MEMORY FOR ABSOLUTE TEMPO

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Abstract

The purpose of this study was to examine whether people can possess accurate memory for absolute tempo. Comprehensive review of the literature from the pitch and tempo combined with memory is given at first. The second, empirical part, presents quantitative and qualitative methods to verify the memory for absolute tempo. Recognition and estimation tasks were developed in which participated all together 40 subjects. In the former one, excerpts of popular pieces of music, mostly instrumental versions from TV title themes, were selected based on subjects' familiarity. In the latter one, the subjects estimated the excerpts' alteration and tempi' correctness. The results of the tasks are finally gathered, analyzed and discussed. Outcomes consent to the assumption that people do not possess absolute memory for tempo.

Keywords: memory, pitch, tempo

Chapter 1

1. Introduction

Human beings have been perceived as an exceptional phenomenon in nature due to possessing a uniquely developed brain. The brain can analyze incoming data from the external reality in logical, constructive and selective ways simultaneously. A selection is made by different parts of the brain that are ascribed to various activities and stimuli coming from the environment. Hence, people are born with the ability to comprehend meaning in music, although they do not have a proper music knowledge to identify those processes. Without any conscious effort, the human brain can process acoustic energy into music's basic perceptual elements such as melody, harmony and rhythm (Snyder, 2001). These complicated transformations take place mostly in the right hemisphere of the human brain, which has been viewed as the ‘musical hemisphere’ (Peretz at al., 1998). However, human perception of music can emerge also from the interplay of neural pathways in both, the right and left hemispheres, some specific to music, others not. Some researchers even argue that music does not have a particular ‘music center’ in the brain (Tramo & Bharucha, 1991). Nevertheless, assuming the right hemisphere is ‘musical hemisphere’, it is responsible for musical memory and crucial for perceiving pitch or tempo, and some aspects of melody, harmony, timbre, and rhythm. Long-term memory (LTM) is particularly identified as a level in which very rare abilities, such as the so-called absolute pitch and absolute tempo occur (Levitin & Rogers 2005, Ward 1999, Zatorre, 1989).

Therefore, this study has been designed to investigate the occurrence of absolute tempo from the memory’s perspective. The phenomenon of absolute tempo (AT) is quite a new concept in music perception. So far, only a few studies on this topic have been carried out. Furthermore, they revealed some discrepancies in the findings, thus several inaccuracies and open questions. It created a debate concerning the existence of absolute tempo at all. For that reason I decided to explore this new domain too. My previous interests in studying absolute pitch (AP) were an additional argument for focusing on this topic.

Due to lack of convincing evidence in the literature, an identical origin of AP and AT has been assumed. Such conclusions are drawn from studies where two domains of perception: pitch and tempo are usually bound together and investigated simultaneously (Levitin & Cook 1996, Bergeson & Trehub 2002, Reed 2003, Moelants, Styns & Leman 2006). Another argument for assuming that AP and AT have the same origin is the fact that scientists observe many common features between them.

In particular, the following questions were studied in this work: do people possess a strong memory for tempo? What percentage of society possesses this skill? Does a musical background and gender play any role? Which tempi are more easily remembered: slower (> 120 bpm) or faster (< 120 bpm?). Which digital alteration is noticed more easily: accelerated or delayed? Finally the main question to be answered is: may people own an ability of absolute tempo?

At the beginning, the results were difficult to foresee. They could be either in accordance with Levitin & Cook's outcomes (1996) which indicate that people own an excellent memory for tempo, or similar to Moelants at al.'s suggestion (2006), that is, that people do not possess absolute memory for tempo. In the former study the subjects were asked to sing their two most familiar songs from memory and the correctness of the excerpt's tempo was measured. In the latter study (Moelants et al., 2006), 30 song excerpts with their titles were presented to the subjects simultaneously. The subjects were then required to reproduce a song from the collection using their LTM. Hence, both studies mentioned above are considered to be active task studies.

My research in contrast focuses on a passive form of memory that operates with tempo. In other words, the manner in which the project was designed required from the subjects to use recognition as a method to retrieve information from their LTM, instead of recalling it. Such a framework was chosen to encourage a maximum number of people to participate in the study. Specifically the active task, singing, could potentially limit the number of participants due to a lack of musical skills. The other reason was to approach the problem concerning the existence of AT from a different perspective than used in quoted previous experiments. All the same, the procedure was similar to the pitch study by Schellenberg and Trehub (2003). However, in my study the subjects were not asked to reproduce the songs, but rather to pursue a multiple – choice hearing test. The examination aimed to verify exclusively the subjects' ability of precise estimation of tempi' correctness. In my opinion, the simplicity of the task encouraged non-musicians to take part in the study regardless of their potential sound competence's problems. All of the active and passive research methods mentioned above are further discussed in the Chapter 3. The final analysis of my research data consents to the Moelants et al. (2006)'s assumption that people do not possess absolute memory for tempo.

The thesis has been divided into four chapters. **Chapter 2** contains the comprehensive review of the literature from the pitch and tempo combined with memory. In section **2.1.** and its subdivisions, the memory structure with its links to music is clearly presented. The memory schema follows the widely known Atkinson & Shiffrin model of human memory (1968) with the extension to Baddeley's working memory schema (Repovš & Baddeley, 2006). The fundamental information about these mental processes has been gathered from Snyder's 'Music and Memory' (Snyder, 2001).

Part **2.2.** discusses the high- and low- level features within long-term memory. In subdivision **2.2.1.** pitch memory with its special case absolute pitch is elaborated. The genesis of absolute pitch described in **2.2.1.1.** should illustrate what could be a hypothetical origin of absolute tempo. In the next sections, **2.2.2.** and **2.2.2.1.,** I elaborate in detail the main issue in my research: memory for absolute tempo and finally I try to define the concept of absolute tempo.

In the **Chapter 3** the empirical research, that is, both quantitative and qualitative methods are described. Furthermore, the research has been divided into two parts. In the *recognition task* explained in **3.2.** I describe how I collected the data. First, I interviewed the people for the most popular and suitable music excerpts and then selected the excerpts to be studied following the interviewees' responses. In the *estimation task* discussed in **3.3.,** the subjects' estimation of the excerpts' alteration was carried out, that is, the listener was asked to judge the correctness of a tempo of musical excerpts.

In the **Chapter 4** all the results are discussed and the other aspects of my research concerning memory for absolute tempo the project are reviewed.

Chapter 2

2. Pitch, tempo and memory research – literature review

In music perception, the term *absolute tempo* (AT) is highly overlapped with human memory and, unfortunately, has not been exactly defined so far. Due to lack of research concerning different views on AT, its common origin with *absolute pitch* (AP) has been assumed in this thesis. The argument for this supposition is that both concepts are often bound together and investigated by many scientists in their projects (Levitin & Cook 1996, Schellenberg & Trehub 2003, Moelants, Styns & Leman 2006). Furthermore, since both belong to the same low-level stimulus features group in long- term memory, AT can be characterized as being based on the resources of AP knowledge. AP is the more often explored issue in the literature and it can be used as a reliable source to illustrate the paradigm of absolute tempo. Anyway, absolute pitch is defined as a special form of pitch labeling memory, which is then a form of long-term memory and categorization behavior that involves self-referencing (Levitin, 1999).

2.1. Memory and its links to music

“…memory is the ability of nerve cells (neurons) in the brain to alter the strength and number of their connections to each other in ways that extend over time. Becasue activity at the connection between any two neurons can cause chemical changes that outlast the activity itself, memory could be said to be a characteristic of virtually all nerve cells” (Snyder 2001, p.4).

Vision of memory and its links to music perception models are clearly presented by Bob Snyder in his book ‘Music and Memory’ (2001). According to the author, memory’s schema is built from the three fundamental levels (see Figure 1): echoic (semantic) memory and early processing, short-term memory (STM) and long-term memory (LTM). Furthermore, it is worth to elaborate the part of STM- working memory using the other sources e.g. Baddeley’s research because nowadays working memory often replaces the STM level when talking about memory paradigm. Anyway, the explicit classification of the memory stages results from the dissimilar time spans and different processes taking part on the each level. However, although those levels are described separately, they cannot function by themselves. In other words, the overall conceptual structure of memory levels shows a strong interdependency of the levels.

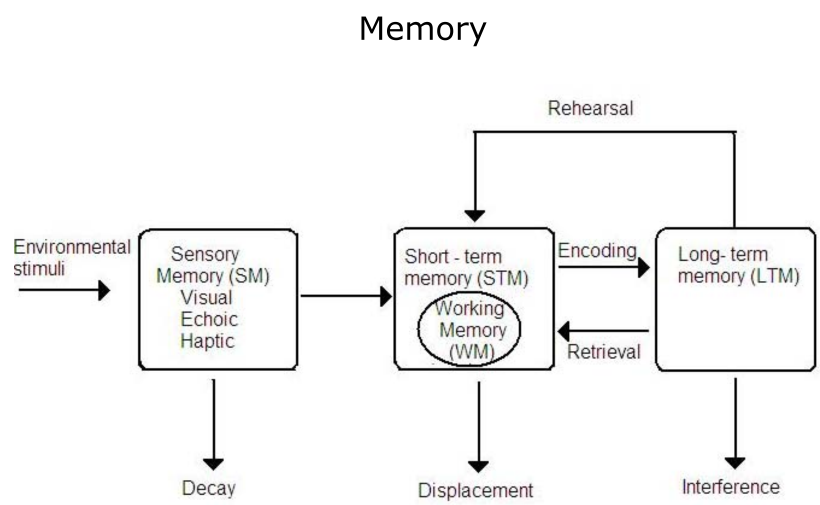

Figure 1. The model of human memory proposed by Atkinson & Shiffrin. Reproduced from Atkinson & Shiffrin (1968)

2.1.1. Echoic memory and early processing

Echoic memory is a high capacity form of memory registration of low auditory data. It is a hearing equivalent of popularly known sensory memory also called a 'sensory buffer' (Levitin, 1999). Echoic memory from its nature is very short. It usually fades away in less than in second. According to the Snyder, its usual time amounts to approximately 250 msec.

At the beginning of the transformation process, the information is un-interpreted. The first neuron activities occur when the auditory stimulus is transmitted into the subject's inner ear and then processed within the specialized nerves-'extractors'. In other words, the acoustical environment i.e. time delay is being selected, ordered and transformed into the impulses in the nerve cells of interior of the ear. The inside incorporated information is hold as an exact copy of the data for a while and then conveyed through sequences of nerve's impulses into the next levels of memory. Hence, when the stimulus itself ends, its brief impression is retained.

At some point of the conversion, the main task of the group of nerves evaluates into perceptual categorization, that is, feature extraction and perceptual binding. During the feature extraction, individual acoustical features like for example presence of frequency slides or overtone structure are detected and selected by a specialized group of neurons. In the next step, in the time of perceptual binding those features are bound into the auditory events. The events are then encoded (relatively) into the discrete categories. Furthermore, the information is no longer continuous and the amount of data being significantly reduced becomes categorical. The events are organized into grouping according to their similarity and proximity, that is, the events either somehow similar one to the other or convergent in time or both variants are collected together. These groupings are called "primitive" groupings because the little memory or learned information is engaged in its arrangement. They are fundamental in early processing. (Snyder 2001, p. 21) In the next step, the events activate the parts of long-term memory (LTM), which were activated by similar, earlier events. It is possible because LTM is also able to store more specifically sensory characteristic such as those involved in memory for voices and tunes (Baddeley 1997, p.26). This feature helps in recognition of some auditory events when they are on several occasions repeated.

2.1.2. Short -term memory

Short-term memory is a type of memory that corresponds to active consciousness or awareness (Meyer, 2003). It is also defined as a memory of very recent past. The processing of information is occurred in matter of seconds. Scientists mention its duration on the order of 3-5 sec. (Snyder, 2001, p.47). The length of time can be prolonged sometime to i.e.10-12 sec. It depends on the amount of information that is processed, internal rehearsals or repetitions. The latter meaning repeating the contents of STM to keep them active what then helps to store that information more permanently in long-term memory. Anyway, even a very short moment allows the sensory – based information for integration with information from the other sources, which are e.g.

retrieved from the LTM memory, through the operation of the limited capacity of its special innate system: working memory (Baddeley 1997, p.26).

As a matter of fact, *working memory* is the most activated part of short- term memory and is built of several structures and processes at various levels of activation. Those processes discriminate between working memory and short-term memory, which is considered as just short term storage. According to Snyder, (Snyder 2001, p.49) working memory consists of immediate perceptions and related activated long-term memories of different types of information: either semiactivated, contextual ones that do not happen in consciousness or one that has just been in consciousness. Its portion is used for performing mental manipulations such as mental arithmetic that is applied i.e. when the subject is obligated to distinguish the tempo differences between two short musical examples.

According to the more accurate Baddeley's model of working memory (see Figure 2), there are nowadays four functional components of working memory: the central executive, the phonological loop, the visuospatial sketchpad and the episodic buffer. The first one acts as supervisory system of the manipulation of information and controls respectively the next two storage subsystems. The phonological loop is responsible for storage and maintenance of information like sound or in a phonological form while the visuospatial sketchpad in visual and spatial one. The episodic buffer is the most recently added component to the entire schema. It is visualized as a limited capacity store that is capable of multi-dimensional coding while allowing the binding of information to create integrated episodes (Repovš & Baddeley, 2006).

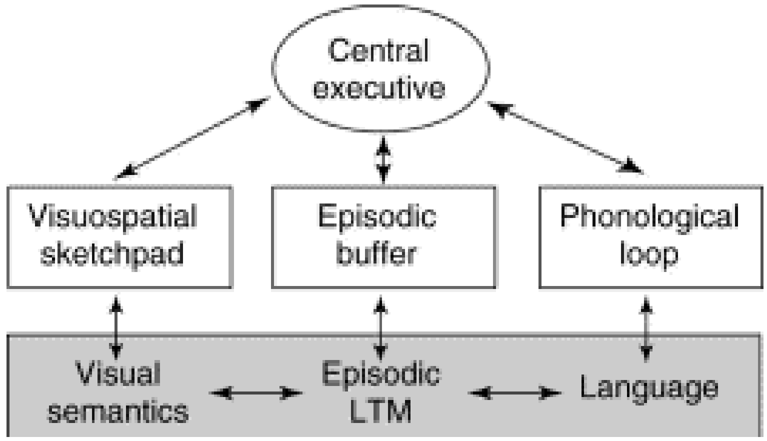

Figure 2. The current multi-component model of working memory. (Repovš & Baddeley, 2006).

Baddeley proposed his working memory model as an alternative to the short-term store in Atkinson & Shiffrin's 'multi-store' memory model (Figure 1), on which Snyder is based.

In comparison with the capacity of echoic memory and long-term memory, the short-term memory one is very small. It is estimated to be on average 7±2 elements (Miller 1956). Miller noticed that the memory span of adults was around seven elements, called 'chunks,' regardless of whether the elements were digits, letters, words, or other units. Later investigations introduced its more detailed verifications but the main idea has remained. Chunking in music is probably used while studying ear-training when the student's task orders to identify and write down the chord and tempo changes, bass line or melody.

2.1.3. Long-term memory

Long-term memory is described as a permanent storeroom of unlimited capacity and lifetime duration.

On this level of memory, three main processes take place consecutively: encoding, storage and retrieval of information. *Encoding* is responsible for assigning the mining to the information to be memorized and is strongly connected to its environmental, emotional and cognitive context.

Storage is seemed as an active process of consolidation that helps information from being forgotten. On this stage, memories of recent facts from memories of older ones are differentiated. In *retrieval* of information, the memory is copied from long-term memory into working memory to be further processed. There are two methods of memory retrieval: *recall*, where the subject is required to produce the stimulus items, and *recognition*, in which case the subject is asked for saying whether the given items was present or not (Baddeley, 2002, p.7).

Long-term memory can be divided into explicit (declarative) and implicit (nondeclarative) memory and their subdivisions (see Figure 3). This various components interact each other continuously. The division is based on the criterion whether or not in question the LTM can be verbalized. Anyway, *explicit memory* is used during the process of conscious memorizing or recalling information and is usually organized into special or temporal sequences or into knowledge hierarchies. It is called “explicit” because each of remembered memories can be named and described in words, that is, explicitly. Furthermore, it has been divided into two separate systems: episodic memory and semantic memory. *Episodic memory* is referred to as autobiographical memory because this memory allows one to remember facts and personal events experienced at a specific time and place. Thus, it is remembered and recalled in a particular temporal or spatial order. However, this type of memory is highly susceptible to distortion i.e. a copy of episode’s memory often replaces the original one. *Semantic memory* is a memory of abstract concepts or categories of objects or events that lets to construct the mental representation of the world. Its content is associated with the meaning of verbal symbols thus it is spoken about “knowing” as opposed to “remembering”. The knowledge of music i.e. knowing the names of notes or songs, recognizing particular musical styles is seemed as the semantic memory whereas a memory of a particular performance as the episodic. The second component of long-term memory, *implicit memory*, is unconsciousness. The contents of this memory is thus often impossible to describe in words. It is referred to as ”motor” memory because it contains knowledge of how to do things (*skills*). Implicit memory is slowly formed through repetitive practice and automatically recallable, without conscious effort. *Priming* is an activation of unconscious context, in other words, the capability of previous experience to affect recall unconsciously. It evokes an automatic process of recognition of objects, people or their names. Furthermore, some emotional memories are assumed to be implicit (*emotional conditioning*) because an emotional response to an immediate experience may be an unconscious reactivation of a previous emotional response to a similar situation. Implicit memory is also a place where many of our conditioned reflexes and conditioned emotional responses are stored (Snyder 2001, p 69-79).

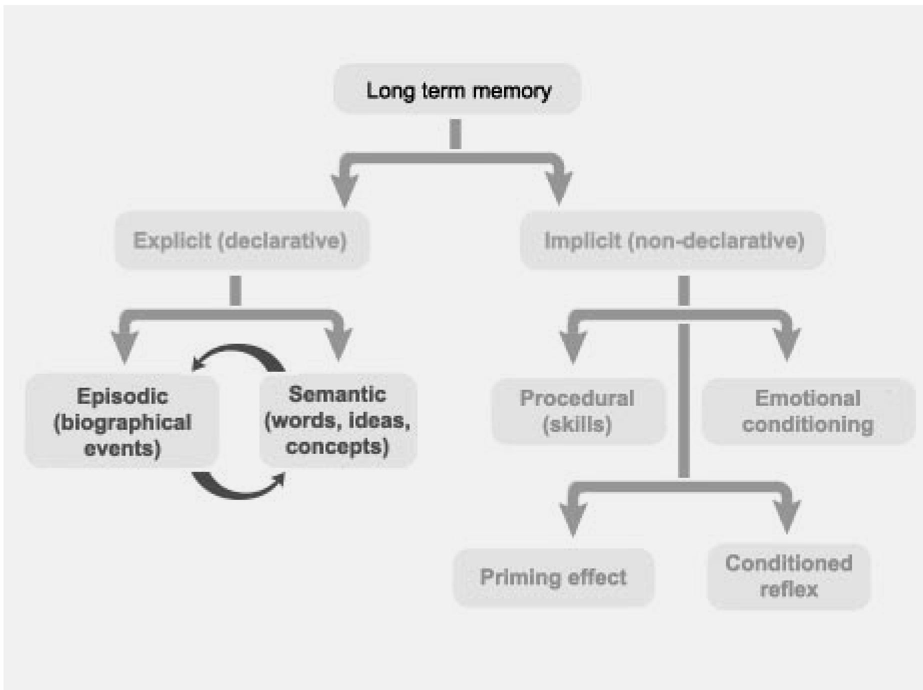

Figure 3. Long-term memory schema with its subdivisions[1].

[1] Retrieved from the site http://thebrain.mcgill.ca/ . Signed by Canadian Institutes of Health Research & Canadian Institutes of Neurosciences, Mental Health and Addiction.

2.2. Musical memory.

Musical memory is a feature popularly ascribed mainly to humans, though animal learning literature has revealed that animals also often use it for identification or differentiation between known and unknown (dangerous) living being or attributes. In his study, Levitin (1996) quoted data (Hulse & Page, 1988; Hurly, Ratcliffe & Weisman, 1990; Konishi & Kenuk, 1975; Tooze, Harrington & Fentress, 1990) that showed that for example starlings and some sparrows use musical memory in order to recognize melody whereas wolves discriminate familiar and unfamiliar howls.

The widely accepted model of memory described in the section 2.1 has illustrated that music memory does not belong only to the long-term memory. Each level of memory has an important role in the encoding of auditory information, which finally locates in the 'long-term storage'. Anyway, scientists often simplify the whole process and refer the term musical memory in its last stage of memory. Furthermore, they have divided it into high- and low-level stimulus features. The first group includes, e.g., melodic contour and harmonic structure whereas the second group contains, e.g. pitch, tempo and timbre. These low-level features have been less studied.

High-level features enable recognition of a musical piece despite its transposition, or changes in instrumentation, timbre or tempo. Trehub (1989, 2001) has discovered that even infants easily perceive differences between shifted upward or downward pitch level in melody, altered tempo and interval changes. In other words, they can identify a familiar piece of music despite having its musical features have been slightly modified. Therefore, high-level features are considered as inherited abilities that presumably everyone possesses since early months of life and do not require much stimulation training, since infants use these successfully.

The literature distinguishes different kinds of memory within the low-level features' group. Many researchers (Bergeson & Trehub 2002; Halpern 1989; Levitin 1994; Levitin & Cook 1996; Moelants 2006; Schellenberg & Trehub 2003; Reed 2003) write about pitch memory, memory for tempo and memory for timbre. The special cases of musical memory are AP and AT, which will be discussed in the following sections.

2.2.1. (Absolute) Pitch Memory

As mentioned in the chapter 1, pitch-labeling memory is the fundamental ability of AP possessors. According to Levitin (1999), the majority of evidence demonstrates AP as simply an ability of LTM and linguistic coding. This statement challenges the hypothesis of some studies from the domain of genetics (e.g., Baharloo et al. 1998) where it is shown that in AP highly developed perceptual mechanisms are involved. *Absolute pitch*, also called 'perfect' pitch, is defined as "the ability to identify the frequency or musical name of specific tone, or, conversely, the ability to produce some designated frequency, frequency level or musical pitch without comparing the tone with any objective reference tone" (Ward 1999).

Resuming to the Levitin's theory, which is based on his investigation of possibilities of human long-term auditory memory, the ability of absolute pitch consists of two abilities: the more common "*pitch memory*" and the more rare "*pitch labeling*" (Levitin, 1994).

Pitch memory is defined as "the ability to maintain stable, long representations of specific pitches in memory, and access them, when required". *Pitch labeling* is described as "the ability to attach meaningful labels to these pitches such as A 440, or DO". Similar opinion can be found in other studies (Moelants, Styns & Leman 2006).

Levitin (1994) states, concentrating on musical memory, that possessors of AP have "one form of absolute pitch memory" because they possess both capabilities. Although according to some studies, only 1 in 10000 people possess 'true' AP (Bachem 1953, Takeuchi & Hulse, 1993) it seems that much more people can possess some kind of AP. This kind of AP would base on memory for pitch. Consequently, even 'ordinary' people can sing a song in appropriate pitch without using any pitch labeling. In other words, it is hypothesized that this kind of absolute pitch memory can be widespread among the non-AP possessors.

The assumption Levitin tried to prove in the project where forty-six students with and without musical background were asked to imagine and to sing from memory two different familiar pop or rock melodies, which they used to know well (they had to choose them first from a selection of

CDs in an earlier phase). Subsequently, the subjects' productions were compared with the original recordings of produced songs. The researcher decided to choose popular categories of music because subjects were accustomed to hearing them in the same pitch and tempi. The experiment consisted of two trials. The results showed that 12% of the subjects performed without an error in both trials, while 40 % of the subjects performed precisely at least one trial. This suggests that the individuals were able to maintain a stable correctness over a long period of time and thus, that they possess absolute pitch memory. He claimed that this ability is independent from subject's musical background, age or gender. His data illustrated that 2/3 of the responses came within two semitones of the original in both trials. To sum up, Levitin's study suggests that many people possess great pitch memory but at the same time they can lack pitch labeling ability. He explains that those people did not receive a musical training or elicitation at their early age, during the so-called the critical period.

In another study (Halpern, 1989) an experiment was created, in which the subjects were asked, on two different occasions, to produce accurate pitch in the opening tones of children's songs from the folk repertoire. Adults tended to begin the same song close to the original pitch within the difference of two semitones of the same key on the two occasions. This stability is supported Levitin's theory that memory for pitch can be stable over time.

The next findings by Bergeson & Trehub (2002) confirmed the conclusions of Halpern's study (Halpern, 1989) about constancy of pitch level in mothers' singing to their babies. They authors examined maternal speech and singing as regards of pitch, tempo and rhythm. The mothers were recorded on two weekly separated occasions. Although the pitch level and tempo of speech differed across the one-week period, the singing remained unchanged. The authors considered this mother's precise imitation of their performances as a form of absolute pitch and absolute tempo.

Similar results were achieved by Schellenberg & Trehub (2003).They hypothesized that pitch memory is widespread. Furthermore, in the AP studies that have been carried out so far, ordinary people that may possess some form of AP have been excluded .Researchers claim that the common test procedures of AP are too general when are narrowed down only to isolated tones and pitch –naming tasks. According to them, isolated tones are musically pointless to the majority of people except AP possessors and pitch naming task automatically excludes individuals without musical training. The goal of their experiments was to test memory on the pitch level of musical recordings that are heard frequently at one pitch only. The subjects listened to five-second excerpts of instrumental soundtracks from highly familiar TV themes and were asked to judge whether the given excerpt in its original pitch or shifted within 1 or 2 semitones. The results give support for pitch memory because participants successfully identified the original pitch levels.

Dissimilar outcomes can be found in the recent study by Moelants et al. (2006).The authors challenge Levitin's theory (Levitin, 1994) of absolute pitch memory. They made an experiment comparable to Levitin's and came to different conclusions. Overall they reported a significantly worse precision for pitch for people singing from LTM, than had been indicated in the previous studies. The study suggests that in general people do not possess an absolute pitch memory. Instead of singing in the original, many time heard pitch, they usually choose the pitch most comfortable to their singing scale. The subjects did not pay attention to the starting pitch. They could only reproduce the songs well when they had the opportunity to listen to the excerpts first. These results can support and explain the dissimilar outcomes of studies investigating the phenomenon of stable pitch in singing familiar songs, that is, why some of the scientists (Halpern 1989, Bergeson & Trehub 2002, Levitin 1994) observed this fact while the others did not (Moelants, Styns & Leman, 2006).

2.2.1.1. Genesis of absolute pitch

Many scientists have tried to describe the AP phenomenon. An extensive article related to AP has been written by Ward (1999). In this text the reader can find different topics: schema of 'pitch helix' from the internal scale of pitch where '*pitch helix*' is a template of musical relations occurring among the notes on the internal level. This schema allows to demonstrate the hearing functions simultaneously in three dimensions; genesis of AP; measurement of AP; stability of the

internal standard; neurological correlates of AP; learning AP; colored hearing; absolute tonality; spontaneous and elicited auralization; value of AP;
Another, more recent, complex study is presented by Levitin (2005), where AP is described as 'the ability either to identify the chroma (pitch class) of a tone presented in isolation or to produce a specified pitch without external reference.'

Broadly, both findings converge in illustrating the nature of processing, categorization and controversies of AP. In general, according to Levitin, AP is an acquisition from early in life and is involved with the specialized brain mechanisms that are nowadays partially identified.

However, it is worthwhile to take into consideration the dispute of AP's definition .Ward in his AP's description identified 'absolute' pitch with 'perfect' pitch, which has aroused some critical voices. Levitin (1999) argues against such identification and claims that AP possessors do not perceive pitch any better than non-AP possessors. According to him, 'perfect pitch' possessor can only tell, whether a tone is perfectly in tune or not. In fact, AP possessors are no better at tone discrimination than other individuals (Bachem, 1954; Levitin, 1996), and they are no more accurate at detecting deviations from perfect intonation. They are better only in the labeling tones.

Regarding the genesis of AP, there are two main hypotheses (Ward, 1999):

1. AP as a heredity talent
2. AP as a learning ability.

According to the heredity hypothesis, AP is presented as a special inborn skill that can be inherited or not. In other words, AP possessor will show a talent of pitch-naming ability regardless of early musical training. Consequently, a musician without AP can never perfectly identify a tone pitch.

The scientists from the genetics domain emphasize an enormous significance of the genetic impacts in discovering AP. The study by Baharloo et al. (1998) attempted to analyze the influences of early musical training and genetic components on the development of AP ability.

They surveyed more than 600 musicians in the music conservatories, the training programs and the orchestras. They came to the conclusion that AP is involved in highly developed perceptual mechanisms. However, Levitin (1999) argues and suggests a misconception. According to him, the majority of evidence demonstrates that the AP ability is based on long-term memory and linguistic coding.

In another study (Baharloo et al, 2000), the same researchers report that if the possessor of AP has siblings, with an extremely large probability the latter one also possesses this rare cognitive ability. However, as the authors themselves report:
"...estimation of [the genetic component] may be confounded by the possibility that exposure to early music training is, in itself, familial.... indeed, we have provided evidence that early music training is familial."
Furthermore, this phenomenon is supported by either of two opposing views:
-absolute pitch is a genetic trait, which requires 'activation' by musical training
-absolute pitch can be trained by anyone but can occur spontaneously if the genetic tendency is strong enough.

According to the learning theory (Ward, 1999), heredity is not connected with AP talent. The AP skills can be developed by everyone if the individual possesses any musical predispositions and favorable circumstances in the early age. Briefly, a success requires only the adults' effort in early musical education of their musically gifted children. The young individual should have the possibility of a special training in their early, so-called critical age, whereby he or she could learn the labeling of pitches. Ward emphasizes that such training is not a simple matter especially in the adults' age. However, they are able to acquire it but without continuous practice the improvement soon disappears.

2.2.2. Memory for (absolute) tempo

Memory for tempo is based on the similar regulations like pitch memory. This can be concluded from studies that usually combine the domain of research between pitch and tempo (Levitin & Cook 1996, Bergeson & Trehub 2002, Reed 2003, Moelants et al 2006).

Absolute memory for tempo is rarely investigated as a separated approach and thus fewer findings can be found about it in literature. Some studies (Moelants 2002), investigating human preferences for tempi, have found that humans prefer tempi that lie in the range of about 100-120 beats per minute (bpm).

A majority of other results suggest that people possess a surprisingly good memory for tempo. Most conclusions were drawn from subjects' reproductions, where the participants sang songs familiar to them that are often heard in unchanged form of pitch and tempo. In a reanalysis of Levitin's study from 1994, (Levitin & Cook, 1996) the authors based on similar data from previous research, maintain that people possess not only absolute pitch memory but also absolute memory for tempo. Anyhow, regardless of lack in precision of the individuals' reproduction, the subjects are almost accurate (most tempi within 8% of actual tempi), which speaks for the ability of absolute memory for tempo. Other researchers also reported similar results. For example, Bergeson and Trehub (2002) noticed stable consistency in tempo when mothers sing to their infants (the tempo deviation was within 3%). Furthermore, Reed (2003) investigated exactness of Levitin's results but in other sorts of melodies that exist in more than one version, that is, melodies that can be heard in different tempi and pitches. He focused on some cognitive aspects: the ability to remember a given tempo over time, the stability of remembered tempo over time, the effect of different musical styles and original tempi on memory for tempo and the effect of musical background. Generally, Reed's results confirm Levitin & Cook's outcomes, that is, a great stability in tempo among 'ordinary' people (see Figure 4).

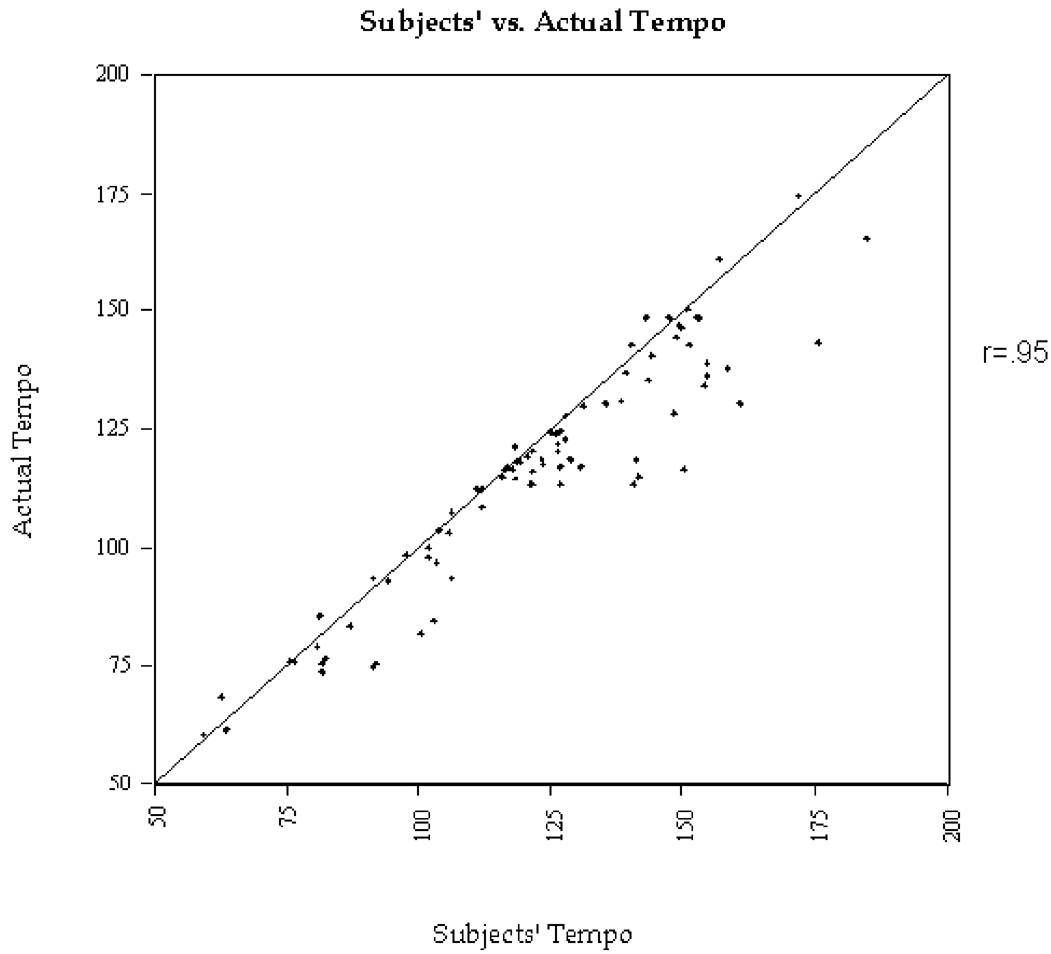

Figure 4. Subjects' tempos versus actual tempos, both trials combined in the research investigated memory for tempo. (Levitin & Cook, 1996)

A dissimilar statement is presented by Moelants, Styns, and Leman (2006). In their experiment 72 subjects were asked to imitate familiar songs. They presented to them a list of 30 pieces in a random order with the brief explanation of the piece, that is, its composer, performer and example's character. As a result, the authors formulated a novel conclusion that people are rather random in imitating a correct tempo using LTM what is comparable to their own 'pitch' results. They observed that even subjects who had heard the piece previously were incorrect with deviations up to 20%. They found, however, that singing with a text can successfully improve a correctness of tempo.

2.2.2.1. Absolute Tempo

In order to explain the term 'absolute tempo', the tempo's concept should first be defined. In musical terminology, tempo is the speed of a given piece. It is a very crucial element of sound, because it can affect the mood and difficulty of a song. According to Moelants (2002), *tempo* can be described as

"…the rate of something regularly repeating. In music perception 'tempo' is used for the speed of the beat (or pulse) – i.e. the dominant (apparent) periodicity underlying the music –, and with repetitive movements associated with it (dancing, finger tapping,…)."

Paraphrasing Moelants, Styns, and Leman (2006), *absolute tempo* can be characterized as the ability to imitate the tempo, close to the tempo of the original version of the piece, or conversely, the ability to produce some designated tempo in nearly the same tempo of its original version over a period of time, without comparing this with any objective reference tempo.

Chapter 3

3. Empirical part of the study

This chapter contains the overview of the methodology used in the thesis' project. The main aim of the study was to find out whether people may possess an ability to develop absolute memory for tempo. Furthermore, the following questions were studied:

- What percentage of society possesses this skill?
- How strong might be a memory for tempo and how it affects remembering the piece of music?
- Does a musical background and gender play any role?
- Which tempi are more easily remembered: slower (> 120 bpm) or faster (< 120 bpm)?
- Which digital alteration is noticed more easily: accelerated or delayed?

The research relies on both quantitative and qualitative methods. Moreover, it has been divided into two attempts. In the former one (called ‘recognition’), the method of collecting data was first interviewing the people in order to find the most popular and suitable excerpts, then limiting the indicated examples to the smaller amount. In the latter one (called ‘estimation’) the subjects’ estimation of the excerpts’ alteration was carried out, that is, the listener was asked to judge the correctness of the tempo of musical excerpts. The excerpts were associated with one specific tempo (e.g. TV themes, hit film music not yet covered by other artists), and were mostly instrumental versions. Finally the all results were gathered, analyzed and discussed.

The more specific research questions which were studied in experiments 1 and 2 have been described in Sections 3.2. and 3.3., respectively.

The project was carried out at the University of Jyväskylä from December 2006 to March 2007. The project consisted of two groups of participants whereby one group contributed to recognition tasks and the other to estimation tasks. A total of forty subjects participated in the experiment on a voluntary basis. Each participant was invited only once to take part in the project.

According to the structure of the project, the shape of the excerpts tended to be similar to the characteristics of excerpts used by Schellenberg & Trehub (2003) and Strauss et al. (2006). Hence, the criteria with which stimuli was selected was based on the excerpt's popularity, musical genre and availability of the original version of the track.

3.1. Research tool

In order to prepare excerpts for both listening tasks, that is, recognition and estimation, the program Audacity has been used.

Audacity is a free and versatile Audio Editor software that allows the user to record, edit, and create multi-track audio files. It is a cross-platform application that can be used under Windows, Macintosh and Linux/Unix systems and has been downloaded from the website[2].

This program can record audio, play sounds, import and export several digital audio formats (i.e. WAV, AIFF, OGG, MP3 and other). The editing capabilities allow basic functions like cut, copy, paste, mixing of tracks, tempo-adjustment, built-in amplitude envelope editor, echo, recording overdubs while playing previously recorded tracks and noise removal. For sound analysis, Audacity has a spectrum analyzer window. The program supports VST, Nyquist and LADSPA plug-in effects that add many features to its repertoire.

Audacity was invented in 1999 as part of a research project. It was then developed into a public audio editor. Nowadays, the program is being developed by volunteers and is distributed under the terms of the General Public License (GPL).

[2] *http://audacity.sourceforge.net/*.

3.2. Recognition task.

The recognition experiment and its preparation phase were carried out in December 2006.
The main goal of this task was to find out the answers to the questions:

- Which are the best known movie music pieces among interviewees? (I aimed at the group of subjects with similar preferences; otherwise it would be impossible to select pieces of music suitable for all subjects).
- Which of the selected examples are the most likely to be familiar for the majority of the subjects taking part in the project? (This way I could select seventeen excerpts serving as a research material in the next phase of the project).

3.2.1. Stimuli selection

In the preliminary phase, the library's CD collection of movie music was searched and dozens of passing individuals were asked to state a few of the most known (according to them) music hits, which could be easily recognized by others.

After this segregation, the thirty-six musical examples were established (see Appendix 1), and modified using the program Audacity for use in the recognition part of the research (see Section 3.2.2.3.). Modification was based on the processing the particular piece of music (their openings) to the form of thirteen seconds, short excerpts and then recording them on the one CD plate in the accidental order with careful obeying the two second break between consecutive musical examples.

A group of 18 respondents, detailed in Section 3.2.2.2 selected the stimuli. In this way, the final seventeen examples, which served as the research material in the last but most important phase of the project, were selected.

3.2.2. Participants

Eighteen anonymous international subjects [non-musician and musician] from the University of Jyväskylä were interviewed to determine the acquaintance's rank of familiarity of the thirty six shortly presented musical examples derived from the widely known famous film musics and writing down their ranks on the paper (see appendix no.2.) They were tested single-time all together at the same time. They were not asked about the age and gender but musical background and home country has been considered. Hence, eight subjects reported some musical education. Furthermore, sixteen Europeans, one American and one Japanese took part in the test.

3.2.3. Procedure

The group's 18 respondents participated collectively. They sat in a typical classroom and listened to the original but shortened musical examples from loudspeakers that where situated in front of them. The procedure was opened by a clear explanation of the task, which was supported by a single listening example. This short example was meant to illustrate the test's procedure to the participants and clarify any doubts. They were instructed to subjectively decide whether they are familiarized with given excerpts after hearing them just once and to cross their answers on the questionnaire in one of the three possible fields with the questions "I know it very well", "I know it but I do not remember the name", "I don't know it" (see Appendix no.2.). The numerical order was always announced before every example to prevent participants from getting lost during the recognition test. The excerpts were heard one by one (with brakes of two seconds in between) and each of them lasted 13 seconds'. At the end, the questionnaires were collected.

3.2.4. Results

The findings of the recognition test fulfilled the general expectation concerning familiarity in this part of research. Most of the 36 examples were identifiable by the participants. The examples' time length was more or less sufficient for recognizing their titles. It is interesting that only one excerpt, ”Titanic”, gathered 100% of responses “ I know it very well ”. The other “winners” with the equal result 86% in this category were “James Bond 1” “Pink Panther” and “Friends”. The first one has been excluded in the further analyses due to the 2s clearly spoken lyrics in the middle of the excerpt. The reason for this, as Moelants, Styns, and Leman (2006) claimed, was that a spoken text in the song can remarkably improve a correctness of the tempo. This could also be a case in tempo estimation.

The less known pieces of music were “Schindler's list”, ”Walker Texas Ranger”, Uutisvuoto” and gained 79% of negative answers, then Moomins and Forest Gump ,71% and “Itse valtiaat”, “Winnie the pooh”, “Muppets”, ”CSI Las Vegas”, 64 %

The other astounding issue is a fact that “The X Files”, the example also used in the prototype research (Schellenberg & Trehub, 2003; Strauss, S., et al., 2006;) did not achieve the best results as it has been expected and came in third with 79 % of voices for “I know it very well” together with “Simpsons”, ”Flinstones”,” Mission Impossible”, “James Bond 2”(the opening without the text).

All results from the recognition test have been collected in Table 1 and are presented graphically in Figure 5.

No.	Excerpt	I know Very well	I know but I don't remember the name	I don't know
1	*Mission Impossible*	79%	14%	7%
2	*Century Fox Fanfare*	71%	29%	0%
3	*Titanic*	100%	0%	0%
4	*Braveheart*	0%	57%	43%
5	*Lord of the Ring*	43%	21%	36%
6	*Schindler's List*	7%	14%	79%
7	*Itse valtiaat*	14%	21%	64%
8	*Forrest Gump*	14%	14%	71%
9	*James Bond 1*	86%	14%	0%
10	*James Bond 2*	79%	21%	0%
11	*Pink Panther*	86%	7%	7%
12	*The X Files*	79%	21%	0%
13	*Simpsons*	79%	7%	14%
14	*God Father*	50%	21%	29%
15	*TV4 Uutiset*	36%	21%	43%
16	*The Matrix*	21%	36%	43%
17	*Knight Rider*	36%	29%	36%
18	*Benny Hill*	29%	36%	36%
19	*Bonanza*	36%	21%	43%
20	*Walker Texas Ranger*	7%	14%	79%
21	*CSI Las Vegas*	21%	14%	64%
22	*Dallas*	36%	29%	36%
23	*Flinstones*	79%	14%	7%
24	*Friends*	86%	7%	7%
25	*Indiana Jones*	57%	29%	14%
26	*MASH*	43%	29%	29%
27	*Muppets*	29%	7%	64%
28	*Scooby-Doo*	36%	7%	57%
29	*Sex and the city*	57%	29%	14%
30	*Winnie the pooh*	0%	36%	64%
31	*Wonder Years*	36%	14%	50%
32	*MacGyver*	29%	14%	57%
33	*Moomins*	7%	21%	71%
34	*Urheilut*	21%	36%	43%
35	*Uutisvuoto*	14%	7%	79%
36	*Beverly Hills*	14%	50%	36%

Table 1. Familiarity with the excerpts in the recognition test.

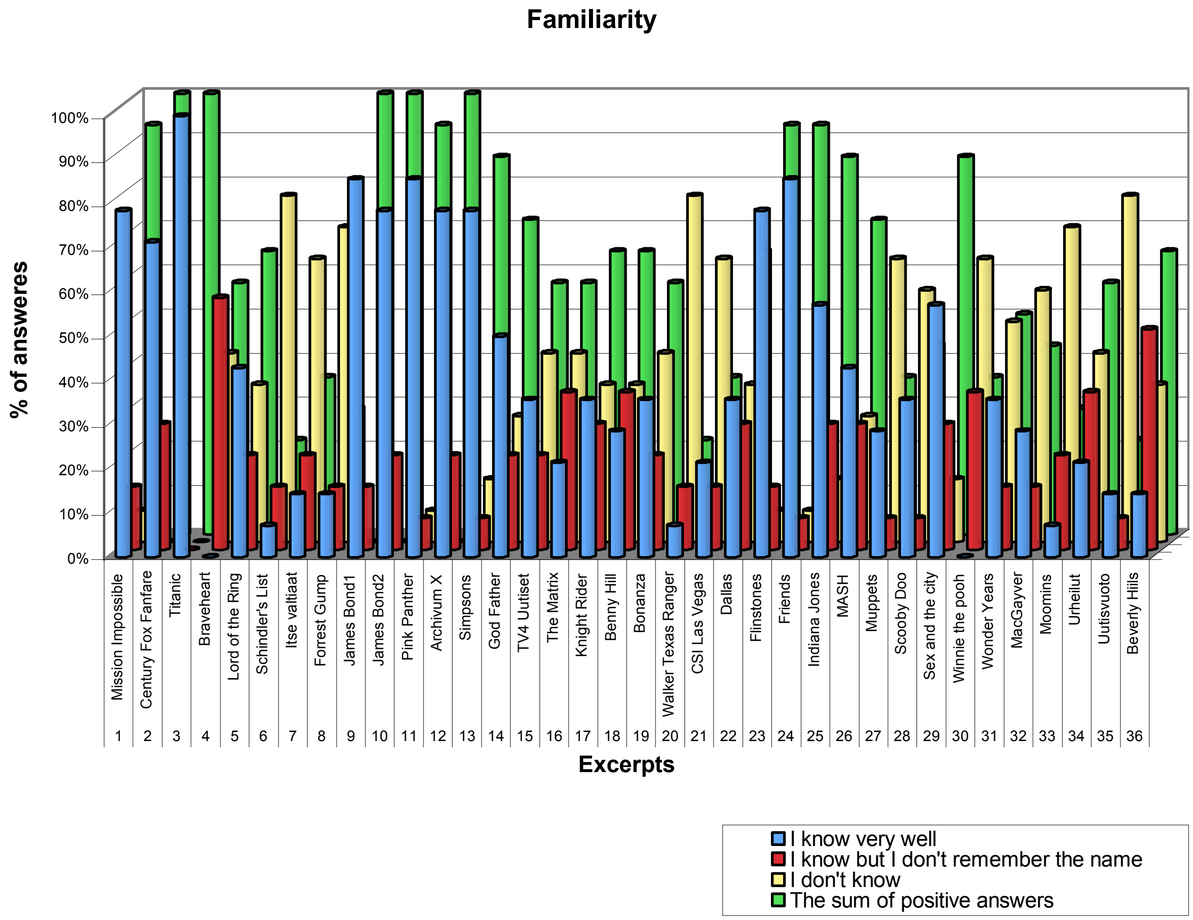

Figure 5. Respondents' familiarity with the preselected 36 excerpts.

Table 2 shows the new combination of the recognition results with an additional column, in which the positive answers have been in turn summarized. This operation revealed the participants' knowledge of the musical examples and was useful in determining the final list of excerpts to be used in the estimation task. The final criteria for selecting excerpts for further processing were:

- Versions of the examples possibly in instrumental form, (though some of them with vocal has been admitted)
- The score of positive outcomes above 60%. (The exception has been made for "The Matrix" due to its relatively high percentage of responses and perfect other conditions.)
- Internationally known excerpts from TV, movies or series

	Excerpt	I know very well	I know but I don't remember the name	I don't know	The sum of positive answers
1	*Century Fox Fanfare*	71%	29%	0%	100%
2	*Titanic*	100%	0%	0%	100%
3	*James Bond1*	86%	14%	0%	100%
4	*James Bond2*	79%	21%	0%	100%
5	*The X Files*	79%	21%	0%	100%
6	*Mission Impossible*	79%	14%	7%	93%
7	*Pink Panther*	86%	7%	7%	93%
8	*Flinstones*	79%	14%	7%	93%
9	*Friends*	86%	7%	7%	93%
10	*Simpsons*	79%	7%	14%	86%
11	*Indiana Jones*	57%	29%	14%	86%
12	*Sex and the city*	57%	29%	14%	86%
13	*God Father*	50%	21%	29%	71%
14	*MASH*	43%	29%	29%	71%
15	*Lord of the Ring*	43%	21%	36%	64%
16	*Knight Rider*	36%	29%	36%	64%
17	*Benny Hill*	29%	36%	36%	64%
18	*Dallas*	36%	29%	36%	64%
19	*Beverly Hills*	14%	50%	36%	64%
20	*Braveheart*	0%	57%	43%	57%
21	*TV4 Uutiset*	36%	21%	43%	57%
22	*The Matrix*	21%	36%	43%	57%
23	*Bonanza*	36%	21%	43%	57%
24	*Urheilut*	21%	36%	43%	57%
25	*Wonder Years*	36%	14%	50%	50%
26	*Scooby-Doo*	36%	7%	57%	43%
27	*MacGyver*	29%	14%	57%	43%
28	*Itse valtiaat*	14%	21%	64%	36%
29	*CSI Las Vegas*	21%	14%	64%	36%
30	*Muppets*	29%	7%	64%	36%
31	*Winnie the pooh*	0%	36%	64%	36%
32	*Forrest Gump*	14%	14%	71%	29%
33	*Moomins*	7%	21%	71%	29%
34	*Schindler's List*	7%	14%	79%	21%
35	*Walker Texas Ranger*	7%	14%	79%	21%
36	*Uutisvuoto*	14%	7%	79%	21%

Table 2. New order of excerpts arranged according to the positive results from the recognition test (from the most familiar to the most less known example).

3.3. Estimation task

Estimation of tempi, my second experiment, was held in January - March 2007. In this part of the study the following questions were addressed:

- What is the probability that the subjects were guessing the answers?
- Is the rate for correct answers better than just by chance?
- Does the rate for correct answers improve on the second listening time?
- Is there a correlation between the rate of correct answers and familiarity or confidence?
- Do musicians and non-musicians differ?
- Is there a gender difference?
- Is there a correlation between tempi and recognition rates?
- Are faster or slower alterations more easily recognized?
- Finally, the main question: do the subjects possess absolute memory for tempo?

These questions are studied, since the available literature concerning absolute memory for tempo differs markedly. In my hypotheses I assumed that it is impossible to have absolute memory for tempo. It was just kind of educated guess. I expected to find in the results the definite proof for my hypotheses.

3.3.1. Stimuli

The final seventeen stimuli, chosen in the recognition phase, were modified. They were prepared (in order to present to the individuals) in three possible versions: the original one, the digitally accelerated or delayed ones (in the tempo change exactly 8 % of original tempo) for 14s. The pitch of the excerpts was not modified.

Tempo change rate of 8% with respect to the original excerpt was established based on a small subjective experiment which aimed at finding an alteration being neither too easy nor too difficult for the subjects. For instance, the change of 10%, e.g. acceleration, would be already too much as it would have clearly indicated the correct answer of the task. On the other site, the 6% change of

original tempo did not bring any profits - the preliminary listening to the excerpts accelerated by 6% did not indicated any change in a tempo speed. Also Levitin and Cook chose the 8% rate as a criterion to accept that someone possess an absolute memory for tempo (Levitin & Cook, 1996).
The preparation of the original excerpts was twofold. First the samples were modified, and then re-shifted back to the original tempo. This helped to avoid errors, e.g., some mechanical noises, scratches, etc., but first and foremost it standardized all excerpts in order to none of them could be easily recognized as the original one. In other words, each example was digitally treated what enabled its uniform quality.

The recordings were taken from popular TV programs and films. The excerpts were mostly in instrumental forms that were taken from the opening credits. They were all supposed to be known by a large share of the participants.

The listening material for trial 1 and trial 2 was recorded on the two compact discs consecutively.

3.3.2. Participants

A group of twenty-two (non-musician and musician) international students from University of Jyväskylä were tested individually. They were asked to fill a questionnaire (see appendix no.3.) concerning their musical background, age, gender and to estimate correctness of tempo of excerpts. There where 8 females and 14 males with the mean age 25.9 and standard deviation of 4.6. Most of the subjects were well familiar with the presented excerpts. Each participant took part only once in the experiment.

3.3.3 Procedure

The participants were examined individually. They were sitting in a small room in front of a table. Two loudspeakers were situated in the corners. The excerpts were presented in the Audio file from the loudspeakers thus the subjects listened to the excerpts in the open auditory field. The

examiner was located behind the subject and controlled the experiment. The floor plan of the room where the research was held can be seen in the schema below (see Figure no.6.).
The subjects marked their answers on a questionnaire by placing a cross next to the suitable answers.

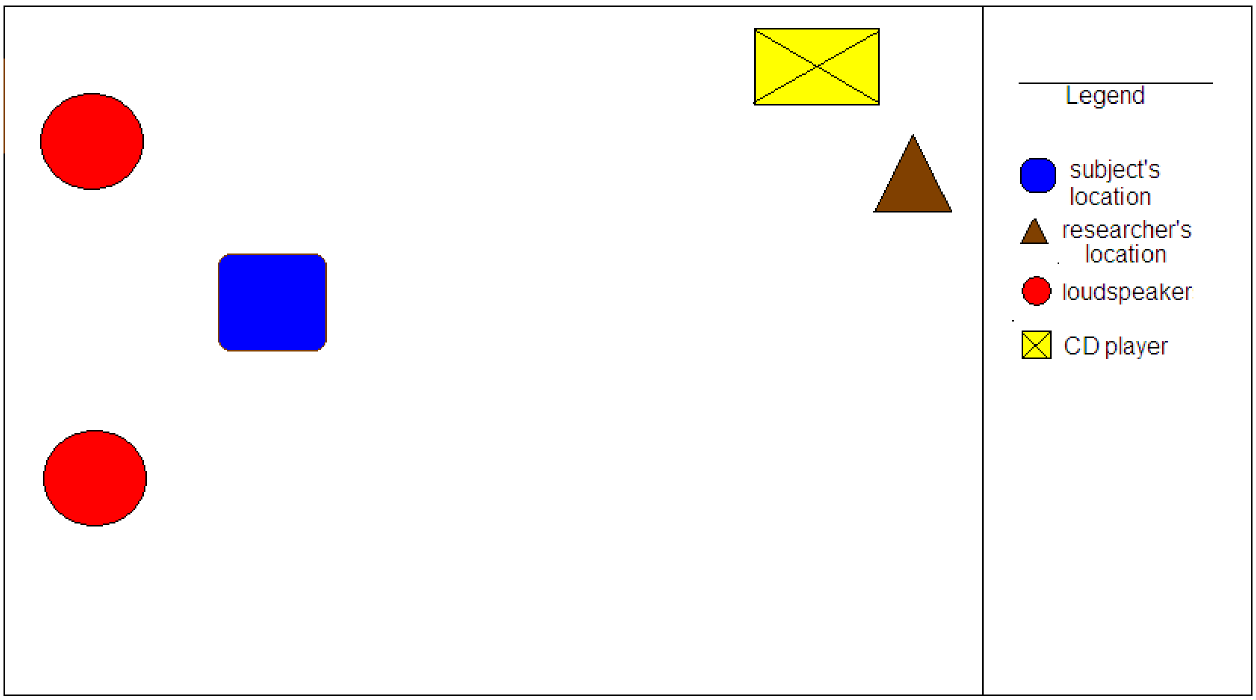

Figure 6. Floor plan of the set up

The listening test contained the seventeen most familiar excerpts. They were digitally altered but pitch had remained unchanged. The procedure was opened by a clear explanation of the task, which was supported by a single listening example. During the exposure two trials were presented. The subjects played two versions (original and altered) of the same excerpt and judge which one had been altered and simultaneously describe if it was slower of faster then the original version. Additionally, they were asked to rate 'familiarity' and 'confidence' within a scale 1-5. After each pair (two versions of one excerpt), there was two-second break. The exact schema of the trial can be seen in Figure 5. In trial 2, the order of the excerpts was randomly modified and in each excerpt the changes were reversed. In other words, trial 1 included one excerpt, for instance, on the position no. 3, which was for example accelerated versus original, whereas in trial 2 the same excerpt existed, for instance, on the position no. 16 and was presented as original versus delayed.

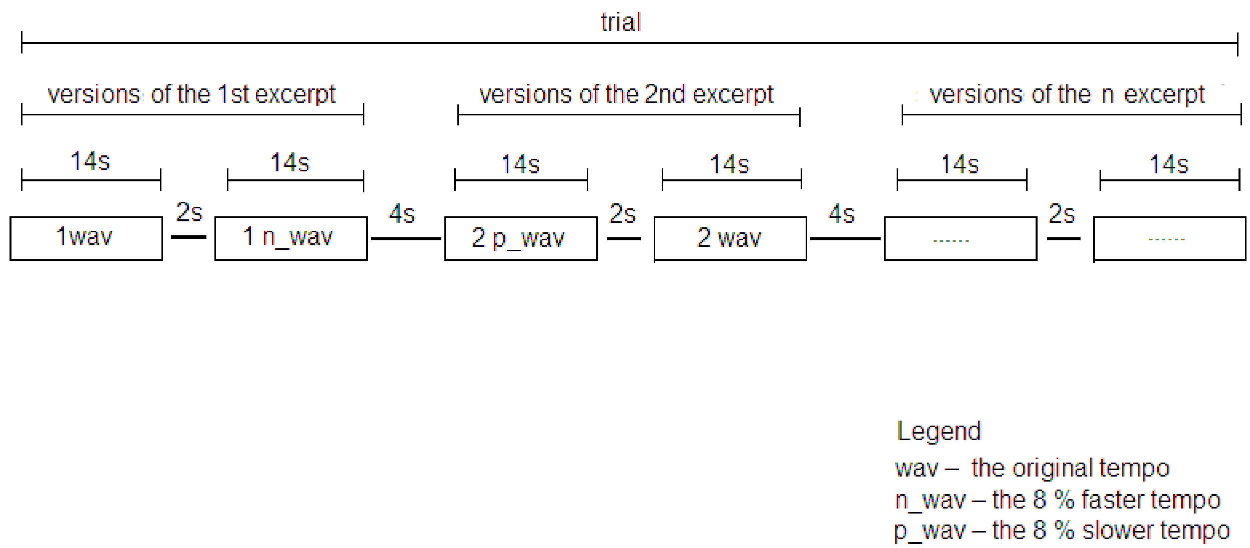

Figure 7. Schema of time sequences [in sec.] and examples of alteration's order in the trial.

Each session involved approximately 45 minutes of participants' attention. Between trials a longer break (about 10-15 min) was inserted in order to relax and thus, to divert the participant's attention from the experiment.

3.3.4. Results

The answers to the questionnaires were collected and transferred into the digital spreadsheet for analysis. The main outcome measure was the percentage of the correct responses. The following factors were considered: amount of the right answers concerning tempi estimation, participants' musical background and their gender, faster or slower tempi alterations. Furthermore, the calculations between variables like confidence, familiarity, correct responses and tempo were carried out.

Tempi estimations

The answers revealed that participants' performance was different in the two trials. In the first one, it did not exceed the 50% chance level, thus as much as 11 out of 22 participants were not correct for each item. Nevertheless, the percentage of correct answers in the first trial was 42%. That is, the altered version with the accurate estimation of modification's type (faster or slower) has been indicated. Besides, 40% of the responses were judged incorrectly. The answers were verified with the first t-test taking the null hypothesis that subjects were guessing during the task. Since in the t-test, for degrees of freedom =16: $t(n) = -1.9220$ the significance $p = 0.07$ ($p > 0.05$) the null hypothesis is accepted.

From the second trial, 61% of the responses were correct whereas 25% of the answers were inaccurate. In this case, second t-test $t(16) = 2.2327$ and $p < 0.04$ (rejecting null hypothesis) which means that subjects were not guessing. The listeners' performance was at a level better than chance. Furthermore, in the third t-test, which was comparing both trials, the null hypothesis was that there is no difference between the trials, the result was $t(16) = 2.4128112$, $p = 0.03$ ($p<0.05$ – null hypothesis is rejected in favour of the alternative one, which is that the trials are different). It illustrates that participants performance significantly improved within those two tasks (see Table 3).

These results suggest that in general the participants did not possess absolute tempo for memory. However, they were able to estimate correctly modified tempi if some short time earlier they had had the possibility to rehearse or listen to the original excerpts. In addition, a considerable discrepancy in correlations within both trials between the recognition rates (correct answers) and confidence (shown in Table 4) has been observed. In the trial 1 correlation amounted to $r=0.02$ and in the trial 2 to $r=0.72$. This fact provides converging evidence that people after at least one rehearsal of original tempo within a short time are much more confident in tempi estimations, thus consequently they obtain better results.

The second trial might seem to be no longer a simple LTM test and the STM also starts to play a role, since on the second trial the participants have already heard the ”correct” version in the first trial, and can base there judgments on that. That is not the case since the second trial was conducted some 20 minutes after the first one. STM lasting few seconds could not play a role in this case.

Estimations	***Trial 1***			***Trial 2***		
	M	*SD*	*%*	*M*	*SD*	*%*
Right	7,2	2,8	**42%**	10,4	3,0	**61%**
Wrong	6,8	1,7	40%	4,3	2,3	25%
Uncertain	3	2,3	18%	2,3	2,5	14%

Table 3. The results from trial 1 and trial 2 of the estimation task.

Correlation1	*Confidence 1*	*Familiarity 1*	*Amount 1[%]*	**Correlation2**	*Confidence 2*	*Familiarity 2*	*Amount 2 [%]*
Familiarity 1	0.76			*Familiarity 2*	0.72		
Amount 1 [%]	0.02	0.43		*Amount 2 [%]*	0.71	0.25	
Tempo	-0.11	-0.16	-0.19	*Tempo*	-0.57	-0.42	-0,41

Table 4. Correlations within trial 1 (correlation 1) and within trial 2 (correlation 2) between the variables: Confidence, familiarity , percentage of the correct answers and tempo.

However, the further analysis of the right answers reviled some interesting divergences within the excerpts between the trials. The detailed excerpt's comparison has been illustrated in the Figure 8.

The differences between the correct answers in trial 1 and trial 2 shown in Table 3 might lead to a straight conclusion that for every single excerpt there will be more correct answers in the second trial than in the first one. In other words, it can be assumed, taking into consideration the scores

42% for trial 1 and 61% for the trial 2, that examples from the second trial will be in general more precisely estimated than the adequate examples in trial 1.

In fact only 11 examples out of 17 (67 %) got better results in trial 2. Does it mean that the proper estimation of the remaining 6 excerpts (33%) in the first trial was a coincidence? Or do any other factors play here an important role? There is no clear explanation. Any positive correlation between tempi and recognition rates has been observed suggesting no systematic dependence between them, hence guessing (see Table 4.).
However, an individual excerpts' observation revealed that four of them ("The Matrix", "Indiana Jones", "Friends" and "The X Files") were presented to participants in trial 1 firstly in the original form and 2 seconds after with the modified tempo (see Appendix 4). This fact confirms the previous assumptions that people can recognize modified tempi if they hear their originals at least once earlier. The other two out of six that were more correctly recognized in trial 1 than in trial 2 excerpts ("MASH" and "God Father") were played in a slow rate (59-99 bpm) that could lead more proper estimations. However, this issue should be studied in more detail by varying the tempi more consistently.

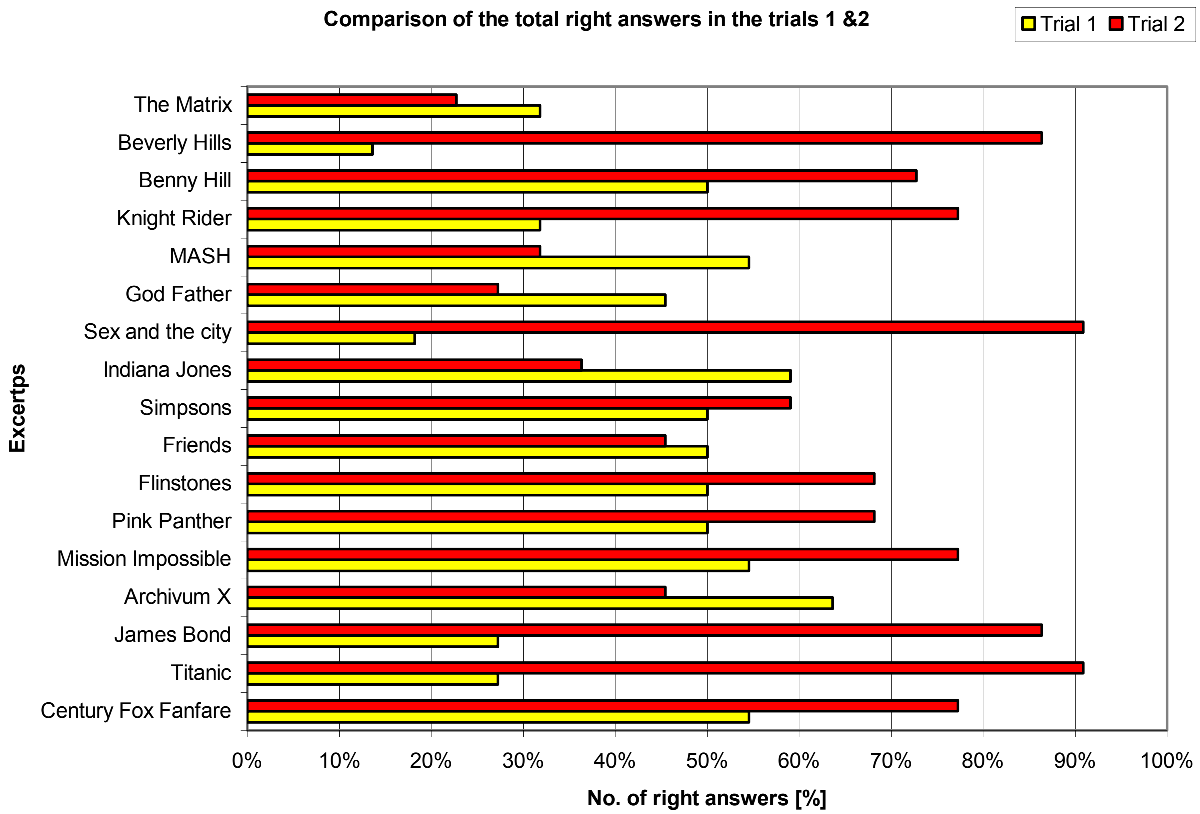

Figure 8. Comparison of the total correct answers between trial 1 and trial 2.

In addition, one could examine the impact of gender and musical background for the percentage of the right answers. Analyzing the results from Table 5 and Table 6 it can be noticed that the percentage thresholds, between the trials 1 and 2, in both cases duplicate the schema of Table 3. Since the first t –test has proved hypothetical participants' guessing in trial 1, it can be concluded that their outcomes from trial 1 are not significant thus, will be omitted in further investigation.

Nevertheless, comparison of gender results from Table 5 suggests that the females' memory for tempo is slightly better that males'. The female subjects achieved a score of 66% right answers whereas male listeners only a score of 58%. However, the outcomes were verified with the fourth t-test in which the null hypothesis stated there should be no difference between genders in recognizing tempo from memory. Since in the t-test, for 20 degrees of freedom: t(n) = 1.125024 the significance was p = 0.27 (p > 0.05), the null hypothesis is accepted. Hence, it can be argued that better female's results stem from the small amount of subjects in the group, which is not able to illustrate the general female's population. In other words, it could be assumed that the gender results would be equal if in both studied groups were an identical number of participants.

		*Right answers in **trial 1***			*Right answers in **trial 2***		
Variables	No. of subjects	M	SD	%	M	SD	%
Male	14	6,7	3,4	**40%**	9,9	3,4	**58%**
Female	8	7,1	2,7	**42%**	11,3	2,1	**66%**

Table 5. Comparison of the gender results among male an female participants within the trials.

Similar calculations between musicians and non-musicians were carried out. Like in the case of gender results, only outcomes of trial 2 were further analyzed. The non-musicians with 65% of the correct answers appear to be better than musicians (59 %).

The verification with the help of the fifth t-test, where the null hypothesis of no difference between non-musicians and musicians has been established, revealed the outcomes: t(n) = -0,23763 where p=0.82 (p>0.05), for 15 degrees of freedom. Hence, the null hypothesis has been accepted, which revealed that there is not significant difference among people taking part in the project, thus non-musicians do not possess better memory for tempo than musicians. This is a very interesting observation.

		*Right answers in **trial 1***			*Right answers in **trial 2***		
Variables	No. of subjects	M	SD	%	M	SD	%
Nonmusicians	8	7,5	3,3	**44%**	11	2,8	**65%**
Musicians	14	6,5	3,1	**38%**	10	3,1	**59%**

Table 6. Comparison of the musical background results among musicians and nonmusicians within the trials.

Confidence and familiarity

A plain coherency between confidence and familiarity compared in the different combinations has been monitored (see Figure 9, Figure 10 and Figure 11). Although in Figure 9, some small differences of an approximate range of 1 rate (in judgment from 1 to 5) are observable, it is not considered to be a noteworthy detail. Furthermore, a highly positive correlation between those two factors has been noticed in both trials. In trail 1 it amounted to r =0.76 and in trial 2 to r=0.72 (see Table 4). Therefore, one can conclude that the project's participant were consistent in giving scores in both trials. Moreover, when the excerpts were more familiar to them, they felt more confident in estimation. On the other hand, when the examples were not so well-known to them, they were unsure, thus gave low confidence's grades.

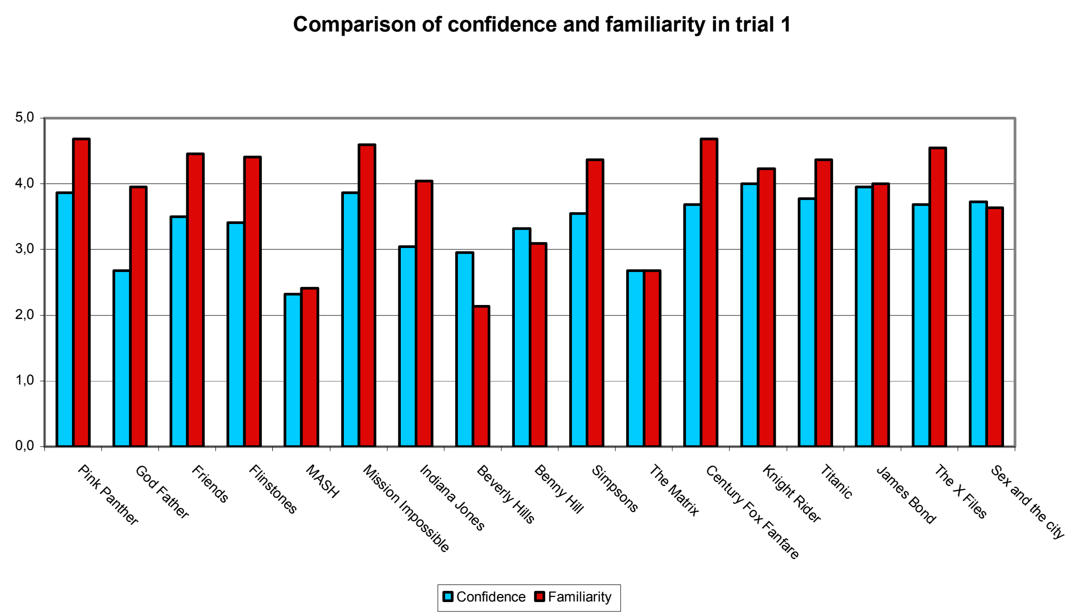

Figure 9. Comparison of confidence and familiarity in the trial 1

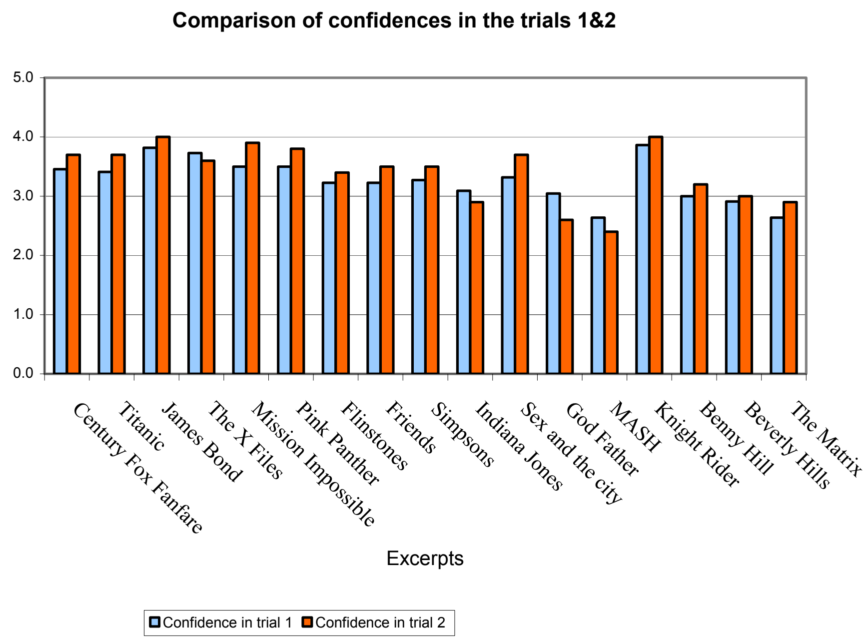

Figure 10. The graph shows a comparison of confidences between the trials.

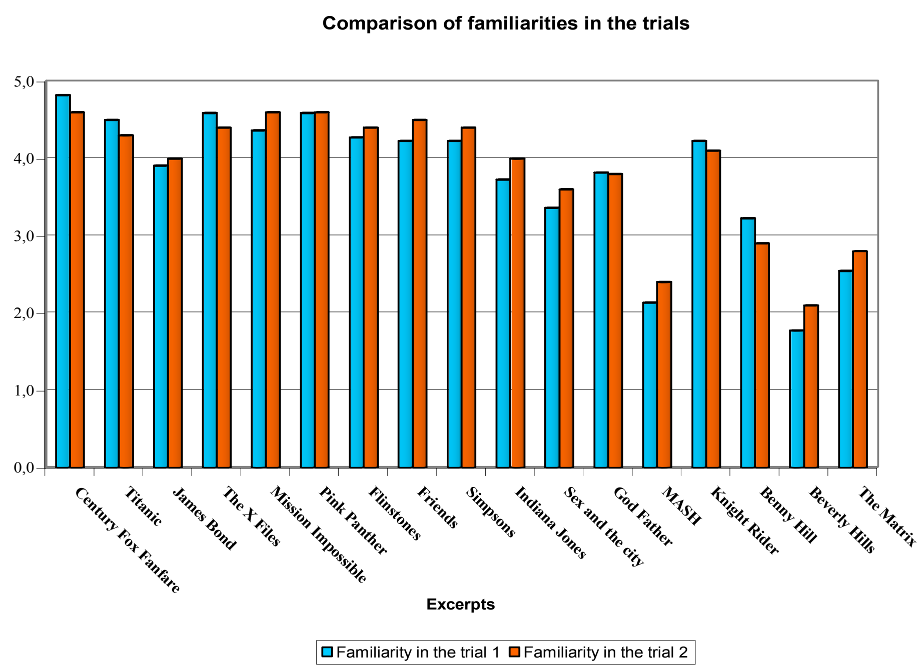

Figure 11. Comparison of familiarities between the trials.

On average, 17 excerpts were fairly well known for the participants, see Figure 10. Many of them reached a 'threshold 4' out of 5 for what is interpreted as 'I know it well". Only 3 excerpts, that is, "MASH" ,"Beverly Hills" and "The Matrix" were below the average, that is, "threshold 3" interpreted as 'I have heard it'. In other words, as much as 3 out of 17 were not familiar to the most participants. Nevertheless, Table 4 showed positive correlations between the amount of correct responses and familiarity: for trial 1: r= 0.43 and for trial 2: r= 0.25.
In general, the 'familiarity' results of estimation task overlap with the 'familiarity' outcomes of recognition task.

Tempo

Researchers claim that people certainly find it easier to tap with preferred tempo. For some of them preferred tempo is usually located around 100 bpm, that is, 600ms (Fraisse, 1982) for the others around 120 bpm (500 ms) (Moelants, 2002).

Excerpt's name	**Tempo estimation [bpm]**
Century Fox Fanfare	113
Titanic	99
James Bond	122
The X Files	124
Mission Impossible	125
Pink Panther	116
Flinstones	162
Friends	125
Simpsons	117
Indiana Jones	126
Sex and the city	83
God Father	99
MASH	59
Knight Rider	115
Benny Hill	122
Beverly Hills	180
The Matrix	169

Table 7. Values of tempo estimation of the excerpts.

The examples of music used as excerpts contained a large range of tempi varying from 59 bpm to 180 bpm (see Table 7). Hence an attempt to detect whether faster or slower examples are more easily recognized has been undertaken. As a result, first a hypothesis that the extreme tempi, meaning the slowest and the fastest, yield the most correct answers has been examined. This assumption might be drawn from the difference of results between the trial 1 and trial 2 (see Figure 8). For instance, in case of “Beverly Hills” (180 bpm) or “Titanic” (99 bpm) this difference amounted to about 73%. On the other hand, one could argue that for example, the changes in tempo in “MASH” (59 bmp) or “The Matrix”(169 bpm) have not been better recognized than the changes in ‘neutral’ examples from the middle of tempi range. Furthermore, as mentioned before, no positive correlations between the recognition and tempi (shown in Table 4) have been observed. Thus, on this level, the analysis of certain responses according to the excerpts' tempi did not yield to any significant conclusions.

Trial1				
Variables	No. of excerpts in the whole trial	M	SD	%
Slower	8	4,5	1,3	56%
Faster	9	4,1	1,5	45%

Table 8. The results of proper recognition of excerpts' modification in trial 1.

Trial 2				
Variables	No. of excerpts in the whole trial	M	SD	%
Slower	9	5,6	1,5	63%
Faster	8	6,0	1,8	75%

Table 9. The results of proper recognition of excerpts' modification in trial 2.

The further examination of tempi focused on detecting which of their alterations are easier to judge: faster (8 % faster than original tempo) or slower (8 % slower than original). The results of proper recognition of excerpts' modification are collected in the tables above. As can be seen, both Table 8 and Table 9 do not show any systematic relation between the variables. One assumption is that people need a much more clear modification of tempo for its better discrimination. For instance, instead of 8% alteration the examples could be changed by 12%. This simplicity might increase the amount of correctly estimated excerpts.

Chapter 4

4. Conclusions

The purpose of this study was to examine whether people can possess accurate memory for absolute tempo like some people do with the absolute pitch. The literature concerning memory for tempo revealed many discrepancies in this field that suggested a necessity to investigate further. In my thesis two contrary hypothesizes has been presented: some researchers argue that some people possess this ability (Levitin & Cook, 1996; Bergeson and Trehub, 2002; Reed 2003) while other researchers do not (Moelants, Styns, and Leman, 2006).

My results consent to the theory of Moelants et al. (2006) according to which people do not possess absolute tempo. The participants were guessing in trial 1 what has been proved using the t-test. However, the same test showed that the second trial could be considered as reliable data. Nevertheless, the fact that the subjects failed more often in trial 1 and answered much better in trial 2 can give a basis for an assumption that my participants do not have absolute memory for tempo. However, they can more or less estimate the modified tempi if a short time earlier, they had a possibility to rehearse in memory or to listen to the unmodified excerpts. Furthermore, high correlation with confidence has been observed because a detailed analysis showed that after at least one rehearsal of original tempo the people were more confident in tempi estimations and consequently obtained better outcomes. Nevertheless, as I showed in Chapter 3, it is not sufficient to point out to absolute memory for tempo.

In both aforementioned studies, by Levitin & Cook (1996) and by Moelants et al. (2006), participants could listen to the excerpts before. As a result, the former collected data, in which memory can be assumed as being perfect while the latter achieved results that people deviate in imitating of the songs up to 20%. The differences can be explained by the method study. Levitin & Cook asked subjects to sing two ‘favorite’ songs from a large collection of music whereas Moelants et al. presented first a list of given examples and asked people if they can imitate one of

them. In case of Levitin & Cook, participants had a subjective choice, thus they could choose a song they used to sing or have a very accurate image of tempo.
My estimation task assumed presentation of given examples without listening to them first. However, two trials given one by one in a short time caused situation similar to the study's design of Moelants et al.

My outcomes showed that gender and musical background do not have a considerable influence on the memory for tempo. Although in my study female participants achieved better results that male ones it was not a statistically significant difference. It could be explained with the hypothesis that women like to watch TV series and watch them weekly as many of them actually reported. Similarly, non-musicians seemed to be better in tempi estimations than musicians. In this case, musicians probably focused too much on involuntary musical analysis of given excerpt whereas non-musicians did not have an adequate high-quality musical knowledge. However, in both cases the differences in number of correct answers within variables (male and female, musicians and non-musicians) were very small, hence are not regarded as a noteworthy factor.

The issue of preferred tempi did lead to strong conclusions. As a matter of fact, studies investigating different features of tempo have been carried out since early 1920's. In his study Brodsky (2005) reported over 80 years of history and wrote that studies in this time period attempted to study if specific compositions can be perceived to have a 'correct" rate, if there are some preferences for tempo among the listeners, if some tempi are perceived as more enjoyable than others, if discrete tempo differences and shifts in pace are noticeable or finally if tempo speed are remembered over prolonged period of time.

According to Brodsky, the first projects in which the subjects had to report their preferred tempo between the two tempo versions of the same compositions have arisen in ca. 1955-1980. In this time, the earliest attempts of judgment whether the second piece was similar/different or faster/slower than the first has been made. All experiments were focused on tempo ratings.

In case of my results, no systematic relationships within tempi have been observed. Furthermore, there was no positive correlation between correct answers and tempi. Similarly, a detailed analysis of tempi alteration did not reveal any regular outcomes. However, Moelants et al. (2006) claim that his participants tended to imitate most of the pieces faster than original tempo was predicting. The author suggested that people do not consider a tempo as a crucial feature giving it a large tolerance. Furthermore, the imitated songs were still well recognizable even when they were sped up or slowed down within certain limits. Already Trehub (1989, 2001) in her studies indicated that babies can easily identify familiar melodies although their tempi have been modified. Hence, it seems that this high-level feature of LTM, that is, recognition despite of tempo deviations, effectively dominates low-level ones. Nevertheless, those discrepancies between tempi observations in both studies, mine and Moelants et al. prove that this issue should be studied further.

The idea of the project has been inspired by some studies in which the long-term memory was investigated (e.g. Schellenberg & Trehub, 2003; Strauss et al., 2006;). In all of them, the popular TV title themes, pre-selected for familiarity, were used. Although they were both based on the same musical material as a stimulus, i.e. “The Waltons”,” I dream about Jeannie”, “Knight Rider”, ”Dallas”, ”The X-files”, ”Emergency room”, their main aims were different. While Schellenberg & Trehub focused on the pitch memory, Strauss et al. dealt with the extremely accelerated tempi in the familiar pieces investigating stability of tempo representations.

My empirical study partially followed the formula of previous studies. I used seventeen excerpts each lasting 14 seconds, of popular pieces of music preselected for familiarity. Recognition and estimation tasks were carried out, instead of production or imitation tasks used by the others in the design of study investigating memory for tempo (Levitin & Cook 1996, Bergeson & Trehub 2002, Reed 2003, Moelants, Styns & Leman 2006). Additionally, the large results’ discrepancy observed in their research motivated to re-visit the general idea and to re-examine this memory problem again.

For the project, participants were recruited using the University of Jyväskylä’s foreign student mailing list and private connections. This was due to the fact that there were not so many voluntary ‘applicants’ from the Music Department. Fortunately, the sufficient amount of participants was eventually recruited.

The people, with and without musical background, were outgoing, reliable and very well cooperating in the study. Only one participant did not understand the instructions and I could not include his responses to my data.

The participants assessed all of the stimuli as being at least somewhat familiar. In general, the excerpts created a positive atmosphere during the listening tasks.

To sum up, in participants opinion, my listening project concerning memory for tempo was a very nice judgment and many of them used it as a personal quiz to check their memory or as a kind of exam to realize how good they are at recognizing the pieces of music, and estimating the original tempi. This was assumed based on the fact that all subjects wanted to know the exact names of the musical examples in the recognition task and correct answers in the second one, that is, in estimation of tempi. Furthermore, from my perspective, both procedures: recognition and estimation went smoothly and without any technical problems. Finally, in my opinion the research can be recognized as successful.

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APPENDIX no.1. The list of thirty-six examples used in the recognition test.

1.*Mission Impossible*
2.*Century Fox Fanfare*
3.*Titanic*
4.*Braveheart*
5.*Lord of the Ring*
6.*Schindler's List*
7.*Itse valtiaat*
8.*Forrest Gump*
9.*James Bond1*
10.*James Bond2*
11.*Pink Panther*
12.*The X Files*
13.*Simpsons*
14.*God Father*
15.*TV4 Uutiset*
16.*The Matrix*
17.*Knight Rider*
18.*Benny Hill*
19.*Bonanza*
20.*Walker Texas Ranger*
21.*CSI Las Vegas*
22.*Dallas*
23.*Flinstones*
24.*Friends*
25.*Indiana Jones*
26.*MASH*
27.*Muppets*
28.*Scooby-Doo*
29.*Sex and the city*
30.*Winnie the pooh*
31.*Wonder Years*
32.*MacGyver*
33.*Moomins*
34.*Urheilut*
35.*Uutisvuoto*
36.*Beverly Hills*

APPENDIX no. 2. The questionnaire concerning the recognition test.

I Listening test

The task: You have 36 excepts of famous films , TV-series or TV-programs examples.
Each one takes 15 sec.
Try to estimate **if** the given **piece of music is familiar** to you.

	I know it **very well**	I know it but **don't remember the name**	**I don't** know it
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			

The country you come from:

Do you have any musical background? : Yes No

Thanks for your help ☺ !

APPENDIX no.3. The questionnaire concerning the estimation test.

Part II. Listening to modified excerpts.

Your task: You will hear 17 excerpts of famous films , TV-series or programs examples.
There are two version of each one: original and modified one.

1. Find out, **which** one (1st or 2nd) **is altered** (has modified (**not original, shifted) tempo**).
2. Simultaneously **estimate if** this tempo is **slower or faster** than in original version.
3. Rank the confidence of your estimation (within the scale 1-5).
4. Rank your familiarity with the listened excerpt (within the scale 1-5).

no.	**1st / 2nd**	**Slower / Faster**	**Confidence**	**Familiarity**
example	/	/	*1 2 3 4 5*	*1 2 3 4 5*
1.	/	/	1 2 3 4 5	1 2 3 4 5
2.	/	/	1 2 3 4 5	1 2 3 4 5
3.	/	/	1 2 3 4 5	1 2 3 4 5
4.	/	/	1 2 3 4 5	1 2 3 4 5
5.	/	/	1 2 3 4 5	1 2 3 4 5
6.	/	/	1 2 3 4 5	1 2 3 4 5
7.	/	/	1 2 3 4 5	1 2 3 4 5
8.	/	/	1 2 3 4 5	1 2 3 4 5
9.	/	/	1 2 3 4 5	1 2 3 4 5
10.	/	/	1 2 3 4 5	1 2 3 4 5
11.	/	/	1 2 3 4 5	1 2 3 4 5
12.	/	/	1 2 3 4 5	1 2 3 4 5
13.	/	/	1 2 3 4 5	1 2 3 4 5
14.	/	/	1 2 3 4 5	1 2 3 4 5
15.	/	/	1 2 3 4 5	1 2 3 4 5
16.	/	/	1 2 3 4 5	1 2 3 4 5
17.	/	/	1 2 3 4 5	1 2 3 4 5

Do you have any musical background? : Yes No

Thanks for your help ☺ !

APPENDIX no.4. The order of the recorded altered versions in the estimation test.

Descriptions:

n_wav – the 8 % faster tempo   p_wav – the 8 % slower tempo   wav – the original tempo

Trial 1			
1	***Century Fox Fanfare***	1wav	1 n_wav
2	***Titanic***	2 p_wav	2 wav
3	***James Bond***	3 n_wav	3 wav
4	***The X Files***	4 wav	4 n_wav
5	***Mission Impossible***	5 p_ wav	5 wav
6	***Pink Panther***	6 n_wav	6 wav
7	***Flinstones***	7 p_ wav	7 wav
8	***Friends***	8 wav	8 p_ wav
9	***Simpsons***	9 n_wav	9 wav
10	***Indiana Jones***	10 wav	10 n_wav
11	***Sex and the city***	11 p_ wav	11 wav
12	***God Father***	12 n_wav	12 wav
13	***Knight Rider***	13 wav	13 p_ wav
14	***MASH***	14 n_ wav	14 wav
15	***Benny Hill***	15 wav	15 p_ wav
16	***Beverly Hills***	16 n_wav	16 wav
17	***The Matrix***	17 wav	17 p_ wav

Table 10a. The recorded order of excerpts in the estimation test within the trial 2.

Trial 2			
1	***Pink Panther***	6 wav	6 p_wav
2	***MASH***	12 wav	12 p_wav
3	***Friends***	8 n_wav	8 wav
4	***Flinstones***	7 wav	7 n_wav
5	***Knight Rider***	13 n_wav	13 wav
6	***Mission Impossible***	5 wav	5 n_wav
7	***Indiana Jones***	10 p_ wav	10wav
8	***Beverly Hills***	16 wav	16 p_wav
9	***Benny Hill***	15 n_wav	15wav
10	***Simpsons***	9 wav	9 p_wav
11	***The Matrix***	17 n_wav	17 wav
12	***Century Fox Fanfare***	1 p_wav	1 wav
13	***God Father***	14 wav	14 p_wav
14	***Titanic***	2 wav	2 n_wav
15	***James Bond***	3 wav	3 p_wav
16	***The X Files***	4 p_wav	4 wav
17	***Sex and the city***	11 wav	11 n_wav

Table10b. The recorded order of excerpts in the estimation test within the trial 2