and parietal lobe are both integral in dealing with movement around the environment and orientation to change. Patients who have frontal lobe damage cannot sustain focus or block out unnecessary stimuli (Ratey, 2001). The precedence effect and/or cocktail party effect occur in response to auditory spatial localization of multiple sounds into one perceived event. This selective listening occurs in all mammals and insects (Coren, Ward, & Enns, 2004). Since so many areas of the brain are involved during the transfer of information, and tempo is a very pervasive stimulus available even before birth, the abundance of environmental tempo indicates its perception is necessary for survival

Hearing surpasses vision on many levels, for example, the eye can see only one color when three different color pigments are mixed. The ear, however, can listen to a group of three separate instruments playing in unison and not only perceive the newly produced sound but can also detect the individual instruments' parts. The eye cannot see around corners and has a very limited distance; however, sound can be heard around corners and from much further distances. Difficulties with hearing generally cause more devastating problems with learning than problems with vision (Leonard, 1978).

The ventromedial prefrontal cortex (VPFC), situated behind the nose, is crucial to working out relationships and understanding contingencies during environmental experience (Damasio, 1995; Gladwell, 2005). People with damage to this area may appear rational and highly intelligent, but they are unable to concentrate (Gladwell, 2005). A damaged VPFC disconnects what you know from what you do (Damasio, 1995; Gladwell, 2005). A team from the University of Iowa investigated participants with damage to the VPFC region and compared them to a control group with no damage. They were investigating preconscious processes preceding rational thought. Behavior, psychophysical, and self-reported measures were recorded throughout the experiment (Bechara, Damasio, Tranel, & Damasio, 1997; Gladwell, 2005). Investigators had two decks of cards - one red, and one blue. The red deck caused more losses, while the blue deck would win, if chosen more often.

Results indicated that normal participants began to produce a stress response just 10 cards into the red deck, but they were unable to voice their hunch until 40 cards had been drawn. People with VPFC damage never produced a stress response. Normal patients began to produce stress responses before they realized the deck was not advantageous and began to avoid the decks once they realized. Participants with VPFC damage did not respond the same way. They never realized there was a problem and continued to respond to their detriment. The study concluded that autonomic responses recorded before occurrence of behavior was evidence for a non-conscious signaling device that allowed for split second decision-making (Bechara et al., 1997). Gladwell (2005) referred to this ability as thin-slicing.

Damasio (1995) has also pinpointed an area of the right hemisphere, in the somatosensory cortex, which is also involved in decision-making and bodily signaling processes. Damasio's studies have confirmed many theories that the different brain sites, simultaneously activating, bind the mind into one moment in time: the psychological present. This idea requires effective attentional mechanisms and working memory. Any dysfunction in timing would cause major interruptions in information transfer and integration (Damasio, 1995). Although we assume the cerebellum is the coordinator of motor function, it has recently been found to be a vital link in timing and coordination of cognitive function as well. This would help a body attend to massive amounts of information if it suddenly awoke and had to react to drifting off a highway. This system is very heavily dependant on dopamine produced by the substantia nigra, which is situated very near the cerebellum. Research shows conflicting duties of the cerebellum. While it can decrease spontaneous firing, to lower random noise, it can also strengthen prolonged firing of messages and assist with synchronization of neurons. Scientists believe the cerebellum is involved with most, if not all, of the neural system because of its rhythmic role in the shifting of attention (Ratey, 2001).

Weber's Law states that the "threshold of discrimination between two stimuli increases linearly with stimulus intensity" (Gescheider, 1997). The ratio of change necessary to notice remains constant as the intensity changes. Scientists have observed clear evidence of Weber's Law when studying monkeys engaged in a discrimination task dealing with the numbers of two visually presented groups of items. The animals displayed a clear linear increase in discrimination thresholds as the numbers in the groups increased. Coren, Ward, and Enns (2004) remind us that the classic study by Shower and Biddulph (1931) found Weber constant for moderate frequencies (less than 1000 Hz) to be .005. In order to detect a frequency change from a beginning tone of 1000 Hz, the tone would have to modulate to 1005 Hz. Madison's study (2004) found tempo drift thresholds of 2-4.5% and showed the effects of direction were almost non-existent. Dahl and Granqvist (2003) pointed out that although there was discrepancy between subjects, the detection of tempo drift remained stable among individuals over time.

Human research in the areas of light, sound, weight, taste, and tempo perception has used Weber's Law as a foundation on many occasions. Studies of tempo, however, have focused mainly on tempo comparisons. Subjects either judged tempi to be the same or different or estimated the length of time between tones. These studies all speak more to memory for duration than discrimination thresholds of just noticeable difference in tempo change. There was no mention in any available text of any attempt to measure the JND of tempo change in the manner now being proposed.

Method

Participants

This study employed the psychology department's participant pool at the University of Central Oklahoma. Participants signed up using Experimentrak through the University computer networking system. Experimentrak is an experimental research database designed to help researchers and qualified participants in the psychology pool communicate. The potential participants received an invitation to participate in the study through their school email address. Participants received appropriate course credit for their participation, even if they were unable to complete the exercise or produced useless information. Participants were 18-34 years of age with no self-reported hearing loss.

Materials

Wundt believed the only element needed for perceiving time was a simple repetition of a sound. When the second sound appears, the first is compared or somehow reproduced; how remains unknown. The first sound ending is the beginning of the perception of the second sound (Fraisse, 1963). This study used sound as stimuli to produce sequences of tempo shifts, with all other attributes (i.e., pitch, loudness, and timbre) remaining constant. Individual sine waves were used rather than complex waves to prevent the ear from having to perform any additional analysis.

Tones were created using NCH Tone Generator for Windows, a free downloadable program available via the World Wide Web. The WavePad (wav.file editor from NCH) program allowed manipulation of the created tones. Conditions began with equal time for both tone and silence. A tempo shift occurred because of adjusting the silence between tones. Tempos were increased and decreased, creating faster and slower tempos. Each condition repeated three times with different orders of change. Keeping all other conditions static, two more frequencies (360 Hz and 780 Hz) were used to lower the possible effect of frequency on perception. Though this type of research generally uses milliseconds to measure perception, beats per minute (bpm) were used because of limitations in available equipment. Using Windows Media Player, participants listened to Wav.files with a Dell Inspiron 6000 laptop computer equipped with a Kensington wireless mouse.

Design

This study investigates two independent variables, each containing two levels. The independent variables are *beginning tempo* and *direction of change*. The beginning tempi are beats per minute (bpm), slow (43 bpm), and fast (75 bpm) and the directions of change are increasing (up) and decreasing (down).

The dependent measures are *number of bpm until perception of change* and the *accuracy of decision*. Each participant experienced all 48 conditions after using the shuffle function in Windows Media to randomize presentation to eliminate possible learning effects. Results were analyzed using the MANOVA procedures in the SPSS program.

Procedure

In 2 blocks of 24 conditions, 48 trials occurred in one session lasting about 20 minutes. Immediately before testing, participants received verbal instructions and fitted themselves with the headphones. The participant sat next to the laptop computer so that the screen was not visible to them. First, the participant set the volume to a comfortable level and learned to use the mouse and then they were instructed how to respond. Conditions were randomized and then presented. Participants placed their dominant hand on the mouse and responded by clicking the mouse at the time of perception. After the experimenter recorded the response, the participant verbally informed the experimenter whether the change represented an increase or a decrease. After the experimenter recorded the results, the next condition was started. The process continued until all 48 conditions were completed. If the participant was unable to understand the instruction clearly or fell into a response set, after the first 24 conditions, they were given class credit and dismissed.

Results

This study consistently showed significant differences between the Slow and Fast beginning conditions, $p < .000$. (See Table 1). The slow beginning condition required significantly less bpm change to notice the tempo change than the fast beginning condition in both directions of change as shown in Figure 1 and Figure 2. Weber's law predicts that although the stimuli necessary between the two conditions should be significantly different, the *ratio* of stimuli necessary to notice a change will remain constant to the initial beginning strength of the stimuli across conditions. The five studies, on average, yielded 3.28 bpm *(8%)* change necessary to notice an *increase* from a slow starting tempo; 6.30 bpm *(8%)* necessary to notice an *increase* from a fast starting tempo; 2.70 bpm *(6%)* necessary to notice a *decrease* from a slow starting tempo; and 6.31 bpm *(8%)* necessary to notice a decrease from a fast starting tempo.

Table 1. Beginning Tempo – Main effect

Slow vs. Fast	df	*F*	*p*	η
Avg. 5 Studies	1	297.26	.001	.87

Figure 1. Beats per minute to change detection (*N*=45).

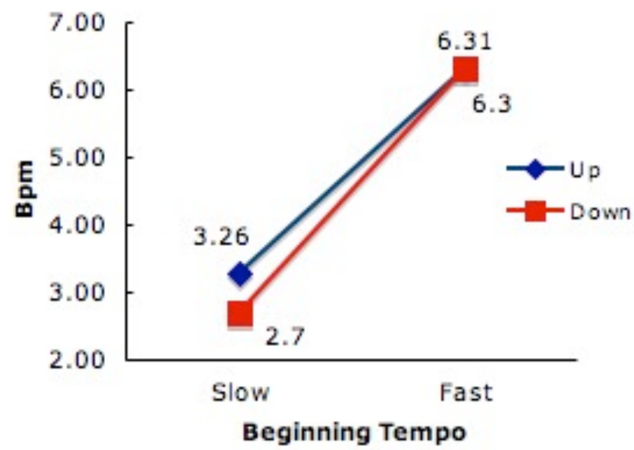
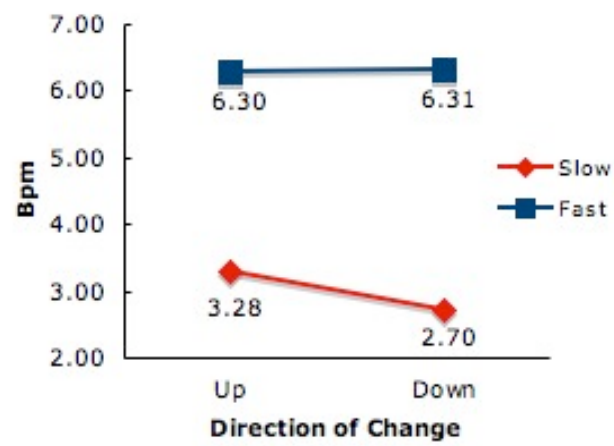


Figure 2. Beats per minute to change detection (*N*=45).



Discussion

Music dupes humans into perceiving environmental cues that do not exist. If humans naturally respond to different frequencies of sound, then the manipulation of these same sound waves in other forms will affect the human body in the same way as an environmental threat, but the reaction would be mysterious due to the lack of threat. In this modern era of overabundant sound, too much information may be interpreted as threatening. The human mind cannot maintain a constant state of high-threat. The signals we manipulate for entertainment and other purposes may be causing an increased perceived amount of stress. All systems require balance to remain healthy. The body has both a sympathetic and parasympathetic system for a reason. Humans exposed to increased cortisol levels on a long-term basis are at greater risk for disease. The human mind is no exception. With silence comes the chance to order the chaotic world of stimuli. The human mind is evolving from the simple to complex in a relatively short period. Technological advances that allow for easier living come with the ability for humans to control the environment. The need for mental intelligence becomes more important as the environment becomes more mentally challenging.

The perception of shifting environmental energy is of evolutionary importance to animals and humans, resulting in the extreme unconscious sensitivity to sound. Without the ability to sense sound and shifting sound pressure levels, through both the auditory and the vestibular systems, humans and other animals would be unable to successfully interact with the environment; acquiring food, keeping up with cohorts and predator avoidance would be impossible without this ability. The more accurately one responds to environmental stimuli, the higher the probability of success. Animals are responsive to the stimuli located in their own environment and sound waves are pervasive to the environment. The persistent and constant presence of temporal cues throughout fetal maturation indicates tempo must be important for the developing brain. The functional basis of music therapy relies on this innate ability of the human to respond to sound. Perhaps the physiological changes that occur because of changes in tempo are the active ingredient to music's effect on the human body. The additional uses for this type of information are too voluminous to list and the availability of this information makes it very easy as well as necessary to pursue further research in this area.

Since humans are so sensitive to tempo shifts, a plausible manner of non-invasive, cost-efficient testing of the basic ability to perceive time shifts may be beneficial in many areas. Tempo-drift discrimination tests could be a tool used to compare minute changes in the ability to perceive temporal shifts. The long-term stability of tempo perception and the neural precocity of the auditory system indicate its importance in the operation of the human body. Taking advantage of this innate ability could allow for more precise diagnosis of disabilities that involve the same brain areas as those used for tempo perception. Research needs to continue to determine the types of deficits in tempo perception that indicate what types of problems and in which brain areas.

The ability to follow an ordered series of notes and report the sensation of change in tempo of the stimulus would give a fair measure of the amount of processing time necessary for discrimination. Determining if sound detection follows the same laws as other sense modalities previously studied will allow comparison of "normal" levels of function to "abnormal" levels.

References

Abrams, R. M., Griffiths, S. K., Huang, X., Sain, J., Landford, G., & Gerhardt, K. J. (1998). Fetal music perception: The role of sound transmission. *Music Perception, 15*(3), 307-317.

Baruch, C., & Drake, C. (1997). Tempo discrimination in infants. *Infant Behavior and Development, 20(*4), 573-577.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 25*, 1293-1295.

Carrasco, C., Redolat, R., & Simón, V. M. (1998). Time estimation in minimally abstinent smokers. *Human Psychopharmacology, 13*, 543-549.

Coren, S., Ward, L. M., & Enns, J. T. (2004). *Sensation and perception* (6th ed.). New Jersey: Wiley & Sons.

Dahl, S., & Granqvist, S. (2003). Estimating internal drift and just noticeable difference in the perception of continuous tempo drift. *Annals of New York Academy of Sciences, 999,* 161-5.

Damasio, A. R. (1995). *Descartes error: Emotion, reason and the human brain.* New York: Avon Books.

DeCasper, A. J., & Spence, M. J. (1986). Prenatal imaternal speech influences newborns' perception of speech sounds. *Infant Behavior and Development, 9*, 133-150.

Fraisse, P. (1963). *The psychology of time*. New York: Harper Row.

Gescheider, G. A. (1985) *Psychophysics: Method, theory and application* (2nd ed.). Hillsdale, NJ: Lawrench Erlbaum.

Gladwell, M. (2005). *Blink: The power of thinking without thinking.* New York: Time Warner.

Jaynes, J. (1976). *The origin of consciousness and the breakdown of the bicameral mind.* MA: Houghton Mifflin.

Lachman, S. J. (1972). *Psychosomatic disorders: A behavioristic interpretation; Approaches to behavior pathology series*. New York: Wiley & Sons.

Leonard, G. (1978). *The silent pulse: A search for the perfect rhythm that exists in each of us.* New York: Dutton.

Lundin, R. W. (1953). *An objective psychology of music.* New York: Ronald Press Co.

Madison, G. (2004). Detection of linear temporal drift in sound sequences: Empirical data and modeling principles. *Acta Psychologica, 117,* 95-118.

Mathews, R. C., Roussel, L. G., Cockran, B. P., Cook, A. E., & Dunaway, D. L. (2000). The role of implicit learning in the acquisition of generative knowledge. *Journal of Cognitive Systems, 1*, 161-174.

Näätänen, R., Syssoeva, O., & Takegata, R. (2004). Automatic time perception in the human brain for intervals ranging from milliseconds to seconds. *Psychophysiology*, *41*, 660-663.

Ornstein, R. (1991). *The evolution of consciousness: Of Darwin, Freud, and cranial fire– the origins of the way we think*. New York: Prentice Hall.

Ratey, J. J. (2001). *A users guide to the brain: Perception, attention and the four theatres of the brain.* New York: Random House.

Seifritz, E., Neuhoff, J., Bilecen, D., Scheffler, K., Mustovic, H., Schächinger, H., et al. (2002). Neural processing of auditory looming in the human brain. *Current Biology, 12*, 2147-2151.

Storr, A. (1992). *Music and the mind.* New York: The Free Press.

Tempo. (n.d.). *Dictionary.com Unabridged (v 1.1)*. Retrieved February 03, 2007, from Dictionary.com website: http://dictionary.reference.com/browse/tempo

Time. (n.d.). *Dictionary.com Unabridged (v 1.1)*. Retrieved February 03, 2007, from Dictionary.com website: http://dictionary.reference.com/browse/time

Tomatis, A. A. (1987). *The ear and the voice*. Maryland: Scarecrow Press.

Trainor, L. J., Wu, L., & Tsang, C. (2004). Long-term memory for music: Infants remember tempo and timbre. *Developmental Science, 7*(3), 289-296.

Wigram, T. (1995). The psychological and physiological effects of low frequency sound and music. *Music Therapy Perspectives, 13,* 16-23.