Memorising Music for Solo Piano Performance

A Theoretical Framework

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Now that this project is about to leave my hands, I am finally ready to take on new challenges outside of academia. I think.

1.
Introduction

«The one who thinks over his experiences most,
and weaves them into systematic relations with
each other will be the one with the best memory.
[...] It will now appear clear that all improvement
of the memory lies in the line of elaborating the
associates of each of the several things to be
remembered» (James 1890:662).

1. 1 Objectives

The main objective of this thesis is to demonstrate how and why classical solo pianists memorise music for musical performance. Consequently, this thesis contains useful material both for students and teachers in the musical domain. Although each individual's musical taste and way of learning are subjective entities, the thesis aims to provide a theoretical framework from which one can build an understanding of how memory works in relation to music. There seems to be a gap between the larger part of the community of performing pianists and the plethora of interesting research surrounding them consisting of numerous studies from scientists with differing backgrounds and objectives. The present thesis should be considered an attempt to bridge some of the gap that exists between the science and psychology of music performance on the one hand and in particular the classically trained pianists on the other.

What exactly is considered most important by performers and by the literature when playing from memory? Are pieces that are learnt by heart simply automatised motoric actions, and if so, in what way is the mind in control of these actions? In other words, does the musical mind and the musician's hands simply *know* what to play after numerous repetitions, or are there other aspects to do with conscious planning and execution involved? A better understanding of how to combine theory and performance may be useful for many pianists as comprehension of these aspects leads to a more reliable memory.

Once a piece of music has been repeated several times, it may feel like the fingers are capable of doing all the playing on their own. That is, until mistakes are made and the performer may occasionally suffer from a complete inability to continue. At this stage our motor memory, or, procedural memory, demonstrates one of its strengths and also its weakness, namely that of automatically controlling motor sequences. Relying entirely on procedural memory means neglecting the advantages offered by deliberately including music-theoretical knowledge into practising and playing. Without some level of awareness of one's playing, an underlying safety net is removed from the often stressful performance situation. Awareness of the memorisation processes related to automatic actions and an increasing knowledge base, and viewing the two as interdependent rather than independent, may provide the performer with a dependable fail-safe system (Chaffin, Logan, & Begosh 2009). The interdependence between knowledge and automaticity will reappear throughout the subsequent chapters, and the goal is to shed some light on how they constantly interact from the initial rehearsal through to the final performance. Central topics within music psychology and music theory will be presented and compared, through pairing the concepts of e.g. the psychology of motor memory and the music theory of scales and chords; the psychology of chunking and working memory, and theories from music performance concerning practice techniques; the psychology of schemata and the music theory behind musical form and structure; music cognition research concerning melodic contour and studies on melodic memory, as well as some related considerations from studies on human motor control.

This research will not, and ultimately cannot, cover all aspects of music and the psychology of memory equally comprehensively. However, the main goal is to attempt to explain the processes that take place in a musician's mind while preparing for a performance and how these processes lead to the construction of a dependable memory. This will be based on a synthesis of the current literature from both musicology and music psychology.

1.2 Motives and relevance

Teachers and students possess an arsenal of practice routines and techniques helping them prepare for performances in the best way possible. Slowly practising a few bars at a time with each hand separately is a familiar step for most pianists early in the rehearsal process. The aim is to establish individual motor programmes for each hand before conjoining them into bimanual motor programmes. Analytical reading of the sheet music before playing gives an initial impression of the character of the piece and helps to identify potential challenges that may emerge. Perhaps less known among amateur performers is the strategy of mental rehearsal carried out in absence of the keyboard, one of the favoured practising techniques of professional performers. As one might expect, pianists find a fair amount of pleasure in the actual playing, nevertheless, learning to master a piece fully places a demand for mental control and a general level of insight, both of which are more easily available after employing a multimodal approach to rehearsal and preparation in which visual, auditory, and tactile feedback are all included and processed carefully (Hughes 1915). The need for a considerable amount of planning and proper preparation becomes apparent when taking into account the pressure placed on the musician when sitting on a stage, being the centre of attention for an audience filled with expectations. Naturally, the artist wants to present a top performance; expressive and spontaneous, yet flawless and in full control. How can such preparations be made, and how does a pianist manage to stay in control of the planned actions even if mistakes are made? First, we have to identify some of the issues that must be dealt with already at the practising level. Following is a short depiction of a common situation one might find oneself in when practising an unfamiliar piece on the piano:

First, one must identify the notes written in the score, and translate them into musical meaning. This will typically include information about pitches and durations. Second, one must locate the keys corresponding to these pitches on the instrument. Third, one must decide which hand and which fingers to place on the keys. Fourth, before physically playing the keys, one must make several decisions regarding dynamics and expressivity, and if/when in relation to a succession of notes, also how to incorporate these into a longer phrase. The execution of each action is often contingent on the way in which previous and following actions are to be executed.

In a practice session each of these tasks would only take a split second for a pianist proficient in sight-reading, and making such a performance sound expressive is a demanding task. Together they would sum up to an amount of time that is mostly unavailable in a live performance situation, reflecting the need for practise even amongst experienced pianists. Expert sight readers can be found amongst trained «piano accompanists and studio orchestra musicians» (Lehmann & McArthur 2002:137), and their training allows them to rapidly incorporate expressive details into the music. However, a tradition for memorising performances started in the second half of the 19th century. In this era the notion of memorised solo performances became manifested through artists like Clara Schumann and Franz Liszt (Chaffin & Imreh 1997). Interestingly, not all pianists find memorising pieces equally useful, and some do not even find it manageable, possibly due to lack of experience away from the score. Some argue along the lines of 'all the information needed is provided in the score, so why make an effort of memorising it all?' I find that the very best performances are the ones displaying a total mastery of the music at hand, whether with or without any visual aids. Amongst pianists who are depending on the score there may be communicative benefits of memorising, seeing as some of the immediacy disappears with regards to the subtle communication with the audience. Consequently, musicians practise in order to reduce challenges to a minimum, and some spend considerably more time practising than others. This may have to do with unproductive practising routines. Necessarily pianists who rely on the sheet music on stage must know the music to some extent after having rehearsed the piece, planned the necessary motor programmes to execute, and chosen how to interpret the music. The purpose of this project is not to make every musician conform to playing without any visual memory aid, as much as it is intended as an overview and a guide to how memory for musical performance works. However, when the full focus is on the sound of the music, and the very performance is given full attention instead of the piece of paper, there may more mental capacity left for the spontaneous creative outburst - the performer's complete presence in the moment. Furthermore, beside the fact that playing without the score displays a serious level of preparation, some evidence suggests it enables the performer to better communicate expressive intentions, as rated by the audience (Williamon 1999).

1.3 Focus and limitations

The thesis sets out to mainly explore the skills that are needed in order to perform music purely from memory. Automatised processes that pianists are rarely able to explain will be discussed in relation to the musical knowledge that most pianists attain through formal education. The main focus will be on how long-term memories and motor memories are constructed, retained, and reactivated, and on the role that musical knowledge plays in the process. In addition, various practising techniques will be presented to demonstrate how professionals secure a maximal level of retrieval from their rigorously constructed musical memory. Connections between memorisation techniques and inherent elements of Western musical culture will be presented. Furthermore, practising techniques will be exemplified in analysed excerpts from Edvard Grieg's *Ballade in G minor (op. 24)*. Theories of memory from the psychology literature will be provided in support of the practise techniques and the findings of the analysis.

Concerning instrument and musical style

First and foremost, as has already been described to some extent, the focus is on piano performance. This is mainly because the majority of research on music and memory has developed during the last four decades, and has been conducted chiefly on classically trained pianists. Also, the piano is a widely known instrument with a large number of active performers, implying there is a need for research being done in this field. Any musical style is in principle possible to memorise, albeit some classical avant-garde music from the 20th century lay a much heavier demand on preparations, planning, and execution strategies than music from the Romantic period in the late 19th century. Accordingly, the latter will be given emphasis due to its familiarity among the larger part of pianists, as a wide range of music from this period has found its way into the standard repertoire. In addition, piano music written in the Romantic period follows many stylistic rules and has a comprehensive structure and feature content. The particular choice of musical style therefore also serves an analytical purpose. Much of the information provided in the thesis is transferable both to other musical styles and musical instruments owing to the many tonal and structural similarities across the Western musical culture. The benefits of identifying musical structures will be demonstrated in the subsequent chapters, and recognising that there is a spectrum of memorability is something pianists might do well to keep in mind. However, anyone with an interest in music performance and/or memory is urged to explore the details about the relationship between musical knowledge and memory models from the pianistic point of view offered here.

Concerning memory

Why do we have memory? What is the capacity of human memory? How long do memories last? Can memories change over time? Are there different types of memories? And what are they exactly? To begin with the latter; memories can be characterised as a function of connections between neurons and the strength of these connections. Memories can be considered as reactivations of the neuronal network corresponding to that which was activated at the time of the first encounter of some sensory input (Hebb 1949). Furthermore, the individual connections within these networks can be differently weighted, i.e. some types of information may be more familiar than others. Thus, according to the Hebbian learning theory, parts of the network that have been previously activated become stronger with each subsequent activation. While some networks are stronger than others due to the amount of exposure we may have received to the corresponding situations, memories are still not to be considered as a mental copy of reality. Neither are they necessarily completely solid. Memories are rather prone to reconstruction as a result of interference, e.g. due to similarity of episodes (Anderson 2010). Therefore, rather than viewing these neural connections as hard-wired and representing bits of truth, they should be considered malleable remnants of the past. Neural networks that were once activated by an external sensory input strengthen with repetition and may thus become more stable. An example of this process in action can be found in a typical practice session where repetition of a sequence, a phrase, or just two notes makes the sequence or phrase easier and easier to perform. Initially the search for the correct artistic response to the recipe written in the sheet music may take some moments, whereas by the second, third, and fourth execution of the same sequence, that particular action becomes increasingly familiar and internalised. On the other hand, a lack of practise may lead to memory decay (ibid.).

While some effort will be devoted to explaining the anatomical foundations of memory, the main emphasis is on functional memory. As such, memory can be classified into types of contents and functions following the taxonomy proposed by Squire (2004). A memory can be semantic, relating to facts and meaning. For example, this could include knowing when Christmas is celebrated, what the celebration represents, and so forth. A memory can also be episodic, relating to specific events in the past. This could include the memory of one particular Christmas celebration. «These two types of memory appear to constitute two ends of a continuum extending from recollections of particular episodes through increasingly general models of types of situations to abstract knowledge representations that no longer have roots in any particular experiences» (Snyder 2010:108). Furthermore, they form parts of our declarative knowledge, and reside in our explicit memory system - the part that is consciously available to us in long-term memory (Baddeley, Eysenck, & Anderson 2010). However, we also have non-declarative memory, or implicit memory, such as automatised skills and responses that are not consciously controlled. This is referred to as our procedural memory, also a part of long-term memory (ibid.). What we normally refer to as memory in general is information stored in our functional long-term memory repository, which resides in a combination of anatomical structures in our brain in addition to widely distributed neural networks. In order for information to enter long-term memory, it must first pass through a filtering process taken care of by our working memory, whose main role in information processing is sorting out what should be given attention and what should be disregarded. Working memory also provides the mental workspace required for interactions between semi-activated material in long-term memory, and the focus of our conscious awareness. This has been illustrated with a multicomponent working memory model posed by Baddeley and Hitch, containing the central executive which is thought to control attention, and three subsystems; the phonological loop, the visuo-spatial sketchpad (Baddeley & Hitch 1974), and the more recently added episodic buffer (Baddeley 2000). The functions of this model will be described in chapter 3. Research suggests that our ability to retain information in short-term memory is limited by both time span and amount of information, as illustrated by e.g. Miller's theory of the «magical number seven, plus or minus two» (Miller 1956). More recently psychologists have modified their view on short-term memory capacity to about four items, but it is yet to be determined what the exact capacity is, or even whether we have a capacity at all (Cowan 2000). Nevertheless, without a limiter in the filtering process, every sensory input would be processed and treated with equal importance, resulting in the lack of ability to generalise information. This ability is an evolutionary trait developed to efficiently avoid dangers and threats, and to seek out rewards such as food or shelter in novel situations and environments (Snyder 2000). A theoretic model of this basic generalisation mechanism was introduced by Bartlett who coined the term 'schema' (Bartlett 1932). Particularly strong memories often contain a combination of several types of memories, making the memory itself multimodal. These may include detailed information regarding sensory experiences such as smells, tastes, sounds, and images. Evidence exists in support of the idea that one should incorporate several modalities to achieve the strongest possible associative mode of thought in order to memorise efficiently (Baumann, Koeneke, Meyer, Lutz, & Jäncke 2005; Hughes 1915). Furthermore, modality tends to pertain to sensory quality, eloquently described by Clark:

> «A whiff of lilacs presents a particular sweet odour. The warmth of the rising sun yields certain tactile sensations. Bees' honey has a specific taste. The qualities that characterize the smell of the lilacs, sensation of the sun, or taste of the honey are all what I will call sensory qualities. Broadly speaking, such qualities characterize what it is like to sense or perceive things. One perceives the blooms, sun and honey in a particular way; sensory qualities characterize the way such things appear» (Clark 1993:1).

The point of illustrating all of these aspects of memory is to demonstrate its importance in normal functioning in everyday life and to illuminate how to best make use of its advantages. The human brain has developed over time to be as effective as possible in interaction with a predictable environment (Bar 2011). If we are to learn anything instead of relying on mere instinctive reactions, we must be able to comprehend, retain, and retrieve information. This is particularly relevant in relation to the separation of the conscious and the unconscious. Conscious and unconscious thought processes can be viewed as two different cognitive processing paths, labelled the central and the peripheral route in Petty and Cacioppo's *Elaboration Likelihood Model* (Petty & Cacioppo 1986). Here, they differentiate between actions being based on rational and irrational thoughts. On the one hand, central route processing employs explicit memories and enables us to make decisions based on comparing arguments to vast amounts of semantic knowledge and episodic memories. On the other hand, peripheral route processing works its way through our implicit memory and is for example what makes us instinctively decide whether to fight or flee in a dangerous situation even before consciously making the rational decision to do so. The latter, quicker and automatic way of reacting corresponds to 'system 1' thinking, while the rational, slow, and deliberate reaction corresponds to 'system 2' thinking as introduced by Kahnemann (2011). Both implicit and explicit processes and memories are important to take into consideration when theorising about musical performance, as both types of processes are constantly involved. There is also a need to distinguish between functional and anatomical memory systems. For instance, there is a multitude of interactions between the various cortical and subcortical brain structures associated with information about what to play and the structures associated with information about how to play. Knowing where these interactions take place is of no particularly practical use to the practising musician, whereas knowing how to activate the functional relationship between them may be useful when preparing for a performance. For example, musicians continually need to pay attention to their own performance and must occasionally make split-second decisions if something goes wrong or if they want to modify their performance in any way. While the (implicit/procedural) automatic processes of playing may be stored as sets of motor programmes or motor memories, the (explicit/declarative) monitoring process involves the use of other cognitive abilities and different memory strategies altogether such as including theoretical knowledge and mobilising specific schemata for a particular situation.

Concerning musical memory

There are many ways in which music may affect our memory. There is a reciprocal relationship between music and memories, meaning for example that music can trigger episodic memories, and episodic memories can trigger musical imagery. Even in the cases of patients who have suffered neurological damage to memory areas, musical memory sometimes seems to be resilient (Sacks 2008). It is not yet clear exactly why musical memory may be spared while other types of memory are impaired, however it might have to do with the way music is widely processed in different networks across the whole brain. Enculturation can make certain types of sounds be unconsciously associated with particular concepts, such as the classic example from horror movies that when the strings of an orchestra play a dissonant high-pitched repetitive pattern, we expect something bad is about to happen. A famous example is Bernard Herrmann's music written for the thriller movie *Psycho*, screened in 1960, where repeated dissonances in the violins appear only moments before the killer strikes in the notable shower scene (Husarik 2009). Moreover, from a young age specific songs become highly associated with holiday seasons, birthdays, and other celebratory and festive occasions. This naturally has to do with exposure to such songs in those given settings, demonstrating some of the power of repetition and association. Recently there has been a development in the advertising business, and sonic branding is now a part of many major brands' marketing strategy (Jackson 2003). Here the use of a short and memorable melody is meant to trigger customers' awareness of a brand and through that trigger all their associated memories of the brand's core message and products. The use of music in public spheres such as shopping centres is another example of how our subconscious is bombarded on a regular basis. These examples demonstrate how music, as a set of systematically structured sounds, can incorporate meanings that are originally detached from the physical sound itself. Interesting as these concepts are, musical memory will eventually be covered in detail from the musician's point of view. The effort of deliberately memorising sounds in succession relate to another relationship between music and memory, more specifically the conscious planning that has taken place when using sound to trigger a memory of more sound through associations.

There are many examples to illustrate the longevity and robustness of memory in musicians as demonstrated by concert pianists, but it is perhaps most interestingly illustrated by patients suffering from brain damage (Sacks 2008). With regards to the expert memory of professional musicians, which differs from that of the average person's memory for music, understanding associations is the key to understanding their memorising strategies. Musicians devote several years of their lives specialising in an art form that on a regular basis places extreme demands on a combination of memory capacity and physical abilities. However, as will be demonstrated in the following chapters, a musician's memory is meticulously constructed over time through conscientious practice and, with an increased amount of experience and knowledge, conventional memory constraints can be overcome.

Concerning the anatomy of the brain

A dense web of billions of neurons constitute what we in general refer to as our brain, arguably the most complex and interesting organ in our body. It has been rigorously explored for centuries, yet many of its attributes, abilities and functions remain mysterious. Early attempts to understand the human brain in the 19th century lead to the blooming of phrenology, claiming that personal characteristics and abilities were located in distinct parts of the brain. By measuring the size and shape of the cranium around specific areas researchers presumed they were able to reveal details about a person's mental abilities. Although later refuted as a pseudoscience, the general idea of mental abilities being located in distinct brain areas has been upheld. In some ways it gave way to modern neuroscience, where scientists work under the presumption that their findings in a few brains to a large extent are transferable to all brains (Ward 2010). Recent developments in brain imaging techniques have now provided extensive maps of the brain's motor cortices, supplementary motor cortical areas, somatosensory cortices, auditory cortices and their corresponding association areas - some of the anatomical areas dealing with movement, the sense of touch, and hearing, all of which are essential to the act of playing the piano. It is outside this thesis' focus to cover the entire neurobiology behind the actions involved in playing, and programming memories. However, current views on the fundamental processes will be accounted for.

In addition, there are areas in the brain considered to serve as central relay stations for sensory input, for example the two hippocampi which are also involved in the formation of new memories and the retrieval of existing memories. Activity in these structures emanating from sensory input can only be fully understood by simultaneously considering their interconnection to the brain regions for the given sensory input - e.g. the auditory cortex for sounds. A complete such understanding is not yet available to scientists, as even elaborately investigated brain regions function in relation to the entire web of neuronal connections that constitute a functional memory. With only introductory comments on the anatomical regions, the formation of functional memories and their retrieval from long-term memory is what will be investigated in detail.

1. 4 The structure of the thesis

The present thesis is separated into six chapters. Research areas on music performance and memory are multifaceted, and the three aspects chosen to form the main body of this thesis comes from three different research areas. A total coverage of musical memory would demand more than just introductory chapters to fields such as musicology, psychology, and physiology. Nevertheless, this does indeed provide those who are particularly interested in musical performance with valid starting points for further exploration.

In chapter 2, the reader is introduced to musicological topics including music theory, practising techniques and musical analysis with the overall focus on their relation to memory. Chapter 3 provides a brief insight into the foundations of psychology and memory with a spotlight on memory for music. Chapter 4 introduces the reader to topics related to movement and motor control, including complex movement patterns such as playing a musical instrument. In chapter 5 some extra-musical ideas are introduced to shed some light on how a musician's memorising mind can be influenced by experiences other than only those to do with music. Lastly, in chapter 6 the arguments will be recapitulated and seen in light of piano performance.

2.
A Musicological Approach

«As neither the enjoyment nor the capacity of producing musical notes are faculties of the least use to man in referance to his daily habits of life, they must be ranked amongst the most mysterious with which he is endowed» (Darwin 1871:333)

Preface

«If music is truly the product of distinct, and distinctly functional, human capacities, a better understanding of music in evolutionary terms should be of immense value in elucidating the significance and distinctness of music as cognitive process and as social behaviour» (Cross 2009:11). Instruments older than ~40,000 years consisting of animal bone flutes with intentionally made holes have been found in central Europe (Higham, Basell, Jacobi, Wood, Ramsey, & Conard 2012) and whether they were used mainly for sending warning signals or they served some other primitive form of communication remains speculations. What is indisputable is that at some point tone patterns emerged and with time turned into what is today considered an important and central cross-cultural asset. Music is a highly appreciated art form, and its most competent artists are highly regarded for their technical, interpretive and communicative skills. As most art forms, music has undergone tremendous development since its first historical appearances. Despite its omnipresence in modern society, it is disputable whether music has any clear evolutionary reason for existing. Psychologist Steven Pinker's unconventional hot potato; music is nothing but 'auditory cheesecake' (Pinker 1997) provides an infamous example of how to provoke a reaction from the evolutionists. While music's first appearances will not be discussed here, it is worth noting that a clearer image of its prevalence may emerge once evolutionary biologists find more common ground. Nonetheless, many musical features are structured in patterns that readily enter our brain and engage our cognitive system. As a result of the intricate ways auditory structures are interpreted, music can be an exquisite trigger for emotions, memories, and learning.

Melody forms one of the fundamental building blocks of music. Regardless of scale mode, i.e. major or minor, basic melodic structures in Western tonal music are traceable several hundred years back in time to the Renaissance and beyond. In polyphonic structures some tones have a better fit than others, based on the physical properties of harmonics and overtones (Pierce 2001). When the overtones and harmonic spectra of several tones are compatible with each other the phenomenon is perceived as consonance, a natural aspect of stable intervals such as the octave, the fifth and the fourth. The less compatible intervals are perceived as more or less dissonant. An important element of tonal music in general is the construction of 'tension and release' which is basically what creates excitement and musical interest. What may seem counter-intuitive is that violating expectations and inviting dissonances provokes the listener's interest and may lead to even further expectations, and when the expectations are finally met the listener may experience a rewarding sensation (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre 2011). Similarly, correctly anticipating musical contents leads to a rewarding sensation (Huron, 2006). Meanwhile, the correct anticipation may be due to a mere exposure effect. «It is as though our brains are saying "well done for predecting these musical events" and then sending out a burst of pleasant neurochemicals as our reward» (Thompson 2009:104). In connection with the earlier mention of how the human brain has adapted to be able to foresee future events based on beneficial experiences, it seems we may have mistaken cause for effect: «instead of attributing our positive feelings to this biological reward system, we misattribute them to the music itself. The result is that the music "sounds nice"» (loc.cit.). On the basis of how emotional responses to music are related to reward, it would seem likely that this mechanism also contributes to the memorability of music. Moreover, with experience, musical expectations and preference can change due to how certain aspects become familiarised to such a degree that they become uninteresting. The level of complexity may therefore be perceived as higher by someone with less experience within a given style. The relationship between complexity and preference can be illustrated by an inverted U-model, in which the preference is highest at medium levels of complexity (Heyduk 1975). Too complex and too simple music is thought to be the least preferred on a general basis.

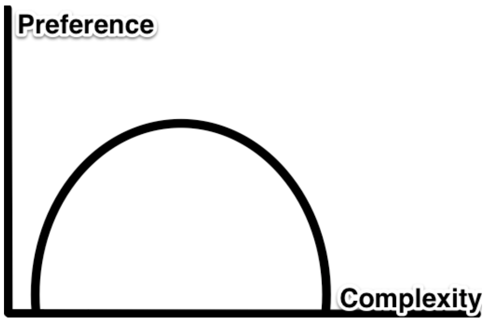


Figure 1: An inverted U-model demonstrating a hypothetical relationship between musical preference of musical complexity, adapted from Heyduk (1975).

What leads to the subjective shifts of perceived complexity is the development of an understanding of the musical contents. It is also worth noting that the same model to some extent can illustrate musical memorability, in that too complex music is very hard to memorise. In this case, too complex would entail the absence of regularities and categories. The purpose of this chapter is to demonstrate the emergence of such categories in music, and to establish a basis for understanding how musical schemata contain increasingly more of these categories with experience. This knowledge will then be seen in relation to memorising strategies.

2. 1 Musical building blocks

Consider musical knowledge as a mental library, one that increases in size with every musical encounter. Due to the nature of how we can construct hierarchicies in conceptual categories, musical features and their contents can be systematically organised. Material that is learnt in an organised way is thus grouped together in long-term memory, i.e. in schemata, and the information is therefore easy to locate and extract from the library. Furthermore, our new musical encounters are understood on the basis of the contents of this categorically organised library. In the following, the contents of the musical building blocks will be illuminated.

In the virtuoso piano music of the Romantic Era, some passages may immediately come across as extremely difficult to perform, and while this holds true for a selection of passages most of them are actually well inside of a framework most musicians have spent their formative years establishing. This framework in its most basic form contains categories of information in the form of sets of pitch classes, harmonic progressions, standardised structural models etc. Having a database of elementary musical features may make it easier to approach novel pieces of music, as many such musical features are popular building blocks in a number of musical genres. The specific contents of the musical building blocks and features will carry different connotations, and have the potential to trigger different responses in performers and listeners, depending on the level of musical training in addition to sociocultural factors (Bermudez & Zatorre 2005; Blood & Zatorre 2001). Connoisseurs are able to acquire similar levels of knowledge to experts in their field of interest. Notwithstanding that abilities to play may be absent, and methodological analyses may be unavailable, listeners may still exhibit a high level of accuracy with regards to recognising music, although musicians have unsurprisingly been found to outperform non-musicians in melody recognition tasks (Trainor, Desjardins, & Rockel 1999). For amateur classical pianists there is a significant difference between a typical piece by Liszt and Mozart who wrote music in two different musical eras, whilst an expert pianist may also distinguish between Liszt and Chopin even though they both wrote highly technical virtuoso pieces in the same era.

When talking about music and memory, it is important to separate the many parts that together constitute music to gain an understanding of how we categorise them into meaningful events. On the most basic level, we can perceive sequences of sounds and tones with some level of organisation as a melody. In Western music culture, melodic sequences traditionally originate from a scale system where one pitch is often of central importance, adding the notion of tonality. The scale system is derived from a tuning system, in much the same way as a melody can be derived from the scale system, in that the scale only contains parts of the whole tuning system and the melody may contain parts of the whole scale. Naturally, the melody can use the whole scale; nevertheless, melodies are often grouped together in sequences that our limited short-term memory can comprehend. When melodic elements are grouped together in clearly separated parts, they are referred to as phrases. The phrases can also be grouped together and form a more abstract representation such as a melodic arch (Huron 1996) which will eventually be seen in its relation to musical schemata containing standardised forms.

In this section the occurrence and importance of various musical forms and features will be described as they take place in the music and in the mind. Amongst others we identify structural forms, melodic forms and patterns, tonal categories and relationships, rhythmical forms and concepts, and the questions arise - do all of these together constitute *a* musical form? Can musical form easily be translated into a hierarchical form, making the structural elements available even for those who do not possess detailed musical background knowledge? If so, what would the immediate hierarchical segregation be based on? Would Gestalt principles be able to account for how melodic elements can be segregated and grouped not only by their tonal features, but also by rhythmical patterns? Would it also have implications for the relationships between the perception of melodic form, the formation of harmonic contents, and the construction of larger-scale structural forms? To get a clearer image of what we are dealing with, the features mentioned above will be discussed individually before taking a look at how they may coincide when internally visualised.

Structural features

In classical music analysis, one of the key features to be extracted is the form (Caplin 2001). Initially this gives a clear image of the overall structures of a piece of music. Usually denoting formal structures with letters, analysts classify sections based on their content and divide the piece into e.g. a binary or a ternary form. The framework of each unit within the whole piece, e.g. the A or the B of a ternary ABA form, can also be subdivided further. Regularities, such as a melody consisting of four or eight bars, a whole section consisting of 32 bars etc., can be traced from Bach to the Beatles and beyond, just to illustrate its longevity. This is not to say that *all* pieces by Bach and every tune the Beatles wrote were symmetrical and regular. Nevertheless, within-structural forms contribute to the establishment of stability and also create natural boundaries which may result in predictable repetitions. In a large corpus of music from a given era, detailed knowledge about the contents of e.g. a 'typical' ABA form can be drawn from a meta-analysis of several compositions due to the similarities of the compositional methods employed by composers within an era. On a large scale this is how eras are constructed and classified by historical musicologists, often long after the 'era' supposedly existed. Structural symmetry is beneficial for comprehension and memorisation and is also more conventional than structural asymmetry, even though asymmetries do occur. The perception of melodic similarities in recurring melodic sequences consisting of familiar tonal material would be unavailable if there was no melodic structure. This suggests there is an on-going process of comparing whatever is being heard in the present to structures established by the preceding music. This seems to be in line with how psychologists view our perception as shaped by experience based on schemata and our ability to chunk information into comprehensible units (Baddeley, Eysenck & Anderson 2010).

Melodic features

Another salient feature is the division of a series of notes into motifs and figures. While the motif of a composition is typically a more or less unique melodic phrase that lets us identify exactly which piece is being listened to, the smaller figures constituting the motif are generic elements most likely present in many other compositions. This is based on the fact that tonal music generally has a tonal centre, and the tonal material that is available in a specific key will have certain limitations with regards to the choice of melodically salient tones. The fact that tones are organised in categories such as scales and modes serves our ability to group auditory events together based on their shared framework, and to isolate material that does not fit into this framework (Shepard 2001a). When it comes to memorising tonal melodies on the piano, the fact that most of the material is derived from well-known categories such as scales means many of the keys can be disregarded. If and when one or more tones that form parts of a tonal melody do not belong to the same tonal framework as the rest of the melody, two issues arise; identifying the other tonal framework(s) involved, and identifying the location of the irregularities. At this point it is useful to look at how our working memory may deal with information when it exceeds our capacity. This will be covered in a later chapter, however, the general idea is that the discrete pitch classes of the melodic material can be compressed and represented as contours of overall structure, or contours of phrases (Dowling, Kwak, & Andrews 1995). Serialist music contains all the twelve tones of the chromatic scale, and memory for this music may thus be impeded due to the information exceeding our hypothesised working memory capacity.

Harmonic features

As briefly mentioned above some chord patterns are ubiquitous, such as the tonic, the subdominant and the dominant chords. Placed in a specific order, these chords constitute what is called a cadence, and is often used to create a sense of closure or resolution in a small phrase, a whole structure, and a whole piece. When analysed, the chords in a progression are denominated by Roman numerals, corresponding to the steps of the diatonic scale from which they emerge. The tonic is hence given the Roman numeral 'I' in major keys, and 'i' in minor keys. Subsequently, the subdominant is assigned 'IV', and the dominant 'V'. The progression 'IV - V - I' is called an authentic cadence, and is arguably one of the most common progressions used in tonal music, second, perhaps, only to 'IV - I'. Reducing the amount of information from e.g. an F major chord, a G major chord, and a C major chord to 'IV - V - I', and even further to one expression that includes all three such as the authentic cadence demonstrates the effectiveness of chunking. To each chord triad, extra tones can be added to create tension. Especially in the case of the dominant (V) chord, the 7th tone is often added so as to maximise both the tension and the resolution when followed by a tonic (I) chord, i.e. the 3rd and 7th tone in a dominant chord respectively function as leading tones to the 1st and the 3rd tone of the tonic chord. Furthermore, chords may have a supporting role in creating a background on which the melody can take place. They can also be structured in such a manner that they carry the melody among them, thus becoming melodic constituents themselves in addition to having harmonic roles. There are obvious schematic advantages with standardised chord progressions, due to the close relation between the melodic content and the chords.

Rhythmic features

While the above mentioned features deal with pitch, melody, and harmony, there is another fundamental element that characterises musical pieces. The tones and chords must not only be played in the right order, but their onsets must also occur at the right time. It is interesting to note how musical time does not always adhere to the absolute time definition most commonly used (e.g. when referring to seconds, minutes and hours). Musical time can be stretched and it can be compressed, and musical time alterations can occur within short distance of one another e.g. by slowing down towards a chord or melodic salient tone which is then sustained for a longer time than the surrounding events, subsequently speeding up to make up for «stolen time» (Hudson 1996). On a small scale the contents in a phrase as just described still follow the rules for rhythmic notation, albeit only relative to the notes in their immediate vicinity. Musical time should therefore be considered as a relative time marker, even though it is in general defined by a superimposed regularity. The temporal structures of music can add to its memorability given the hierarchical organisation of patterns that allow us to refer to expressions such as beat, pulse, tempo, metre, and rhythm. A pulse is a series of isochronous events, or beats, and metre is a cyclically organised variant of a pulse, usually marked with accented patterns (Snyder 2000). The tempo is a description of how many times the isochronous beats in a pulse occur in a given amount of time. When melodic features are fixed in ordered patterns adhering to these conventions, the result is a combination of hierarchical structures, each with their own sets of rules and standards. Learning how to take advantage of these hierarchical organisations is one of the fundamental issues of memorising music.

On a side note, there is an on-going discussion regarding what is culturally conditioned and what is a natural attribute. Without delving too deep into this debate, it is worth noting how we are surrounded by a world of principles and recurring episodes. Many prominent natural elements are periodic. Or, at least, they are interpreted by our brain as periodic, due to our tendency to group events into systematic patterns (Thompson 2009). The earth and moon move around in space in a pattern and speed determined by gravity. Humanity has long since learned to take advantage of that fact, and split years into months, months into days, days into hours, hours into seconds, and so forth. In the same way as musical pieces were described to split into parts and sections with melodies and phrases, rhythmical features can also be divided into subsections. Although time as such is an abstract concept standardised by human terms, our apparent need for systematisation provides us with the ability to monitor time as a defined amount of a physical event. Measuring our surroundings and classifying them into categories is still a popular activity for researchers. Comparing measurements across modalities, such as counting and timing events, have led to further categorisations of frequency and the creation of natural laws. This allows us to predict future events with more or less certainty. Our very own body is also governed by periodicity. The human heart steadily supplies our organs with oxygen by beating approximately once every second. Our walking gaits are rhythmically stable in order to keep us in balance. The very existence of these ubiquitous elements facilitates conditioning to periodicity. Some of the basic temporal structures found in music can therefore be assumed to originate somewhere outside the musical domain, and their resilience in music can be regarded as beneficial in terms of increasing predictability. Predictability facilitates memorability as it naturally decreases randomness.

2. 2 Musical contour models

Psychologists have for some time been trying to identify a model for how we cognitively process melodies, and have found that describing a succession of sounds can be done with contour models (Dowling & Fujitani 1971). Sound is a concrete, physical object, and musical sounds traditionally have properties that can be measured and described by acousticians and physicists in terms of loudness and frequencies, whilst musicologists and musicians are equipped with the descriptive tools of musical notation. However, as with any perceivable sensation, transferring it to other formats hardly represents the richness of the input in its original form. Explaining percepts in words, for instance, is a difficult task. Similarly, gustatory sensations are difficult to describe as sounds, and images make poor representations of olfactory sensations. They share few or none obvious relations. Nevertheless, it is interesting to note how sensations are often referred to in terms of their sensory qualities, as mentioned in the first chapter. In our imagination, there seems to be no limitations regarding the shapes or metaphors they can be associated with. Yet when discussing percepts we are often limited to the use of words and associations. In relation to memory, associations strengthen our ability to both retain and retrieve information, as will be described in depth in the next chapter. One way of using metaphors in relation to music is to describe melodic movements in distances and directions, such as moving up or down. Research on retention and recognition of melodic information suggests that through cognitive processes information is extracted and compressed into a representation in the form of a contour model (Dowling, Kwak, & Andrews 1995). Huron's simple contour model (Huron 1996) and the more comprehensive step contour model (Eerola & Toiviainen 2004) represent two different levels of compression, and in the following they will be presented briefly as examples of how memory for melodies seem to be supported by visualisation.

Levels of detail in memory for melodies

Following is a description of Huron's approach to simplifying contours:

> «the first and last pitches were determined and all the remaining pitches in the phrase were averaged together. Using these three values, all phrases were classified as belonging to one of nine contour categories. A phrase was deemed to have an *ascending* contour if the final pitch was higher than the average mid-phrase pitch, which in turn was higher than the first pitch in the phrase. Any phrase displaying the reverse relationship was deemed to have a *descending* contour. If both the first and last pitches in the phrase were higher than the average mid-phrase pitch, then the contour was deemed to be *concave*; the inverse relationship was deemed to be a *convex* contour» (Huron 1996).

Huron provided evidence for the idea of an overall 'melodic arch' based on his finding of convex contour models in almost 40 % of 5-note to 16-note phrases in a large selection of folk songs, where the pitch information of the phrases had been averaged and highly compressed (ibid.). He also identified numerous phrases as having a descending contour (28.8 %), ascending contour (19.4 %), or concave contour (9.7 %) (ibid.). Due to the rather extreme compression of the tonal contents in Huron's model, the four contour models alone account for 96,5% of the phrases. In other words, it does not seem to explain how we cognitively process melodies altogether. However, there are advantages to keeping a general overview, and this may thus still be a useful tool for larger-scale contour representations.

At the opposite end of the compression spectrum, Eerola and Toiviainen's step contour model transforms MIDI signals - containing both discrete pitch information and tone durations - to extensive visual representations of music, without the use of Western musical notation in the end product (Eerola & Toiviainen 2004). A contour model that represents the entire melodic content of a phrase is thought to be closer to our cognitive representation than Huron's simpler contour model (Billig & Müllensiefen 2012). It would seem that melodies represented by contours are more in line with fundamental processing skills than representing melodies as a series of exact intervals. The latter requires trained skill, unless one possesses absolute pitch, in which case the notes would already be associated with specific labels and the intervals between them may be instantly recognised (Ward 1999). Absolute pitch possessors are few and far between, and will not be given much emphasis in this thesis. It is, however, worth contemplating that with absolute pitch it may be easier to recognise whether a melody is the same as or different from a comparison since pitches are instantly labelled (ibid.). Nevertheless, the evidence for superior melodic memory in absolute pitch possessors per se is inconclusive (Takeuchi & Hulse 1993). Owing to the fact that memorising is supported by comprehension and the ability to construct elaborate and meaningful associations, the skill sets of trained musicians and the abilities of absolute pitch possessors point in the direction that melodies may be easier to memorise for these two cohorts than for non-musicians (Halpern & Bower 1982; Tervaniemi, Rytkönen, Schröger, Ilmoniemi, & Näätänen 2001).

2. 3 Practise and performance techniques

Preface

A fundamental advantage of practise is that it frees up work capacity as elementary techniques are established. Mental schemata are created over time as musical commonalities are identified and the information becomes easier to chunk and categorise. Motor programmes are created through repetition of material, and learning how to trigger these programmes when needed is an essential skill of playing an instrument. Owing to the relatively short amount of time needed in order to achieve results through repeated practising, motor programmes appear to be the prominent source for memorised performances among beginning pianists (Chaffin & Imreh cited in Chaffin & Imreh 1997). Arguably, this is also the main reason why amateur performers find themselves in the unwanted situation of having their memory failing on them in the middle of a recital (Sloboda cited in Chaffin & Imreh 1997). When it comes to evaluating practise, the two most important variables are identified as quantity and quality. Research on piano practise focusses on, but is not limited to, starting age, accumulated time, and the duration of practise sessions, in addition to the quality of each practise session. The most eminent expert performers begun playing at an early age, with pianists and violinists starting between ages 3-8 years (Jørgensen 2001), reaching expert levels in the twenties after several thousands of hours (15-16 years) of practise (Sosniak 1985). Ericsson, Krampe and Tesch-Römer (1993) distinguished between levels of expertise and found that the top performing experts have reached at least 10,000 hours of practise. These figures produce a quite clear image of the saying practise makes perfect, *if* the practise is deliberate. Combined with evidence from research on brain plasticity in musicians which suggests adaptations are «due to musical training during sensitive periods of brain development» (Schlaug 2009:201), the numbers above also indicate the importance of an early start. Accumulated time spent doing domain-related activities alone does not account for expert skill acquisition (Ericsson et al. 1993).

Another interesting topic of discussion relating to beginning musicians is whether music literacy should be trained before or after playing by ear. Arguments point in both directions, and is often compared to that of learning a language. One line of argument is that children learn to speak before they learn to read, and thus have the capability to learn through associating known words with their corresponding visual representations (Brunning, Schraw & Ronning cited in McPherson & Gabrielsson 2002). This is supported by the widely recognised Suzuki method, where students learn to establish an understanding of musical sounds before learning to read the symbols that represent these sounds (Suzuki 1983). Following this suggestion, the assumption can be made that learning to associate familiar music with the auditory functions of a piano at an early stage may lead to a better understanding of the link between musical content and the keyboard.

There is an obvious need for a high level of motivation to endure such an exceptional amount of time carrying out often particularly tedious tasks, and some motivational factors can be identified by research on the quality of the practise. The amount of *deliberate practise* is one of the key elements suggested as a predictor of successful expert-level performance (Ericsson et al. 1993). A central aspect of deliberate practise is the highly focussed and controlled approach to the material at hand. The student should be aware of what needs to be practised and how. The research findings also demonstrate that immediate feedback from a superior - a teacher or an accomplished performer - as well as proper guidance on practising methods can be useful and motivating (ibid.). Once a certain level of competence is reached and the student has obtained an adequate amount of techniques and skills, unassisted effective practise is only available and efficient for a limited amount of time per day. Until the student is able to practise without supervision, the research findings suggest that repeated practise without feedback may not improve performance (ibid.). Ericsson et al. found that «expert musicians in their study spent approximately four hours a day - every day including weekends - on deliberate practise» (Ericsson & Charness 1994:741). Effective practice has been described as «that which achieves the desired end-product, in as short time as possible, without interfering with longer-term goals» (Jørgensen & Hallam 2009:265). The act of practising music and carrying out music-related activities is closely related to the individual's broader understanding of music. Metacognitive skills build up with expertise, allowing performers to focus on technique, interpretation, progress, and other elements regarding planning of a performance (Hallam 2001; Nielsen 1999).

Repetition and practise

Repetition is one of the most easily accessible and most commonly applied methods contributing to a stronger memory. Whether by repeated listening, or repeated playing of a piece of music, the cognitive schema for the given piece will progressively fill up with details which were previously not attended to. Repeated engagement in musical activities, herein especially playing music, also enlarges the motor cortex, somatosensory cortex and the corpus callosum (Schlaug 2009; Stewart 2008), which enables motor programmes to be executed efficiently in cooperation with the basal ganglia and the cerebellum (Altenmüller & Schneider 2009). While practising it is important to build up associations between what it sounds like, what it looks like, and how it feels to play. Attending to details is important when constructing extensive associative links between the three modalities. This also leads to a more comprehensive cognitive schema of the music. Furthermore, the connections within neural networks between motor cortices, auditory cortices and memory centres such as the hippocampi strengthen, thus establishing a complex cross-modal web of information ready to be retrieved when activated by the proper association. This will be covered in more detail in chapter 4, which will focus on human motor control. Much music is written in such a way that repetition is elegantly inherent, especially in the classical musical styles up to the time of the late 19th century culminating in the Romaniticism. The implications of repetition on perception and cognition are considerable and will be covered more thoroughly in the following chapter. Suffice to say at this point that repetition as a musical feature contributes to musical structure in a most convenient manner, as it allows for identification of recurring sequences, and makes systematic segmentation of a musical piece readily available (Chaffin & Imreh 2002). Repetitions are commonly found both in melodic recurrences, and larger similarities between structural entities. Based on grouping principles, a musical sequence containing repetitions can be reduced to less information by identifying the repeated parts as either identical to, or similar to information that has already been encountered.

Building a framework

The different historical eras offer a few stereotypical characteristics that set them apart from the rest. Once familiarised with the musical style of an era, details regarding the composer, and the tonality of a piece of music, a framework containing many of the prerequisite details for playing the music will emerge. In other words, learning contextual details of a piece contributes to preparing for learning the piece itself. The key signature immediately informs the performer which chords are to be expected, and gives an indication of which scales are likely to be present. When deciding to focus mainly on classical pianists, one of the most important reasons was the tradition for teachers to expose their students to a selection of pieces from more than one era. Thus, from an early stage/ age, a repertoire is carefully built up and will in time consist of a wide knowledge base of rules and commonalities of classical music. Even though only a selection of pieces from the standard classical music corpus are learnt, the basic ability to isolate musical elements across genres and composers is established as a valuable precursor for further acquisition of skills. A wide body of pieces from a range of classical styles will have placed demands on the pianist to be able to approach novel problems based on existing techniques, abilities, and knowledge, establishing an understanding of chord progressions, phrasings and typical melodic structures along the way. As the level of difficulty increases, so does the network of intertwining schemata containing information about both the specific contents of a repository of music, and how to execute it on an instrument. At a more fundamental level, scales, chords, arpeggios, and melodic phrases are practised at increasing difficulties throughout the musician's formative years.

Practice methodologies

There are many proposed models concerning how to practise a piece of music, some based on technical reasons, some on reasons having to do with memorising. Above all, it is widely recognised that practise is highly individual. No single method can account for what makes an expert an expert. There are, however, similarities between many teachers' methods. Some of the commonly applied steps will be presented below.

At first the music needs not be played at all, as a quick glance at the full score may reveal many clues about what to expect. Naturally, the ability to extract meaningful information from the musical notation is closely dependent on the musicians' level of musical literacy, auditory imagery skills and experience. Nevertheless, with the proper guidance of a teacher even a naïve first reading may provide useful information regarding general form and structure and specific melodic contours such as phrases, and prepare the student for a convenient approach. The first attempts of playing the piece may immediately follow the teacher's demonstration of the piece, as learning through mirroring and copying, has proven fruitful for some. This involves mirroring neural activations at a cortical level, a subject which will be covered in chapter 4. However, having the teacher play the piece beforehand provides a source for comparison and establishes a fundamental idea of how the music may sound. If the teacher is not capable of playing the piece, other examples such as videos or recordings could be made available in order to provide a model for the student to follow. This approach has been found useful for students who have not yet established profound interpretative skills, but may be limiting for more experienced performers (Hallam 1998). Seen in relation to how experience is intertwined with metacognitive skills, the accomplished performers are able to define their own interpretations (Hallam 1997). When the student then plays the music for the first time, every available skill relating to sight-reading, playing by ear, triggering of motor programmes, and semantic memory of music, are competing for cognitive resources. This pushes the capabilities of working memory to the limit. Therefore, playing - preferably with one hand at a time - at slow tempi to avoid mistakes is paramount. In the beginning stages of practise, the first building blocks of the larger schema and the muscular memory for the piece are laid down. This immediately illustrates the importance of proper preparation and instruction. If the same mistakes are made repeatedly, the teacher should provide the student with immediate feedback and guidance to avoid consolidation of an unwanted motor programme. The first attempts at playing novel material should be limited to sections of meaningful lengths for the student to be able to build a structural understanding of the music as opposed to a note-for-note representation. According to Bamberger, McPherson and Gabrielsson;

> «learners must first gain experience in playing musical patterns before they learn to decontextualize these patterns into individual notes because the "units of perception" that novices intuitively attend to when processing music are "structurally meaningful entities such as motives, figures, and phrases," not individual notes» (Bamberger cited in McPherson & Gabrielsson 2002:105).

Embarking on too large sections will introduce an insurmountable amount of new information for the student to deal with. Depending on the total length of the piece of music, practising in this fashion can continue until the end of a larger-scale musical form is reached. Once the student has reached a level of control over each hand, the tempo should once again be brought to a minimum, maximising the potential for a successful attempt of employing both hands. At this point a number of complications may arise, for example if the hands are playing interpolating rhythmical patterns and the student's brain is striving to avoid synchronous behaviour of the hands. When a sufficient level of control is reached, the tempo may be increased at a leisurely pace, ensuring no erroneous patterns are established. If sections of the music contain technical material superior to that of the student's abilities, the teacher should provide exercises that will enable the student to acquire the specific skills needed for these sections. For example, if melodic structures are present in keys or patterns that are unfamiliar for the student, s/he should practice basic exercises such as scales, patterns and chords in this key to familiarise with it, thus establishing a broader understanding of the melodic structure in the piece. Step by step, a schematic comprehension will provide a better ability to retain the melody, and allow it to be consolidated in the student's long-term memory.

Practising performance memory

The advantages of strategically chunking and labelling musical elements are many. Reducing the amount of information needed in order to acquire new knowledge is one, reducing the memory load when playing is another. Our short-term memory and concentration is being put to the test when several tasks are being performed at once, such as for example reading and playing at the same time. When mentally practising a piece, with one's eyes closed and the hands off the piano in a silent room, rumination and random noises are the only naturally occurring sources of disturbance. The level of concentration needed to invest in a piece of music before it is prepared well enough to be played effortlessly can often tempt students to skip valuable steps of the crucial learning phase. For example, a common problem among young, aspiring musicians is to start over from the beginning, or they may be «backing up to correct omissions or errors» (Lehmann & McArthur 2002:148). This eventually leads to the first few bars being learnt unconsciously purely based on repetition. Although this is partially a wanted outcome of a practise session, some unwanted side effects materialise. The predominant side effect is the way the piece is learnt as a chain of events with only one point of departure. A recommended strategy is to devise several starting points within the piece to ensure the best possible fluency between parts of the music. These points are referred to as performance cues (Chaffin & Imreh 1997).

Practising in a rehearsal studio is very different from playing on stage with an audience. When a piece is nearly ready for public performance, students are therefore encouraged to practise *as though* they had an audience, or even have someone sit in on a rehearsal. When available, the most advantageous approach is to practise in the same venue and on the same instrument that will be used where a potential concert is taking place. Professional pianists may occasionally have very specific preferences when it comes to instrument of choice, due to the differences in hammer-action and timbre of each instrument make. Research on context-dependent memory suggests that the ability to accurately recall information is best in a similar (or identical) situation as the information was first encountered (Godden & Baddeley, 1975). In their research deep-sea divers memorised numbers either on land or in a deep dive. The researchers found that the divers' recall was best in the same condition as they had previously been placed when memorising the numbers. This supports the idea of practising in a concert environment; however the preference for a specific piano may prove to relate mostly to preference. Nonetheless, context-dependent learning is believed by some to extend to playing on a specific instrument: «A phenomenon that vividly demonstrates the phenomenon, or the belief in it, was the habit of the great concert pianist Vladimir Horowitz always to perform on his own piano. Horowitz believed in his "home piano" advantage» (Rosenbaum 2010:36).

As the late Edwin Hughes put it: «The pianist has almost constantly to do with a many-voiced musical texture, and he must not only be able, as the orchestral conductor, to hear the various parts, but must be able at the same time to execute them himself» (Hughes 1915:594). In his text he compares the role of the pianist to that of the singer, violinist, and cellist, who, in contrast, normally need to focus only on the melody. In order for the pianist to memorise the music, he suggests three approaches: «by ear, by visual memory, either of the notes on the printed page or the notes on the keyboard, and by finger memory or reflex action» (ibid.:597). In the first two approaches he stresses the importance of learning the components of the music, both the harmonic and the formal structure, and the ability to bring up a clear mental image of the notes (loc. cit.). His claims furthermore support the approach of this thesis that motor memory alone is a fragile repository for whole performances. Hughes does not refute the motor memory entirely, as he states «the safest way is of course to have all the above mentioned methods to fall back on, to know the composition well by ear, hearing the piece unfold in advance of the fingers, to know it by visual memory of the keys, or the printed page, and also from a harmonic and formal standpoint» (ibid.: 599-600). Although support for this claim is to date mostly anecdotal «research in cognitive psychology would support the notion that the more ways in which musical information is encoded, the more associations and connections will be formed to that information and, therefore, the more likely an individual is to remember it» (Aiello & Williamon 2002:175).

Another approach is a theoretical framework suggesting a method that leads to the formation of a long-term working memory (Ericsson & Kintsch 1995). The first stage concerns meaningful encoding of novel material, the second stage is the use of well learnt retrieval schemes, and the third stage concerns rehearsal for an efficient retrieval of the material (ibid.). For a pianist, all three stages can be related to the musical features and rehearsal strategies suggested above. Novel material can be identified and compared to well-known tonal and melodic features while retrieval schemata can be based on a combination of structural features and performance cues as proposed by Chaffin & Imreh (1997). Practising cues are used to bridge together parts of a whole piece. One of the main advantages relying on schemata - i.e. generalised frameworks - can at the same time be a source of considerable inconvenience. In an inattentive moment, two programmed cues may be quite similar, and can thus trigger an unwanted schema or motor program. This would in most cases not be detected before it is already too late and the auditory and visual feedback is available to tell you something went wrong. This underlines the importance of choosing performance cues with caution, and also suggests they should be rehearsed. Repetition through deliberate practise ensures proper consolidation of the material and allows for intentional retrieval. Hierarchically, a composition can be split into a multitude of elements. Grieg's *Ballade in G minor* constituting a set of varations on a theme can easily be split into single variations, and further into halves or other structural parts, and even further down to a set of bars, a phrase, one bar, a rhythmic pattern, a sequence of two chords, two notes, etc. The benefits of such a dissection will become clearer in the next chapter. However, before proceeding to an introduction to our memory, an analytical approach to the piece of music that will be referred to throughout the subsequent chapters is offered.

Unlearning mistakes

When practising novel musical material there are several suggested approaches, and what separates them is the overall goal of the practise session. If a piece is practised for performance purposes it is important to use the right fingers and hit the correct keys as early as possible in the practising procedure (Lehmann & McArthur 2002). This is to avoid any unwanted movements or musical material to consolidate into long-term memory. If and when mistakes are practised to a certain level, for instance in the case where a note has been misread or misinterpreted, or misheard if the student is playing by ear, and it has become a natural part of the piece, the student must take measures to 'unlearn' the mistake. Unfortunately our memory system does not work in such a way that we may simply choose to forget consolidated information. Instead we must relearn the knowledge so that it incorporates the desired substitute - in this case, the correct note. This can be regarded as small-scale plasticity, a phenomenon that will be explained more in chapter 4. If the purpose of the practise session is to strengthen sight-reading abilities, students are urged to continue playing and disregard mistakes that are made in order to maintain a sense of continuity (Lehmann & McArthur 2002).

Sight-reading and relearning

Once musical experience has reached a level where basic music features are recognised and rapidly associated with specific movement patterns, and musical literacy is established, sight-reading becomes an impressive display of working memory capacity. When an experienced pianist is able to sight-read and play without hesitation, it may seem extraordinary; however, this also has an explanation. The pianist reads the music, translates the information into required movements, gets an immediate idea of musical contour and keeps this information in a buffer - the working memory - in a compressed form so that once the pianist starts playing, he is actually reading the next measure, or may even be further ahead (Goolsby cited in Lehmann & McArthur 2002). This suggests a sight-reader is multitasking at a high level, constantly deciphering, compressing, and decompressing information. The deciphering is the translation from notation into auditory information and movements, the compression is the chunking of this information into patterns, and the decompression is the physical output of playing, or triggering the proper motor programmes. Meanwhile, novel information is already being deciphered and compressed, and the cognitive load at this point is very high. If the wanted goal is to memorise the music, only smaller portions should be played in succession in order to create sustainable links between the parts through repetition. The parts themselves should be limited to a number of chunks which do not exceed the capacity of working memory, i.e. 7±2. Coincidently, many musical phrases tend to exist within these boundaries.

When a piece is learnt, the information is stored in long-term memory, but after some time the functional retrieval cues may decay. In view of the fact that schemata are quite persistent, relearning a piece can be achieved by isolating the areas where the piece breaks down and revitalise the performance cues that were once learnt. When retrieval of information from long-term memory fails, it may be due to a lowered activation level, or due to unattended cues (Anderson 2010:166).

2. 4 Analysing Grieg's *Ballade in G minor*

Music analysis, as we know it today, is a relatively young tool for music theorists and performers, merely two centuries old (Cook 1987:7). Over the course of its first two centuries as a musicological affair, it has taken forms encompassing all sorts of musical and contextual features. Depending on the analyst, the analyst's expectations, the material, the material's context, the recipient of the results of the analysis, and the medium in which the results are being presented, there are different analytical methods to employ (Bent & Pople 2013). In accordance with Bent and Pople's introductory writings on musical analysis there are mainly three axes to consider regarding analysis in general, each of which incorporates several subdivisions: an objective analysis for learning compositional techniques; a subjective analysis for exploration, understanding and discovery; or an aesthetic analysis in order to investigate extra-musical representations (ibid.).

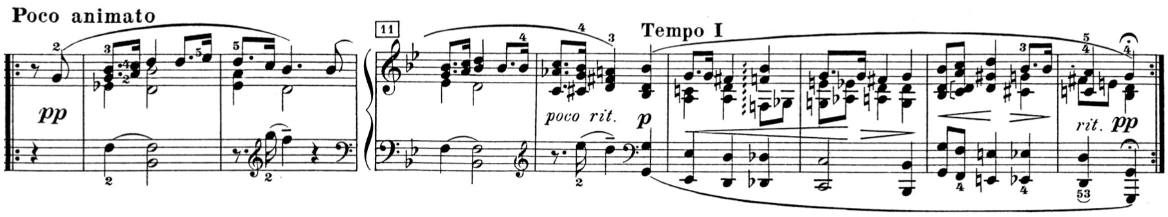
> «the analyst, like the aesthetician, is in part concerned with the nature of the musical work: with what it is, or embodies, or signifies; with how it has come to be; with its effects or implications; with its relevance to, or value for, its recipients. Where they differ is in the centres of gravity of their studies: the analyst focusses his attention on a musical structure (whether a chord, a phrase, a work, the output of a composer or court etc.), and seeks to define its constituent elements and explain how they operate; but the aesthetician focusses on the nature of music per se and its place among the arts, in life and reality» (ibid).

Historians may be more concerned with large-scale structural similarities in music, and analysis can produce useful abstracts for linking together pieces across time and space. Immediately, the analysis to be expected here can be placed within the descriptive sphere, intended for performers and scholars. This type of exploratory analysis can be likened to reductionism, however; the main reduction is done internally after the individual constituents have been identified. The particular piece is chosen to exemplify a number of elements that are present in music from the Romantic Era, and the systematic approach of deconstructing the key elements is chosen to demonstrate how even a relatively elementary analytical skill may be sufficient for providing the mental images advocated above. Even though aesthetics are important for performers of classical music, the analytic modus operandi suggested in the following only sets out to shed light on musical structures that are beneficial in psychological terms, or, to elucidate how and why elements in the music can be used for minimising memory load. Therefore, this particular analysis attempts only to demonstrate ways in which the notes, phrases and motifs constitute parts of a whole. Due to the nature of tonal music, the linkage between melodic motifs is not unique on a small scale. Nevertheless, as larger structures emerge, musical pieces establish their identity and stand out from the rest based on their particular combination of the tonal material, i.e. the relationship between notes makes the melody what it is. Identifying these individual prominent features is a relatively straightforward task when utilising the proper analytical tools. «The point of musical analysis is to explain what is obvious - the experience of musical unity or whatever - in terms of structures that are not obvious and can only be deduced from analytical study» (Cook 1987:222). Sounds are difficult to describe with written words, and music is no different. However, it is straightforward to describe music as a set of pitches and rhythms. As described earlier, adding an analytical approach to music into the mix when preparing a performance assists in creating comprehensible schemata and gives the musician the opportunity to form a thorough mental image of the music.

The following analysis is intended as a psychological approach, to provide a solid piece of material to use for exemplifying both various memory models, and music-theoretical issues. In its reductionist simplicity it may be compared to some extent to the approaches of Meyer and Reti as they are introduced by Cook (ibid.). While Reti's view favoured motivic recurrence and Meyer's view extracted melodic pitch reductions and rhythm, the resemblance to the descriptive method which will be employed below is modest. While it includes some harmonic progressions, it also compares the extracted motifs to the aforementioned contour models and relates them to memorability based on similarities to the motifs' surrounding material.

The core content of the Ballade is based on a Norwegian folk tune:

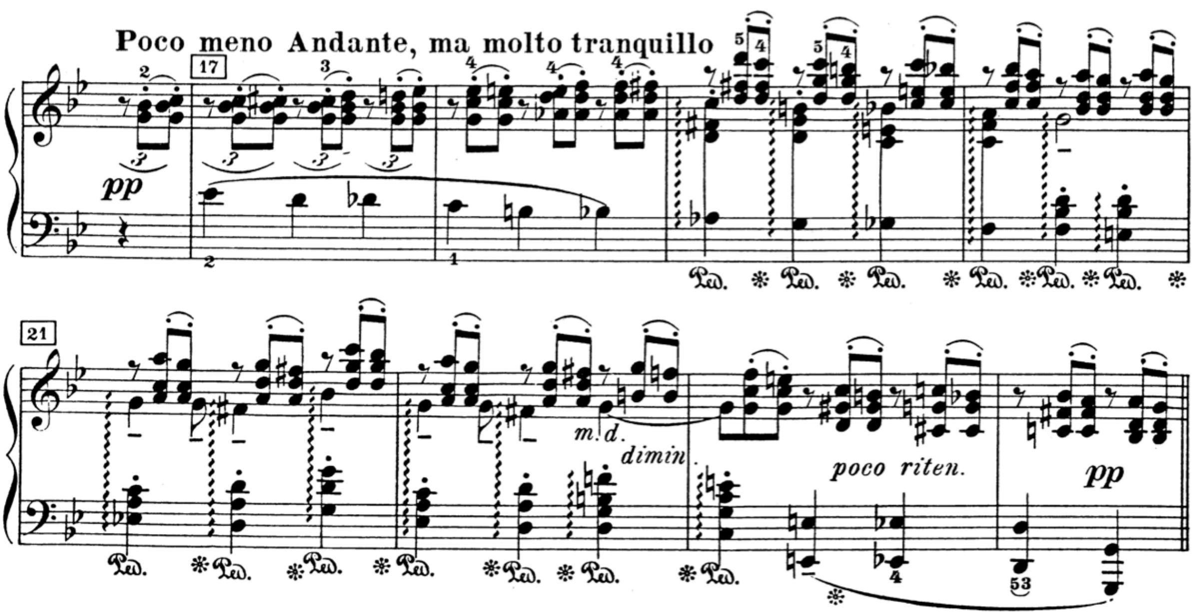
Seen as the top melody in the eight bars (plus anacrusis) above, the tonal material consists chronologically of the minor third B♭, the tonic G, and the leading tone F♯ in a descending pattern, repeated once, then followed by the tonic G, and an ascending phrase containing the minor third B♭, the fourth C, and the fifth D, before descending via the minor third B♭, and the second A, only to arrive back at the tonic G. In other words, the tonal range of the melody is relatively small, reaching from the leading tone F♯ to the fifth D. The chord structures underlying the melody are mainly a pattern of augmented sixth chords and various alterations and dominant 7 chords, resolving into dominant chords. The descending chromatic line from E♭ to C and A♭ to C allows the chords to continually alternate between new augmented sixth chords and dominant chords, until they culminate in a cadence from the dominant D (V7) to the tonic G minor (i). Rhythmically, the chords form a stable environment, for the most part following the melody on its path. The side theme is a short melody, with another essence than the main theme. In abstract terms, one might claim that the main theme is distinguished by its resigned character, manifested by the recurring falling sequence from B♭, through G, down to the F♯. The side theme on the other hand is characterised by the aspiring, rising melody from G, through B♭, C and D, followed by another phrase starting on D, using E as an auxiliary note, landing back on D, and then as the melody falls back through C down to B♭, it is accompanied by an upper voice played by the left hand, consisting of G and F, making it a falling parallel fifth. The second part of the side theme is similarly structured, and also contains an upper voice accompaniment by the left hand - this time a falling parallel fourth - and its melodic content near the end leads smoothly over to the recapitulation of the main theme. The tempo is more lively (poco animato), and the expression softer (*pp*) in the side theme than in the main theme. Now the tonal material has already been split into short phrases, and certain directional qualities have been assigned to the phrases. This is to indicate how their contours would appear on a small scale.



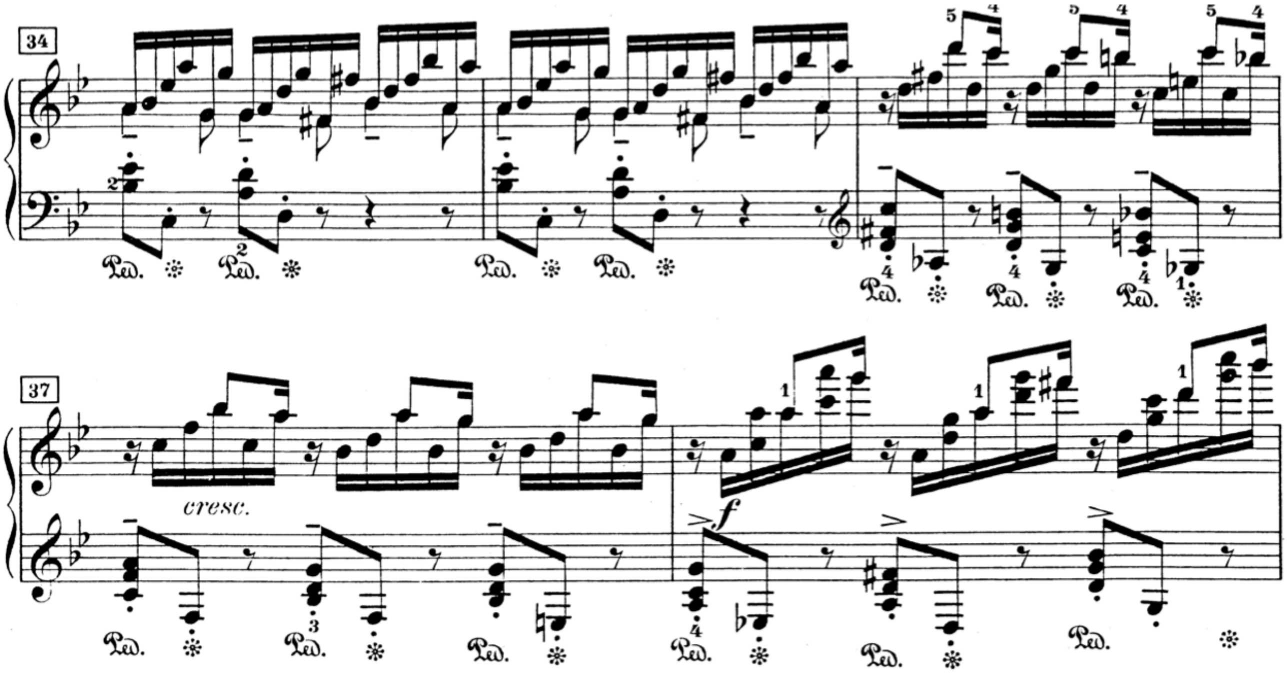
Throughout this analysis, the core elements mentioned above remain as the objects of interest, and since this is a variation piece, they are omnipresent. Therefore, what an analysis can bring to the table at this stage is pinpointing the distinctions a performer may want to pay attention to, i.e. what constitutes new information and what is familiar material. Where familiar material exists it can be used for schematic purposes, establishing prominent performance cues in order to ensure correct retrieval. Familiar material can occur as smaller or larger formal structures, as melodic information, as harmonic sequences and chord progressions, through particular rhythms, or a combination of these. Where novelties represent the majority of the material in a variation, finding ways to chunk the information into intelligible parts allows for new schemata to be constructed. Again, linking the various parts of the material together with carefully chosen performance cues is particularly important, yet such cues can often be provided by the music itself as many of the variations have a quite distinctive character in both the beginning and ending phrase.

Identifying challenges and similarities

The first point to be addressed is in the first variation, assigned the tempo *poco meno Andante ma molto tranquillo*. In this variation, the melody is concealed in between three-note chords in both hands, in measures 5-6. Here, a choice must be made whether to play this melody with the thumb of the right or left hand. The melody is notated tenuto, while the chords are written staccato, and since the right hand is required to play a chord containing a sizable interval the thumb of the left hand is most likely the finger of choice to play the tenuto correctly. However, this is not without technical difficulty as the left hand plays an arpeggiated chord which, in order to land on the melody note, must stretch out wide. This can be dealt with by isolating the challenging area and practising jumps between the index finger and the thumb on the last note of each chord and the melody. Whichever thumb is chosen to play the melody should be the same throughout both measures in order to add consistency. Remember from earlier that fingerings are chosen carefully to avoid randomness. The chord progressions in the first variation are based on the same as introduced in the original theme. The bass line is more or less identical to the opening theme in the first four measures. The novel information in this variation is based on the eighth note triplet pattern of chords in the right hand, a pattern that is present in every measure of the first variation. Thinking of triplets while on the fermata on the last chord of the exposition may function as a rhythmical cue to the first variation. Throughout this variation, repetition of similar structures makes chunking of the material achievable.



In the third variation, *allegro agitato,* the metre has changed, and the rhythmic pattern of the arpeggiated right hand consisting of sixteenth notes is this variation's recognisable feature in addition to the large leaps in the left hand. Again the melody is present, played by the thumb of the right hand in the first three measures. Aside from the tempo, the challenge here is the need for accuracy in the left hand leaps. As in the former variation, this can be dealt with by practising the leaps slowly. In measures 5-8, the right hand plays a pattern of a broken three-note chord first in one octave and then copies the motion in the octave above. The challenge here is to move the thumb to the correct key in time. The tonal material of the chords in both hands is based on the same material that was used in the previous variation. Thus, the rhythmic configuration is what stands out as novel information. Again, the inherent repetitions of similar structures permit chunking.



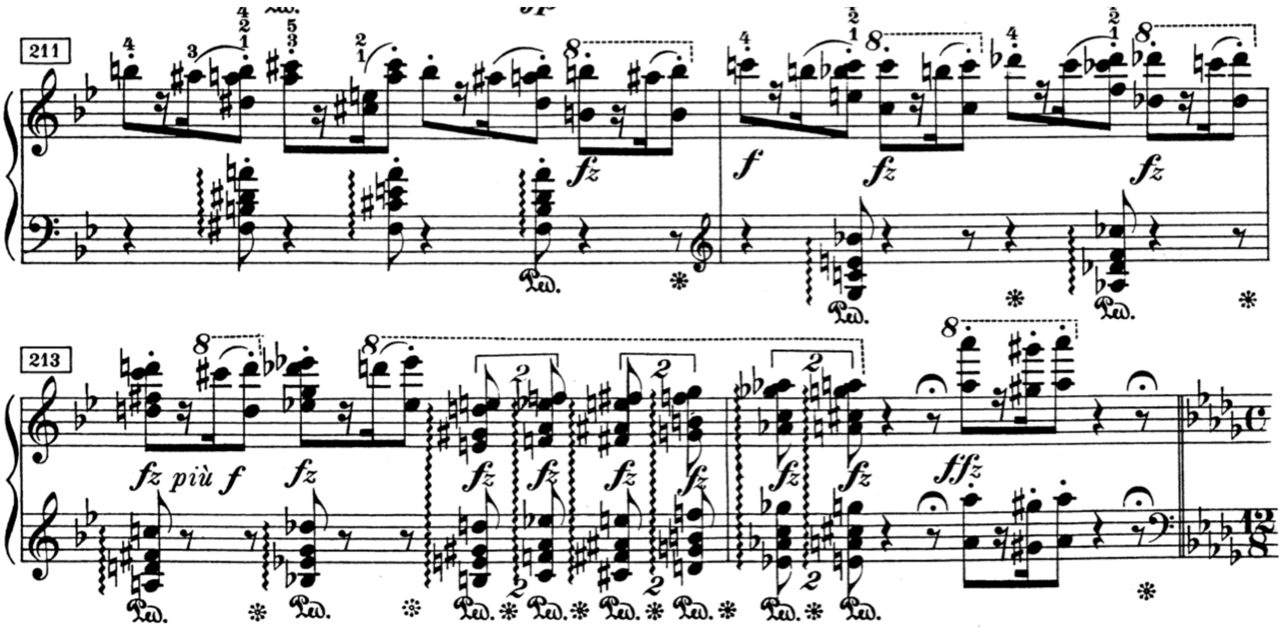
The sixth variation, *allegro scherzando,* consists of a high-speed chase between the two hands, and while it may immediately come across as a lot of information the two hands play the exact same notes an octave apart in the entirety of the main motif section, or the A section. In the B section, the same formula applies to the first four measures, except for two single notes differing from the right to the left hand. Again, even though this adds novel information twice, the differences occur structurally in the same place in the first bar as in the third bar, and the difference is a semitone in both cases. This means the pianist can still rely on chunking and structural memory, and relatively easily compress this whole section down to its rhythmic pattern; a 32nd and eighth-note pattern in both hands, and the declining contour of the first two chords. The seventh variation consists of the same melodic material with a new rhythmic structure. Both hands continually play

16th notes in an overlapping manner. As in the sixth variation, this section can be reduced to the rhythmic structure and the contour of the first melodic structure - the first four tones.

Above, variation 6. Below, variation 7.

In the eighth variation, *lento*, both hands continually play many-voiced chord structures, carrying the melody as the uppermost tone. In addition, the melody is echoed on the off-beats with the left hand in the first four measures, and in both hands in the subsequent four measures of the A section. The rhythmic pattern follows the structure from the exposition leaving the contents of the chords as the only novel melodic material; however, in general, the chords still adhere to the harmonic chord progressions as the previous variations.

The three last measures of the tenth variation, *Un poco Allegro e alla burla*, contain ten dominant major seventh chords in the left hand, all moving upwards chromatically, while the right hand plays an extension of the major seventh chords in the last two measures. Here the pianist would basically only need to know the first chord of the penultimate measure to be able to practise the challenging sequence that lies ahead. The preceding contents of the variation consists of a similar rhythmic pattern and there are multiple structural similarities across the measures.



In the twelfth variation, *Meno Allegro e maestoso*, the contour of the main theme is maintained, but after a series of modulations in the preceding variation it is now presented in the major mode. The melody is carried on top of yet another set of chords, and has been stripped of its original rhythmic pattern. This variation is characterised not only by its chords, which according to the notation should be played in the dynamic range of *fff*, and *con tutta forza*, but also by what succeeds them. Both hands play chords on the first beat of the measure and octaves on the second beat, meaning this variation requires speed, force and accuracy, three qualities that are hard to combine. Nevertheless, the tonal material in both the chords and the octaves belongs to the same categories, i.e. in the first measure a G major chord is succeeded by octaves of G in both hands. In this variation it is helpful to skip the octaves and rehearse the chord progressions first, adding the octaves later. Furthermore, each octave pattern can be associated with its preceding chord structure. The movement of both hands in this variation is similar to the eighth variation.

The thirteenth variation, *allegro furioso*, contains another technical challenge. The main motif forms the tonal material of the right hand in the first eight measures, followed by a series of modulations of the main motif. Both hands chiefly play mirroring arpeggiated structures, and once the tonal material has been identified these structures are more easily visualised as chords rather than as series of single notes due to the tempo of the variation.

The point with presenting all these elements is to illustrate how novel material can be more easily overcome when isolating the challenging areas and treating their contents as associations of something that is already mastered. These analytic remarks are not conclusive, and should be regarded as tips, or, a proposed guide for simplification. Throughout the entire Ballade the tonal material can be associated with elements from the first sixteen measures, as would be expected in a variation piece, and the memorisation of each single variation is available through reduction of the material to chunks containing increasing amounts of information.

The analytic approach offered above is not as thorough as a full personal interpretation would require. For a comprehensive approach an even more reductionist method is suggested by Dickinson (2009/2010). In her study, the reduction follows the method of *Schenkerian Analysis*. With Schenker's reductionist approach the music can be seen as having a background, a middleground, and a surface level. «Any analysis by Schenker is intended to show how the music in question is derived by means of elaboration from its tonic triad, which is its ultimate Schenkerian background» (Cook 1987:39-40). The analytic comments provided above are intended to point performers in the direction of seeing beyond the written material.

2. 5 Practise in relation to the Ballade in G minor

As is the case with most written music, the notes represent a kind of recipe from the composer to the performer. Historically there are arguments both for and against following the notes too rigorously, since the act of writing down thoughts that only exist as imagined sounds and textures certainly has its limitations. «Musical notation has never been able to convey all the information essential for [...] performance. The score is at best a good clue to the composer's creative spirit» (Rosenblum 1991:xvii). Although the debate concerning performance practice is not likely to settle any time soon, historical musicologists and performers alike continue to explore the possibilities within the existing classical musical corpus. Differences from performer to performer include subjective interpretation of tempo, timing, phrasing, and other musical features not necessarily relating to the notes themselves. Individualisation is important in order to shape a personal performance, and the numerous decisions made throughout a piece concerning the above mentioned musical features contribute to establishing a solid mental picture of the music in the individual. However, before getting too entangled in the many implicated psychological aspects, there are a few more points to cover from the musician's point of view. It is important to recognise the different angles from which musicians and psychologists view music performance, with one angle mainly being based on cognitive theories and the other focusing specifically on the interactions between the performer and the instrument. The complex problem solving performed by a musician throughout the learning phase of a musical piece does indeed involve the use of trained cognitive abilities, even if the musician may be unaware of this. In the following, some of these cognitive skills will be illuminated and compared to the practical issues that may occur when practising the aforementioned piece of music.

Classically trained pianists that have been practising scales, chords, and arpeggios in various keys, will already be familiarised with a significant amount of the contents of the piece at hand. Certainly, some fingerings will be novel, while some patterns and sequences will be close to (or even identical to) elements that have already been practised. The interesting bit is how the piece in its entirety is put together, and how the pianist is able to link all the pieces of the puzzle together in the right order. Playing a piece of music is much the same as telling a story. At some point in time, the elementary building blocks of the story may very well all have been arbitrary bits of information. Incomprehensible, even, before learning the multitude of meanings behind words, and learning how to interpret the combinations of the words as meaningful phrases, sentences, paragraphs, and so on. Before a literary deciphering can take place, the elements of the alphabet need to be learned. However, once the foundation is laid out, the words constitute pieces of a whole in the same way that letters constitute pieces of a word. Moreover, the contents of sentences, paragraphs, and even whole stories can be understood through their meaning, or the concepts they represent. Retelling a story word for word may become quite a challenge, due to the nature of how the meanings and/or concepts are remembered through associations. Associations are furthermore based on schematic representations, which are based on previous experience. Retelling the core contents is therefore an easier task to perform. Verbatim recital on the other hand requires more than a general understanding of the contents, as Bartlett (1932) found.

A central trait of both language and music is syntax: the order in which words or motifs are presented. In both cases a phrase may change meaning or become completely incomprehensible if something is out of place. Once enculturation effects set in, music may be understood as a set of sounds governed by rules and systems (Lerdahl & Jackendoff 1983); the contents of a scale represent more than simply notes, and chord progressions create tension and expectations. Adhering to structural norms creates natural fragments, allowing common progressions to occur. When memorising music, many hints are available to those who are particularly observant. For example, a typical element among composers is to repeat the main theme upon conclusion, so as to release tension. This is in fact exactly what happens in the *Ballade*. The first eight bars are repeated in their entirety, with one added tone. Another element is to use a feature of the main motif in recurring material. This can include using a single feature such as either melodic, rhythmic, or contour similarities, or a combination of the features. Again, these elements can be found in the piece mentioned above, unsurprisingly, as this is a variation piece. Nevertheless, the concealment of melodic passages in close tonal relationships to the main theme is a way of creating a thread throughout the piece. In most cases these elements are not perceived by performers alone, but are audible to any trained ear. Learning to correctly anticipate musical components is achievable up to a certain level through experience within a genre. Then there are those odd details, the moments where you can tell the composer has been inspired and particularly creative, or at least written something out of the ordinary. For those who do not know what to be aware of, these details may be just as undetectable as a gorilla in a ball game (Simons & Chabris 1999). For the trained ear however, details may not pass by easily and unnoticed, as their applied schemata are capable of dealing with low-level irregularities. What would seem to fit well, then, is that once a pianist has developed schemata containing enough information for him/her to disregard the majority of the musical 'standard' information of the piece, the details are the only things left for attention. Focussing solely on these details, and placing them in the context of the already familiar material, thus becomes the main challenge. Furthermore, if these details are technically challenging, they will require more practise, leading to more repetitions, again leading to them being incorporated in the schema for the particular context they belong to. Also, through repeated practise sessions on technically advanced movements, the procedural memory for that particular part of the piece will provide the safety net needed in order to feel in control despite of its challenging nature. This holds true for a great amount of the virtuoso piano pieces of the Romantic Era. Virtually any composition by Chopin, Liszt, or Rachmaninov, just to mention a few, contains sections which demand a high level of precision in their execution, and a mastery of finger movements beyond the range of conscious control. With practise, these types of movements become part of the pianists procedural memory, controlled by a combination of brain regions, specifically a combination of the basal ganglia and the cerebellum which allows for precise timing of rapid movements (Altenmüller & Schneider 2009), in addition to memory regions such as the hippocampi. As demonstrated earlier, there are several such passages in Grieg's *Ballade*.

For complex motor memories to properly consolidate in long term memory, they require a certain level of attentiveness over time so as not to wither on the vine. In the following, a selection of potentially challenging areas from the Ballade's fourteen variations are identified, with suggestions on how to solve them based on the psychologically justifiable practise methods mentioned above. Note that these are only a handful of sections chosen to exemplify how rehearsal aids memory and vice versa.

3.
A Music Psychology Approach

«The musical growth of [...] a genius will, at last in its early stages, be askew: as thinker of musical thoughts he will get ahead of himself as a pusher of keys. We will learn to *think* a piece, and having thought it, go to the piano and play it without having to assemble and integrate sets of isolated skills with scales, arpeggios, trills and other physical devices upon which most pianists must labour» (Payzant 1992:80-81)

Preface

During the last decades, advances in brain imaging techniques have enabled researchers to gain new insights into the neuronal activity underlying musical performance (Altenmüller & Gruhn 2002). With the use of electroencephalography (EEG) and magnetoencephalography (MEG) it is possible to track the sudden changes in neuronal activity at a cortical level, and with, for example, a functional magnetic resonance imaging (fMRI) approach, it has become easier to establish which brain structure is associated with which action (ibid.). A basic neuroanatomical introduction seems appropriate in order for the reader to productively visualise the connections between brain structures, their locations, and their general functions.

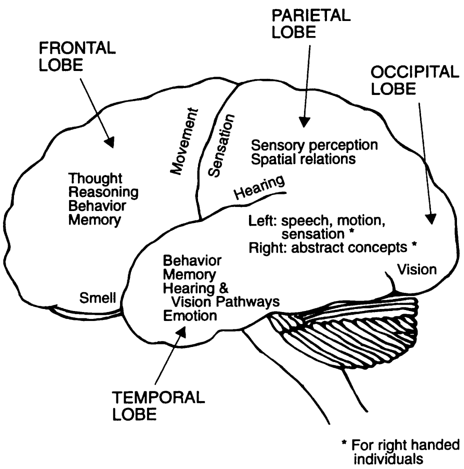


Figure 2: Lobes of the human brain, as seen from the left. Adapted from www.snog.org.au

The cerebral cortex is anatomically split into the frontal, temporal, parietal, and occipital lobes. It is physically divided into two hemispheres connected to each other via the corpus callosum, a fibre bundle consisting of about 100 million nerve fibres. The two hemispheres control the contralateral part of the body, e.g. the primary motor cortex in the left hemisphere controls movements in the right side of the body and vice versa (Altenmüller & Gruhn 2002). In the case of visual and auditory input, the complex pathways from eyes and ears to the cortex involves a process in which some information remains ipsilateral (on the same side), and some information is transmitted contralaterally (the opposite side). Among the advantages of this system is its accurate source identification ability. There is extensive communication between the two sides of the pathway, and also between the two hemispheres. The auditory cortices are located in the temporal lobes, in the posterior part of the Sylvian fissure, located lateral to the limbic system.

All sensory input enters the brain through one of the five sensory organs, i.e the nose, ears, eyes, skin, or tongue. The interaction with these organs in turn convert physical input to an electrical/neuronal signal which is transmitted to the brainstem (containing among other structures the cerebellum) for immediate filtering and processing. Next in line are the thalamus and the hypothalamus in the forebrain, acting as relay stations for all sensory input signals, passing them on to the amygdala and hippocampus where emotions and associative memories are coded. The signal is also transmitted to the primary and secondary sensory cortices for cognitive processing. The following chapter will focus mainly on memory, which in order to be properly understood needs a rather general introduction. However, as it continues into the more detailed fields, the memory processes needed for perceiving and producing music will be emphasised. As mentioned in the introductory chapter, at this stage separating anatomical structures from functional memory is paramount.

3. 1 Dissecting functional memory

Memory forms a considerable part of the psychology literature, and has been extensively studied since Ebbinghaus' first attempts of memorising his nonsensical syllables at the turn of the 20th century (Baddeley 1990). Memory is a fundamental part of an adaptive system, from the human brain to computers. It allows us to understand, to learn, and eventually survive. It is what makes us who we are, and what keeps us from acting merely on instinct. Memory is arguably one of the most important and impressive faculties of a living organism in possession of cognitive abilities. Yet, despite its apparent omnipresence it is not fully understood. Studies have shown that individuals who have lost their memory of the past may still have retained their ability to learn new facts and skills. Others may have lost their ability to learn new facts and skills, but show no impairment of their memories of the past. Known as amnesia, the loss of memory and the loss of ability to memorise can certainly become a troublesome part of one's life, yet for researchers the cases of retrograde and anterograde amnesics provide insights into the foundations of human memory.

Even more interesting are the cases of individuals who seems to have lost only parts of their memory, such as in the case of the earlier mentioned Clive Wearing. A former professional musician, he can still play the piano and conduct a choir even though he is unaware of his past as a professional conductor. He is, in fact, completely oblivious to the fact that he is still able to play, due to a severe case of amnesia following a viral infection that damaged most of his memory areas in the brain (Sacks 2008). Both his retrograde and anterograde memory was so damaged, it was as if he had been «deprived, in some uncanny and terrible way, of all experience, deprived of consciousness and life itself» (ibid.:203). In spite of that, when asked to play a certain piece on the piano his immediate reply was that he had never played the piece, however, while playing he would claim to suddenly remember (ibid.:212). His memory which, at best, is said to only serve him for minutes at a time got him into some trouble while playing the piano. As Baddeley put it: «Many pieces have a point at which a return sign means that that section has to be played once again before continuing. Initially, Clive ran into difficulties at this point, becoming stuck in an apperently eternal loop» (Baddeley 1990:5).

His ability to still perform music poses a number of questions. For example; how does he know what the notes in the score represent, and how does he know what to do with the information even if he can decipher it? The fact that the ability to play is still there supports the idea that not all types of memories are stored in the same cortical and subcortical areas, and it also suggests memory is not a unitary system. That is to say, not all memories are the same type of memory. This can, to a certain degree, be explained by how memories are sets of associations, in addition to how memory contents may differ, as described earlier. Furthermore, researchers seem to agree upon the fact that memory is not a unitary system, even if the system's subdivision is not yet unequivocally defined (Baddeley, Eysenck, & Anderson 2010).

Perceptual vs. conceptual categories

An important aspect to take into consideration when studying musical memory is the fact that sound is a temporal phenomenon, and must conseqeuently be regarded as distinct from other physical/perceivable objects. Sound is what we perceive when pressure waves within a certain frequency band (≈ 20 - 20,000 hz) travel through a medium (typically air or water) and reach our ears. Furthermore, comparative to most visible objects, it has no tangible features. Intuitively, then, one can assume that memories for this percept will be stored differently from memories for, say, an instrument which can be seen and touched. On the other hand, feature detection takes place at a perceptual level (Bregman 1990). When memorising musical sound - being the temporal phenomenon that it is - applying strategic association techniques is central in order to overcome the temporal limitations of short-term and working memory. The mental representation of the sound, especially if it is a familiar one, may contain semantic information that will assist in remembering the particular timbre of the sound, while melodic contents may exist as building blocks mentioned in the previous chapter. The essence in this context is to know how to elaborate and associate; elements of learning that will be dealt with momentarily.

The way our brain deals with input by grouping percepts is thought to adhere to a set of principles posited by Gestalt psychology, such as proximity, similarity, continuation, and symmetry (Shepard 2001b). These principles will also be described in more detail later. Nevertheless, perceptual categories are made on the basis of such primitive grouping principles and feature extraction (Deutsch 1999; Snyder 2000). This activity is based on the natural tendency for the brain to organise perceptual input prior to cognitive processes, and has been termed *bottom-up* processing (Snyder 2000). In the other end of this bottom-to-top spectrum that is the perceptual-cognitive system, experience-based conceptual categories influence perception in what is known as *top-down* processing. Both of these affect our listening and, thus, our comprehension of sound as music or noise. While bottom-up processing primarily partitions the continuity of auditory input into manageable units (Bregman 1990), top-down processing makes use of schemata and experience, and can extract higher-level structures (Snyder 2000).

Mnemonics

Outside of the musical domain, there are many examples of strategies for memorising large quantities of information employing conceptual categories, such as cognitive maps. A cognitive map is a mental representation of a physical environment, for example a map that lets us maneuver effortlessly around our own house or our hometown. By visualising a specific route in such a map and highlighting details along the route, bits of information can be hooked onto each of these details in what is known as the *Loci system* (Higbee 2001). There are also common strategies for memorising e.g. numbers, names, or decks of cards by association techniques such as the *link system* and the *peg system* (ibid.). These are collectively referred to as *mnemonics*, and can be used to demonstrate the power of associative thinking. The more imaginative the association, the stronger it will be. It is therefore often recommended to use exaggerated images (ibid.). More mnemonics will be presented later. The reason for mentioning them at this stage is to illustrate how functional memory can be strengthened by learning strategies on how to efficiently associate and retrieve information. The types of memory and memorising strategies of particular interest to the performing musician will be explored further, however, following is a brief introduction to the memory systems that is widely agreed upon as the foundations of functional human memory, i.e. short-term memory and working memory in a lower level of a hierarchy, and long-term memory in a higher level.

3. 2 Short-term memory and working memory

Several models have been constructed in attempts to explain how neural activity gives rise to the phenomenon of memory. One of the early, acclaimed models, is the multi-store model posed by Atkinson and Shiffrin (1968). In their model, information enters a sensory memory, is encoded in a short-term store, or working memory, and can through rehearsal be encoded into a long-term store. Once information has been encoded in long-term memory it can be accessed, or, retrieved, by short-term/working memory (ibid.). One of the problematic assumptions of this model was that «holding items in the short-term store would guarantee learning» (Baddeley 2010:42).

Rather than accumulated time in the short-term store, it was proposed by Craik and Lockhart that levels of processing were better predictors for learning (ibid.). The problems with Atkinson and Shiffrin's model was to some extent dealt with by Baddeley and Hitch, who devised a new model of working memory. This model proposed an alternative view on how we are able to focus attention with the central executive, retain auditory information in a phonological loop and visual information on a visuo-spatial sketchpad, and how this information can be linked to conscious awareness and interact with long-term memory through the episodic buffer (Baddeley & Hitch 1974; Baddeley 2000). Research has long since arrived at the conclusion that our working memory has limitations, both with regards to time span and amount of information it is able to process (Passer, Smith, Holt, Bremner, Sutherland, & Vliek 2009). Moreover, working memory and short-term memory are not interchangeable terms. Working memory is «the alliance of temporary memory systems that play a crucial role in many cognitive tasks such as reasoning, learning and understanding» (Baddeley 1997:8), and can be seen as a mental workspace combining storage and processing (Baddeley 2010). Working memory is distinguished from short-term memory in that it is regarded as a functional model while short-term memory is regularly regarded as a theoretical storage space (ibid.). Psychologist George Miller proposed a theory in 1956 stating that our working memory limit is restricted to approximately seven bits of information. As his research showed that this number was hardly a constant, he developed the expression «the magical number seven, plus or minus two» (Miller 1956).

Chunking

How do pianists deal with this issue? Obviously they must hold more than seven or eight subsequent tones in their working memory. There are ways of «breaking this informational bottleneck» as Miller puts it (Miller 1956:95). A concept known as chunking explains how we are able to work with vast amounts of information, numerously exceeding the postulated 7±2 bits. Chunking may be thought of as a way of grouping together pieces of information that we can easily associate with sets of information in a hierarchical fashion. Consider the following example:

Memorise these letters: W N O U Y O N C A E S E H Y W. Now recite them, looking away from the page. The fifteen letters clearly exceed our capacity to retain information in working memory. Suppose they were presented into groups of three: WNO UYO NCA ESE HYW. By grouping the letters, the task is somewhat easier, yet it is still difficult due to the groups' lack of meaning. What if some of the letters were to be rearranged: NOW YOU CAN SEE WHY. Organising every single piece of information into meaningful structures, the original 15 single bits of information has been chunked to one meaningful phrase of five three-lettered words.

The act of grouping together elementary bits of information to chunks can also be done in other modalities. In fact, most of us do this on a daily basis. Our brain has a tendency to look for patterns in our surroundings, and automatically performs grouping tasks to make sense of sensory input, based on the bottom-up process mentioned above. However, in the previous example there was a top-down process involved, making use of your conceptual category of language. Semantically these words all have meaning, and due to their structural and syntactical presentation so does the phrase as a whole. The ability to group larger pieces of information to chunks is heightened in situations where we have more experience. This grouping exercise can also be traced in the music domain, as was illustrated in the previous chapter. One example from above is how relying on a tonal framework allows the pianist to reduce the information in a measure down to one single chord, which again can be seen as a part of a longer chord progression. Another example is how melodic material can be seen as groups of tones from a scale. Thus, chunking can occur at phrase level, and, in a relatively short amount of time, entire sections can be chunked into chord progressions and melodic sequences, so long as the pianist is equipped with a framework that enables him to find coherent structures in the increasingly larger material. This may be where experience comes in. Chunking music is all about learning how to take advantage of these hierarchical levels of knowledge, and this is much more easily done when a music-theoretical framework is able to support the process, whether such a framework is explicitly or implicitly learnt. I.e. one does not have to have read a book on music theory per se, to learn about the tonal relationships and structural organisation of music, as this can be done by ear (Bamberger 1991). One of the many possible explanations for how chunking can occur in music is to once again look at a working memory model; remembering the constituents of Baddeley and Hitch's working memory model, the phonological loop deals with auditory information and provides the mental workspace needed to retain information for comparison with existing schematic knowledge in long-term memory.

To briefly summarise, musicians rely on their musical knowledge to overcome the limitations of short-term memory capacity by chunking auditory information into meaningful groups, or they must «draw on previously learned material or on syntactical rules presumably held in long-term memory» (Berz 1995:356). Then what? When it reaches long-term memory, it just stays there?

Levels of processing

Craik and Lockhart's idea of remembering through levels of processing was a clever one indeed. It places emphasis on how information should be elaborately rehearsed, by linking it to existing semantic information, images, and creative associations (1972). We seem to learn better when we are deeply engaging with the information; focussing on «*why* it is meaningful, why it is significant, why it is colorful» (Foer 2013). As was suggested in the previous chapter, deliberate practice cannot be stressed enough. Conscious, deliberate, and elaborate processing of information including creative use of associations is one of the safest ways to learn new information and for properly consolidating it in long-term memory. Still, retrieval cues are needed, and they may take the form of any of the associations initially used for retention.

3. 3 Long-term memory

Consider the allegory of the musical library introduced in chapter two; how do we access the contents of this library? Only if the information is meaningfully organised can it be accessed efficiently, and in long-term memory this organisation consists of using hierarchical schemata.

Long-term memory is the part of our storage that is thought to contain our implicit and explicit memory systems, more commonly known as our unconscious and conscious knowledge base. The manner in which information enters our long term memory determines its availability in the future, i.e. if we are able to associate new material with existing knowledge there is a better chance it will consolidate. Learning is one of the adaptive skills of the human race, one that we are highly dependent on (Baddeley 1997:6). Throughout the preceding chapters, it has been established that memories are a set of associations, and research on expert memory has been demonstrated to underline the importance of meaningful encoding in order to establish reliable and understandable associations. While retention is often supported by repetition; meaningful encoding is needed in order for the retained information to be able to be retrieved effeciently. The more elaborate associations, the better the chance to trigger a memory. Extensive knowledge within a domain, such as music, facilitate faster encoding of information from that domain as a result of the combination of bottom-up and top-down processes described above. With knowledge, stored in long-term memory, comes the ability to extend the limitations of retention as demonstrated in the previous section on chunking. Given the specificity of expert knowledge, transferring memory skills to other domains is not a straightforward task. However, when pianists are learning new movements or pieces they rely somewhat on within-domain transferability of skills, due to the schematic representation of knowledge (Palmer 2006).

Implicit memory includes automatised skills, or trained action patterns we may perform but normally would find hard to describe in words. The saying goes ‘once you learn how to ride a bike you never forget’, however, few people are capable of explaining all the actions taking place. As an example, compare tying your shoelaces with explaining in words how to do so. Related to this type of automatised action are the terms motor memory and procedural learning, whose foundations will be discussed in the next chapter. Explicit memory, contrastingly, consists of facts and events, and is the part of our memory that we can deliberately access. The explicit memory is further subdivided into two, with facts and concepts belonging to our semantic memory, and events and experiences belonging to our episodic memory.

The knowledge of facts, meanings and concepts; so often come across that they are no longer affiliated with a distinct episodic memory, but are instead entities of their own in long-term memory, are referred to as semantic memory (Eysenck 2010). As so many previously mentioned concepts, semantic memory can also be regarded as hierarchically structured, in the way that knowledge is conceptualised. The semantic memory for e.g. a particular note may contain information about its frequency, its location on an instrument, or its place in a musical score. However, semantic knowledge of a specific note or tone does not explain the ability to immediately play that note, as one will also need to bring forth instructions for how to actually play the note on the piano, with all the preparations of movement needed and the actual movement itself included. When considering musical memory, semantic memory, episodic memory and procedural memory go hand in hand.

Despite the fact that there seems to exist disagreements regarding what a proper model for memory should contain and what it may look like, there seems to be a consensus about the underlying neural structure. A memory can be thought of as a neural network, or what memory pioneer Richard Semon called an engram (Schacter 2001). Engrams are furthermore associated with brain plasticity, another aspect that will be covered more in detail in the next chapter. When the memory at hand was first perceived or experienced, the neurons that were activated established connections to other neurons. When the same connections are reactivated they also reinforce. The highly influential work of Donald Hebb gave rise to the term ‘neurons that fire together wire together’ (in one of the most cited, yet, humorously, also highly unavailable book ‘The Organization of Behaviour: A Neuropsychological Theory’, 1949). An interesting aspect to consider about memories is how they are brought into consciousness through associations and cues. The more associations to other aspects in long-term memory, the easier it will be to trigger a certain memory. This can easily be illustrated by simply drawing a mind map of every available associations to the word music. As instruments, composers and concepts etc. emerge, these will again carry many associations. Many memorising techniques are based solemnly on exploiting this simple, yet, strong concept, as was illustrated above. As complex memories consist of wide-reaching neural networks, musical memory may owe its particular durability to the inherent ability of music to be associated with other modalities (Gerrig & Zimbardo 2005).

Episodic memory

This feat of long-term memory has also been referred to as autobiographical memory, and mental time travel (Baddeley et al. 2010) due to the memory's strong associative nature. Some episodes can make particularly strong impressions, either by being strongly associated with emotions or otherwise. When such episodes are rendered into long-term memory, they often contain residues of the many types of input that may have been experienced at the time. Due to their contents being specifically associated with one particular event, they are distinct from semantic memory. Yet even if they are able to remain highly detailed and accurate for a long time, they can not be trusted completely, as studies of eyewitness testimony have proved they are prone to manipulation (Loftus & Zanni 1975). As other forms of memory they too can be influenced and changed in the unconscious. The intricate connection between music and episodic memory can be illustrated by many examples of songs triggering specific memories, or specific situations triggering the internal playback of a particular song that may have been encountered in a similar situation. In relation to music, one song in particular may trigger the memory of one particular episode, and this may also work the other way around. Furthermore, if a song triggers the memory of an episode, this episode may have been strongly influened by e.g. emotions, thus leading to a potential misinterpretation of the song itself being associated with that particular emotion. This, seen in relation to the previously mentioned studies on rewards related to correct anticipation of music, suggests we are a host of credulous music consumers who happily succumb to believing in uncontrollable parts of our mind.

3. 4 Schemata

Schemata can be viewed as a conceptualised collection of previous experiences; a generalised framework containing the fundamental elements of recurring sensory inputs, episodes and abstract representations. As a form of semantic memory, similar to conceptual categories, schemata can be structured around associational connections between concepts and entities, and can also be viewed as a metacategory (Snyder 2000:95).

Upon exposure to the word piano, a general idea is that it is made of wood, contains black and white keys, and it is capable of making sounds. A pianists schema of a piano is a bit more detailed; the keys are organised in a certain fashion and form part of a mechanical relay system which when struck sets strings into motion, and it contains pedals serving particular purposes. Furthermore, there is normally a lid on top, a note stand above the keys, and several detachable parts covering the strings and the mechanical parts. Naturally, detailed knowledge of one's particular expertise is expected, so where the schema reaches its limits in an average pianist, it goes on for a piano tuner, who will also be particularly aware of the felt tips of each hammer, and the tuning properties of each bolt at the end of each string. (Further schematic knowledge of a piano would be expected in someone working with for example quality control in a piano factory, where one would also know about the particulars of each part of the piano, how it is made, how the parts are connected etc.). Up to this point, a schema and a conceptual category would be able to function similarly, however, the schema may also contain highly specific and detailed contents related to playing the piano. Furthermore, schemata can represent a specific piece, and it may - if pieces are similar - adapt to the contents of other schemata, thus creating a sort of synthesis-schemata of these pieces, perhaps in a manner that allows musicians to recognise genres and type-specificities in a similar fashion to how historical musicologists see historical eras.

What kind of implications do schemata have on a day to day basis? When answering this question, it is hard not to include spatial orientation, which, incidentally, is also a central issue in musical imagery. A regular method of illustrating a schema is by way of imagining one of many typical situations. Anyone who has ever been in a kitchen might expect to find a number of items in this particular room. Even in unfamiliar kitchens, the same core items is likely to be present. A sink, accompanied by some cupboards, a kitchen bench, a stove, and a refrigerator, for example, may represent a generic kitchen, and one would most likely classify this room as a kitchen even at first sight. Should a shower and a bed be found in the same room, however, most people who are familiar with a regular kitchen would find these objects completely out of place. Irregularities such as a shower in the place of the stove would stand out from the surroundings not because a shower on its own is an unfamiliar sight, but because it is expected to be in another room entirely. Additionally, when opening a drawer containing cutlery, one would expect to find knives, forks, and spoons. Finding knives, a hammer, and a wrench, say, would be highly irregular, and not fitting overall schema of the kitchen. This would, however, not be an unexpected sight should one be in the garage or the tool shed. This illustrates how a hierarchy of schemata can contain details beyond the initially triggered schema.

In music, information can be hierarchically organised in much the same way. The hierarchical fashion in which schemata can be triggered, then, allows for information to emerge in a performer contatining the previously mentioned core elements of music theory. The black and white keys on the piano keyboard may represent more than merely black and white keys, for example, such as a range of possible scales and chords, bits and pieces of melodies, and so forth. On a larger scale, a schema may exist containing material regarding classical music, as opposed to contemporary popular music. In the classical music schema, a drum set playing a disco groove would be the shower in the kitchen. Furthermore, playing a regular chord progression such as ii7 - V7 - I on the piano could be like opening the kitchen drawer, until the point where a jazz line is played by the right hand. Metaphorically, the overall melodic part of the jazz line may represent the drawer, i.e. something one might expect to find in the kitchen, while the contents of that melodic line would be like finding the hammer and wrench, i.e. contents that would not normally be constituents of a kitchen drawer. A melodic jazz line superimposed on a ii7 - V7 - I progression would on the other hand make perfect sense in the tool shed, where the overall schema contains some of the same material such as a bench and drawers, but the contents of jazz music include the use of various alterations of the scales, just like the contents of the drawer in the tool shed may contain tools carrying a certain resemblance to the kitchen drawer contents.

As mentioned above, schemata can also play a neat role in identifying errors and anomalies. Studies of chess players have demonstrated that their ability to recall an image of plausible positions of pieces on the chess board is better than when the pieces are placed randomly across the board (Ericsson & Chase 1982). Similarly, musicians have a better ability to recognise and identify errors in material adhering to rules they are familiar with, than in music from unfamiliar genres. In both domains, the professionals outperform their corresponding amateurs and the uninitiated, supporting the idea that increased training and exposure to domain-specific activities lead to expert knowledge within that particular domain (ibid.). A number of scientists have highlighted the practicality of using musical form as a hierarchical retreival scheme based on its presence in the music, among them Chaffin and Imreh (1997) and Hallam (1997). According to Snyder, this may have to do with «*what is foregrounded:* what features stand out and immediately emerge in the experience» (Snyder 2000:103).

3. 5 Gestalt theory

Among the models attempting to explain our abilities to extract patterns from our surroundings and group certain features together, and most of them originate from/in gestalt psychology. The expression ‘the whole is perceived as more than the sum of its parts’ is often illustrated with images of simple dots and lines, corresponding to one of the central issues of cognition, namely our ability to segregate streams of information into potentially meaningful structures. As our brain seems to prefer systems and patterns, presumably for rapid interpretation, it is advantageous to gain an insight into how some of the cognitive processes concerning grouping may manifest themselves in everyday situations. This may for instance have to do with separating figure (melody) from background (harmonic structures). The gestalt principles of perception are divided into proximity, similarity, continuation, and closure (Passer et al. 2009:204).

Imagine sitting down at the dinner table. You see your plate in front of you, and a knife and fork on either side. You can not see the entire knife or fork, but you still accept the fact the they are both whole regardless of how much you can see owing to the principle of good *continuation*, and your experience with knives and forks who tend to be in one piece. On the table, there are a number of candlelights placed out, and you immediately recognise that there are two equal groups of three, due to the *proximity* of the three, and despite the distance between the two groups you identify them as *similar*. In each of the group of candlelights, one candle is taller then the others. The two groups are each placed in a triangular shape, a shape you identify due to the concept of *closure*, even if they are just spaced out on the table with no obvious relation, and seeing the two groups as belonging together due to their symmetrical appearance, the *closure* concept may allow you to see the two triangle shapes as together forming a square. Identifying, classifying, and grouping information in this manner can be seen in relation to our bottom-up processing. Furthermore, by understanding grouping principles, some light can be shed on how and why chunking works so efficiently. Lastly, it is interesting to note how our perception can sometimes be misinformed due to gestalt principles, such as when one stimulus gives rise to more than one interpretation.

Figure 3: A visual stimulus producing two interpretations. Image from www.nwlink.com

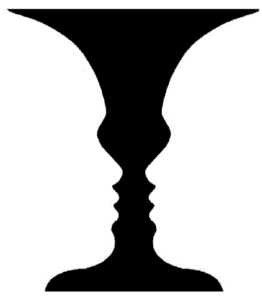


Figure 4: A visual stimulus producing two interpretations. Image from phylliciapoynterict.wordpress.com

One who has studied the relation of gestalt principles and music is Diana Deutsch, who found that many of the compositional archetypes still in use today may have been influenced by principles such as proximity, similarity and continuation (Deutsch 1999). This may explain why these traits can be identified in much of the music we know today.

3. 6 Musical memory

Memory for music has been compared to other domain-specific memories, and researhers have found that some strategies for memorising can be applied in several fields. Ericsson and Kintsch proposed a three-component approach to how large amounts of information can be approached. This model consists of meaningful encoding (how information is perceived and understood), use of well learnt retrieval schemes, and rehearsing for time-effective retrieval (Ericsson & Kintsch, 1995). Meaningful encoding of musical material, whether it is written or played, requires some level of knowledge about the basic elements that constitute music. In professional performers this knowledge constitutes a fundamental part of the skill acquisition which often takes place during childhood and adolescence (ibid.). A commonality of expert performers is that they started practising at a young age (Bloom, 1985). This is also a crucial period for brain development, as research suggest the human brain is more susceptible to plasticity before the age of seven (Schlaug, Jäncke, Huang, Staiger & Steinmetz, 1995). They have also been found to have exceeded 10,000 hours of practise, which, distributed amongst the years of effective rehearsal, leads to most performers reaching an expert level in their early twenties (Ericsson, Krampe & Tesch-Römer, 1993). «A relatively uncontroversial assertion is that attaining an expert level of performance in a domain requires mastery of all of the relevant knowledge and prerequisite skills» (Ericsson and Charness, 1994). As introduced in the second chapter, performance cues are suggested implemented into the memory of a piece. These include expressive and interpretive performance cues, relating to subjective metaphors and music-theoretical expressions, respectively.

Structural memory

Similarly to a narrative structure which enables us to comprehend a storyline in language, cartoons, films, and the like (Rubin cited in Chaffin, Logan & Begosh 2009), experienced musicians are able to parse out details from the musical structure. The musical features mentioned above; melodic, harmonic, rhythmic and formal structures, become parts of a whole with a designated role depending on the specific information contained within them. Chaffin, Logan and Begosh found that «musical form and the storyline of a musical programme are both manifestations [of] the underlying ability to identify large-scale structural relations between events» (Chaffin, Logan & Begosh 2009:357). Seen in relation to their findings, structural memory can to some extent explain phrase to phrase memory for melodies, chord progression to chord progression memory for harmonic sequences, and variation to variation memory through the entirety of the *Ballade in G minor*. Furthermore, this would be supported by the hierarchical organisation of semantic memory. Additionally, this partitioning of a piece of music follows the schematic outline of reductionist analysis as suggested by Dickinson (2009/2010).

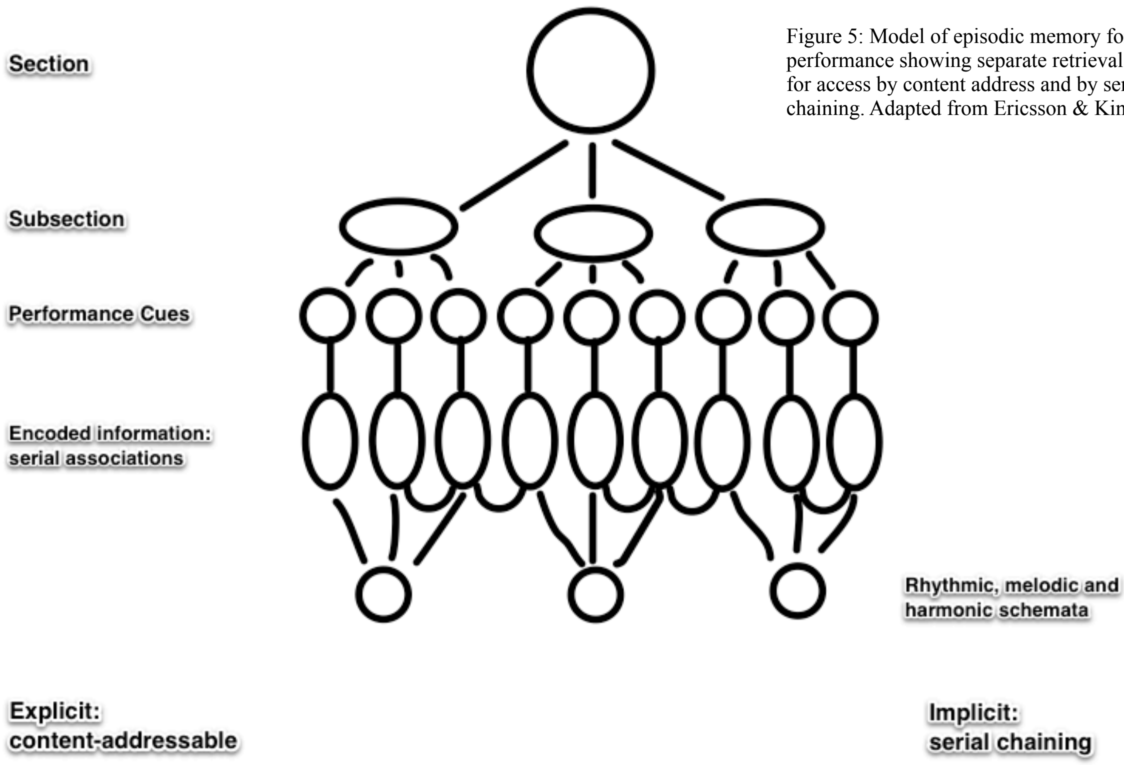


Figure 5: Model of episodic memory for music performance showing separate retrieval organisations for access by content address and by serial associative chaining. Adapted from Ericsson & Kintsch (1995).

The model above is an adaptation of Ericsson and Kintsch (1995), relating to how a section of a piece of music may be split up in a hierarchical fashion. The labels on the right are the levels available to content-addressable memory; explicit, semantic knowledge that can be supervised and engaged while playing. The label on the left signifies how the different musical schemata forms an implicit background knowledge for serial chaining to automatically occur. The lines indicate connections between each single section, which on top constitutes a large-scale formal section, divided into three - in this case arbitrary - subsections, each with their connected performance cues and serial association cues.

Emotional memory

Music has the ability to evoke emotions largely due to evolution (Thompson 2009). As part of our so-called reptile brain, our oldest and most central survival skills are closely related to the immediate correct reaction to sensory input that is potentially harmful or beneficial. The close link between our sense of smell/hearing and emotion is also what makes this combination a strong multimodal stimulation for memory consolidation. Within the limbic system of our brain lies structures such as the amygdalae and the hippocampi, structures that are important for dealing with emotions and memories, respectively. As the limbic system is anatomically close to the thalamus, communication between them can be rapid.

In music, emotions form a central part of the performance both for the performer and the audience. While the performer continually triggers memories for what to play, these memories can contain information about what emotion the performer wants to induce in the audience, and during the performance the emotions can affect the performer as well. Chaffin et al. also «observed that musicians find it difficult to play from memory when asked to perform without expression and surmise that playing without expression eliminates emotional cues that normally contribute to the retrieval of the music from memory» (Chaffin et al. 2009:356). Although this alone does not prove emotional memory to be a separate storage system, it does illustrate the importance of emotional cues in relation to musical retrieval. As such, the expressive cues suggested by Chaffin et al. (ibid.) may owe their strengths to the possible link between expressivity and emotion. Furthermore, as Thompson (2009) suggests; it is worth considering how music may be connected with emotions also through episodic memory, in that music can trigger a specific episode in which emotional arousal was particularly high.

Visual memory

In chapter 2 the concept of visualising melodies as contours was introduced. Aside from a potential internalised visual model of melodic contour, it has been suggested that the visual memory of the score and memory of the hands interacting with the piano can also support memorising sections of a piece of music, or a whole piece. A study of visual memory suggests our ability to memorise details from visual information is indeed highly functional (Brady, Konkle, Alvarez, & Oliva 2008). Seen in relation to how familar material in general is more quickly and efficiently processed, based on conceptual categories in long-term memory, this would suggest that musicians' visual memory for the score can contain a considerable amount of information. Visualising particular points in the musical score at critical points in the music, such as around the areas of each performance cue may thus be possible. Considering the elaborate approach suggested in the initial study phase of learning a new piece of music - where detailed reading of the score is present at an early stage - in addition to how performance cues are subject to rigorous elaboration, the visual memory for these areas may be available. Furthermore there may be a reciprocal advantage of associationg melodic material with visual material.

Support for Hughes' (1915) argument that kinaesthetic memory for music should be supported by visual and aural memories of the music seems justified by the findings of these two chapters based on research from musicology and music psychology. In the following, the kinaesthetic element of playing music will be investigated.

4.
A Motor Control Approach

«A centipede was happy quite,
Until a frog in fun
said, "Pray, which leg comes after which?"
This raised her mind to such a pitch,
She lay distracted in the ditch
Considering how to run»
(Craster 1959:89)

4. 1 Motor Control

The ability to play a musical instrument is one of the finest examples of how complex motor actions can be trained and mastered. Combined with a sophisticated and musically trained mind, a series of keystrokes by a pianist can produce a form of instantaneous art. What may come across as simply moving fingers may move hearts. The physical execution of these keystrokes has only recently become subject of rigorous research, as previous research on music performance has mainly had its focus on practising, interpretation, and rather anecdotal comments concerning the muscle memory needed in order to play without constraints. The accurate coordination between auditory feedback and physical movements can only be obtained through the use of deliberate practice (Altenmüller & Schneider 2009). Furthermore, playing music depends on the use of planned actions and voluntary movements (ibid.). Executing planned voluntary movements takes time, and even if it is in the order of hundreds of milliseconds, the fluent movement necessary for successfully playing an instrument requires that several movements, or movement patterns, are activated in an overlapping fashion. This fluency of hand and finger movements has been compared to the way our lips proactively form the shape needed for producing several speech sounds at the same time in a process called coarticulation (Rosenbaum 2010). Among many theories trying to explain the development of skills and motor programmes, the *hierarchical learning* and *generalised programmes* presented by Rosenbaum (ibid.) align with the stipulations mentioned earlier regarding how and why repetitions are a central part of practising, and also support the role of hierarchically organised schemata and conceptualised categories. Consciously focussing on the execution of isolated movements is a slow mechanism relative to trained motor programmes in procedural memory (Duke, Cash, & Allen 2011). This underlines the importance of assigning the playing of rapid sequences to motor memory alone, leaving the monitoring of playing to conscious processes involving retrieval schemata and the musical schemata including musical form (Chaffin & Logan 2006). In other words, one should avoid concentrating too much on the individual movements, and rather focus on the effects the movements produce (Duke, Cash, & Allen 2011). This is in line with how the motor programmes are intially learnt: «Practicing an instrument involves assembling, storing, and constantly improving complex sensorimotor programmes through prolonged and repeated execution of motor patterns under the controlled monitoring of the auditory system» (Altenmüller & Schneider 2009:337). While auditory feedback can be used to regulate and coordinate the activation of motor programmes, the movements themselves - in particular rapid series of keystrokes - should be automatised to such a level that expressive elements concerning subjective timing and dynamic phrasing are the only details of interest (Chaffin & Imreh 2002). This can be seen in relation to the need for spare mental capacity for creative spontaneity, as was introduced in the first chapter.

A number of complications arise when studying human motor control, such as the *degrees of freedom problem*, the *sequencing and timing problem*, the *perceptual-motor integration problem*, and the *motor skill acquisition problem* (Rosenbaum 2010). The degrees of freedom problem points to the infinite number of ways most physical tasks can be performed when few or no instructions on how to fulfill the task are given in advance. The problems are usually solved implicitly in the most efficient and direct way we can imagine, leading to the most practical result and final posture (ibid.). How does this relate to music? Revisiting the practise log of Gabriela Imreh, we know that her first 6 sessions was spent on deciding on which fingerings would provide her with the most control based on how she anticipated the music would be performed at top speed (Chaffin & Imreh 1997). Once a functioning fingering is decided, it is crucial not to change it unless it turns out not to be as practical as first assumed. Changes made after practise has commenced introduces interference that can potentially harm the outcome, as this may introduce noise in the construction of a reliable motor memory. Relating to the second problem introduced by Rosenbaum, namely that of sequencing and timing, consistency during the rehearsal stage helps avoding so-called action slips, also in suppor of the fact that professional musicians use performance cues to ensure there are no action slips occuring during the transition from one musical section to another. The timing, as well as the perceptual-motor integration problem, is complicated to address without recognising how people use feedback to control and correct movements. Playing the piano is an example of a closed-loop negative feedback process, meaning that information is provided both visually and auditory and thus enters the closed loop so that errors can be corrected, or negated even before any movement is made (Rosenbaum 2010). This is illustrated by how pianists in a rehearsal setting depend to a certain degree on visually locating the keys, and physically interacting with them by placing the hands in appropriate starting positions, before the playing itself provides auditory feedback which the performer can then compare with the information provided in the score. The fourth problem, regarding skill acquisition, has to some extent been dealt with previously in the chapter about practising techniques. The essence of skill acquisition is learning by doing, focussing on what needs to be improved, and devoting the right amount of time into achieving the intended improvements (ibid.). Moreover, with regards to the briefly mentioned context-dependent learning, Rosenbaum refers to specificity of practice. Transferred to music, specificity of practice relates to how a moderately difficult piece on a piano is very hard to transpose to another key. This naturally has to do with how the black and white keys on the keyboard are not equally spaced nor placed.

Even though muscle physiology is an integral part of a complete understanding of motor control, this chapter will focus on the structure of motor memory. Therefore, as in the previous chapter, theories will be explained from a psychological point of view. The theories will in turn deal with how motor memories consolidate in long-term memory and how they are recalled and activated. «As with all skilled human motor activities, effective planning, movement preparation and practising are largely based on procedural knowledge» (Altenmüller & Schneider 2009:341). The level of unconsciousness in procedural memory makes it challenging to provide answers to the questions of how motor programmes are sequenced and activated. Nonetheless, Rosenbaum presents four historical solutions to the sequencing puzzle, or serial order problem as it was termed by Lashley (Lashley cited in Rosenbaum 2010). The theories attempt to describe activations of motor programs in terms of response chaining (James 1890); element-to-position associations; inter-element inhibition (Estes cited in Rosenbaum 2010); and a theory concerning hierarchies similar to the ones introduced in the previous chapters.

Sequencing and timing

Response chaining in its most elementary form suggests that «the stimulus produced by a movement triggers the next movement in the sequence» (Rosenbaum 2010:94). In accordance with the previously mentioned theories of how networks solidify by mere repetition, James argued that with practice the connections between stimuli and response were strengthened, resulting in quicker and smoother movement sequences (loc. cit.). The theory has been refuted based on a number of issues, mainly to do with timing, the multiple possible outcomes of a single stimuli, and the fact that movements can still be produced in the absence of feedback (ibid.). Also, chaining theories fail to account for rule-governed behaviour. Our ability to generalise information into rules and then to adapt responses to acquired schema knowledge is beyond the capacity of response chaining theory, as it requires unique strings for every event. Even if the response chaining theory has been disproven and today may seem slightly unsophisticated, it pioneered a lot of research and in some ways still provide a starting point for understanding motor memory.

Another theory trying do describe the sequencing problem states that chunks of information can be associated with serial positions, thus making it easier to deal with the timing problem since each chunk of information can be associated with a designated time signature. Evidence for the element-to-position association theory has been found in studies of memory for word lists, where subjects occasionally failed to recall the correct word from the list and instead recalled a word with the same position in another list (Fuchs & Melton cited in Rosenbaum 2010:97). This theory also fails to accurately describe how rule-governed behaviour is possible, yet poses another useful step toward an understanding of the theories concerning motor control.

The third theory that will be explained is an intriguing version of the response chaining theory, stating that «sequencing is represented solely in terms of connections between the elements of the sequence itself» (Estes cited in Rosenbaum 2010:98). Whereas response chaining only involves an excitatory link between elements, the inter-element inhibition, as the name clearly indicates, also involve an inhibitory link. According to this theory the elements of a sequence are connected from beginning to end; with the elements in the beginning of the sequence being chained with inhibitory links to all following elements. As soon as one element has been executed, it no longer inhibits the following elements, thus initiating a domino effect. Again, the theory provides useful insight into how trained motor sequences may be executed, yet inter-element inhibition in its current fashion also fails to include and explain rule-governed behaviour.

According to Rosenbaum, a hierarchical model can incorporate rules and outperforms the previous models «in the context of the sequencing and timing problem» (Rosenbaum 2010:99). Evidence supporting the theory of hierarchies suggests that we rely on chunking abilities and organise information in schemata, as mentioned in the previous chapter. Once the information has successfully been incorporated in a schema, it is also available for recall in the form of chunks, or sequences. Further support for this claim is provided by how we control body movements not by triggering muscle activity but by imagining a goal and using well known and well trained movements to complete the goal. Pursuing this angle, then, explaining how a piece of music can be memorised as series of smaller chains that constitute pieces of a whole in a hierarchical fashion aligns with how the formal structure of the piece of music adheres to psychologically established theories concerning long-term memory and how only a limited amount of chunks can be brought into conscious awareness in our short-term memory at a time.

A fundamental element of keyboard playing is the way the keystroke is executed by the fingers, and the way the tone is manipulated by factors such as the pedals. Issues regarding the use of curved vs. straight fingers, the use of fingers vs. arms, leap trajectories between keys, and playing of repeated tones have been addressed by pianists and researchers over the years with mixed results. Parncutt and Troup recently reviewed the literature, and found that «scienfitic writers tend to focus on simple hypotheses and assumptions that are easy to demonstrate and explain but are of limited interest to musicians» (Parncutt & Troup 2002:285), while «artistic writers - often great pianists and piano teachers - have tended to fashion complex pseudo-scientific theories post hoc to match their beliefs, so that such theories can be controversial and unreliable» (loc. cit.).

It is worth considering that playing an instrument is not always a natural and ergonomic exercise. Playing the piano sometimes involve straining movements and awkward positioning of the hands, and efforts should be made in order to attain a relaxed approach to the instrument. According to Riisnæs, playing should «feel nice and comfortable», a feat that is best achieved when learning how to release tension in the muscle groups of the hand, arms, and upper body in general (Riisnæs 2013). These points will be looked at briefly, however, in the following part the neuronal basis for motor specialisation will be investigated.

4. 2 Plasticity

Our motor cortices and somatosensory cortices are developed in such a fashion that from our very first motoric actions, the brain is subject to fine-tuning. We learn how to crawl, and then to rise up and walk. We learn how to hold on to what we want in our hands, how to manipulate it and interact with it, and eventually also how to throw the item away when we don't want it anymore. This requires a constant need for balance and coordination, involving the use of a wide range of supporting muscle groups to which the small child is completely oblivious. Nevertheless, the child will continue to develop plenty of skills regardless of its lack of physiological and psychological comprehension. Say the child gets its hands or feet on a ball, or an instrument. Any interaction with the ball or instrument is likely to produce some kind of result. Whether it is by banging the hands on the keys of a piano, thus creating sounds of clustered tones, or kicking a ball more so it rolls or flies away in some random direction. Again, through trial and error one is able to learn to control and fine-tune the actions that in time will lead to a desired result, as a consequence of direct feedback. After the initial banging of the keys, a creative mind may start alternating the use of the hands, and with time maybe even change from using the fist to the use of each individual finger. Again, through several trials, a system may emerge in the child's mind and create intriguing results such as small melodies, or at least some rhytmical patterns. At this point, the motor cortex and the somatosensory cortex will have been stimulated to such an extent that they are predisposed to plasticity. The networks of neurons involved in the production of movements experience a series of activations, and in this process myelination takes place in the neural connections between them, strengthening them and making rapid communication available.

Plasticity is the result of anatomic changes in the brain after numerous activations of a neural network. Although the human brain is more susceptible to change at younger ages, as demonstrated by research on pianists and violinists, changes can also be traced in adults (Bengtsson, Nagy, Skare, Forsman, Forssberg, & Ullén 2005; Münte, Altenmüller, & Jäncke 2002). There are mainly two directions of skill acquisition through plasticity; structural reorganisation, and structural adaptation, and it would seem age of onset is the premium predictor of which (Bengtsson et al. 2005). At younger ages the brain is still adapting to new environments, new interactions, and novel situations, creating habits along the way. This results in structural adaptation; as we are getting accustomed to the different settings, the networks strengthen. Furthermore, this is in line with the *Hebbian learning theory* mentioned in chapter 1. Once we come of age these networks can still adapt further to some extent, yet after years of creating a neuronal foundation for behaviour new patterns can be formed to be associated with existing networks (ibid.). This is not the same as creating completely novel networks, as much as it is a rewiring process, or, a structural reorganisation. In particular in cases where people have suffered a stroke, the changes taking place for regaining control of skills is a rewiring process in effect. The brain rewires pathways that are broken, either by rebuilding them or finding a way through a network by bypassing the damaged area. Regarding pianists, changes have been identified in motor cortical areas, somatosensory cortex, and auditory cortices, suggesting that achieved expertise is the result of training, not innate abilities (Bengtsson et al. 2005; Han, Yang, Lv, Zhu, He, Tang, Gong, Luo, Zang, & Dong 2008). Even though the nature vs. nurture debate contains arguments pointing in both directions there is plenty of evidence supporting the fact that training leads to expertise, and few examples of untrained experts.

Studies have shown that the ‘omega shape’ in the lateral prefrontal sulcus corresponds to enlarged hand control areas, based on the findings in pianists and violinists (Amunts, Schlaug, Jäncke, Steinmetz, Schleicher, Dabringhaus, & Zilles 1997). This is a direct response to extended amounts of training, yet evidence of a potential transfer of abilities is scarce, altough it has been found that pianists’ control over execution of precise timed movement sequences corresponds to their skills at another type of keyboard, similar to the one on computers. Furthermore, there are differences between the brains of a violinist and a pianist, and between pianists and nonmusicians, suggesting that pianists develop enlarged motor cortical representations of both hands (Amunts et al. 1997), compared to results relating only to the left hand of a violinist (Elbert, Pantev, Wienbruch, Rockstroh, & Taub 1995). These results may be expected due to the pianist’s bimanual dexterity on the instrument.

4. 3 Mental simulation

Research has shown how thinking of music can lead to activation of auditory and motor cortical areas (Palmer 2006). This seems to support the suggestions to implement conscious and meticulous mental practise into the act of memorising. Another intriguing finding is how musicians are able to learn by studying other performers through a mental simulation activity (Gallese & Sinigaglia 2011). The learning by doing proposition can therefore be expanded to also include learning by ‘almost doing’, provided a basic visuo-motor coordination is established.

> «Held illustrated a classic experiment that made this point [...]. Two kittens were reared in darkness except when they got to spend a few minutes each day in a special environment where one kitten could walk freely and the other kitten got to ride a small gondola yoked to the kitten that was free to roam. Both kittens received essentially the same visual input, but only the kitten that could walk could actively control the visual input being received. The question was whether the kittens would exhibit the same level of visuo-motor coordination when they were later tested outside the experimental chamber. When the kittens were later tested, only the kitten that could move freely behaved normally. The other kitten proved to be functionally blind. This was shown by holding each kitten in the air and slowly lowering each one, face down, toward a horizontal surface. Only the freely moving kitten exhibited the normal visual “placing” reaction that kittes and cats show when they are lowered to flat suraces. The implication is that the development of normal visuo-motor coordination depended on the opportunity to correlate visual input with actively generated motor commands. When the passive cat moved its legs in the gondola, no consistent changes in visual input followed; its movements and visual perceptions were uncorrelated» (Held in Rosenbaum 2010:34).

This example shows not only how much fun researchers are having with cats in gondolas, but also how the passive cat was unable to connect the dots between visual input and how to manipulate it. However, if a visuo-motor coordination has already been established, there is evidence supporting the efficiency of both playing the piano without auditory feedback (Baumann et al. 2005), and listening without playing (Lahav, Boulanger, Schlaug, & Saltzmann 2005). In the following, mental simulation will be seen in relation to a most peculiar finding of mental mirroring activity.

During a single-cell recording of the brain of a macaque monkey, a researcher incidentally came across some hitherto unknown neuronal activity. While the researcher was reaching for his food during a break, the monkey brain showed signs of activity indicating that it was mentally simulating the action of reaching out for food. This mental mirroring activity is now considered a fundamental part of how humans too learn through embodiment.

> «The Mirror Mechanism, given the present state of knowledge, maps the sensory representation of the action, emotion or sensation of another onto the perceiver's own motor, viscero-motor or somatosensory representation of that action, emotion or sensation. This mapping enables one to perceive the action, emotion or sensation of another as if s/he were performing that action or experiencing that emotion or sensation her/himself» (Gallese & Sinigaglia: 2011).

Mental practice, as was suggested in the first chapter, can be seen as a form of mental simulation, in that listening (and imagination) can function as a replacement for observation. In one study participants with no musical background were taught to play an unfamiliar musical piece by ear in one piano lesson, and after one week of lab controlled listening they were asked to replay the piece (Lahav, Katz, Chess, & Saltzmann 2013). Of the three listening groups, the one who did not listen to the learnt piece during the weeek in th lab performed significantly worse than participants from the two groups that did listen to the learnt piece for 20 minutes. Furthermore, one group performed a distraction task while listening, and the other group was only passively listening to the music - the study fails to report whether participants were allowed to or refused to employ any cognitive strategies when listening, therefore the passive listening group may have been an actively listening passive group. Nonetheless, the passive listening group outperformed the other groups, suggesting that listening alone can improve the motor memory for a piece. Even so, the improvement would still not match physically practising the motoric actions, yet it provides clear evidence for the usefulness of mental practise, and mental simulation through listening. «Learning and memory are thus strongly shaped by the inseparable relationship between perception and action, allowing us, on demand, to quickly prime the action given its audible output» (Lahav et al. 2013:315).

4. 4 Motor memory

Remembering and retrieving the entire piece of music internally does not alone stand to explain how the music is played on a piano. Neither is the ability to accurately reproduce the written notes, or even the ability to sing each note correctly. Despite the fact that this demonstrates a highly functional memory of the contents of the piece, it does not account for the movements needed in order to produce the music as a series of keystrokes. At some point, a connection between the auditory information and the correlated keypresses must be established. While mental rehearsal of the notes or the music can be done based on listening to recordings of the piece and analysing the score, physical movement is still needed in order to create sound on an acoustic instrument. Before playing it is helpful to have determined the key signature, in order to place the hands in the right place when sitting in front of the keyboard. Knowing the first notes allows the pianist to carefully plan which fingers to use when translating them from either visual cues/visual imagery (the score or memorised score) or auditory cues/auditory imagery (the music or memorised sounds) to movements used to manipulate the instrument.

Due to practise and experience, activity in the secondary motor cortex is triggered in instrumentalists when hearing or imagining sounds on an instrument they master. Thus, mental practise will already have contributed to the actions about to take place even before playing a piece for the first time. Even more so if the piece has been demonstrated by a teacher. In the initial practise session, from the first keystroke onwards, the pianist’s memory load is continously put to the test. Simultaneously, neural firing of networks controlling finger movements, planning of finger movements, associative memories for similar motor actions, not to mention activity involving associations in every other direction available (emotions, episodic memories, etc.), leads to strengthening of these networks. Repetition of the same task leads to consolidation of the networks involved both in the movements, and the auditory cortices dealing with the interpretation of the accompanying sounds. Comparison between the intended sounds and the desired sounds, if they are not already in sync, provides direct feedback to the performer that something must change. Further practise on the same material accordingly leads to an establishment of a long term memory, for example taking the shape of a schema. This schema can develop on an existing one, thus creating a detailed attribution to the pianist's current long term memory somewhere down the hierarchy of the schema at hand. A new schema may also emerge, if the music shares few or none essential characteristics with previous musical knowledge. When the motor programmes needed for executing the particular music that has been practised are properly consolidated, they are on their way to entering the part of long term memory containing procedural memory. The descriptions needed for performing these actions are no longer necessary at this point, and only the fine-tuning is left. Thus, the pianist's interpretation regarding accuracy in timing, articulation, and phrasing must still be practised, so as to add these details to the schema already generated.

In turn, when several parts of the music have been meticulously practised, the schemata for each and every part represent a reduction of a large number of details down to large chunks of information. As the memory for this chunk of music is now spread across numerous associations, including auditory and visuomotor memories, the memory load has been reduced and permits the performer to monitor an increasing amount of new information, for instance regarding structural form. In combination with a proper analysis of the tonal material, not only would the information be intelligible, it would be less ambiguous. As illustrated above, the numerous variations in Grieg's Ballade contain tonal material chiefly in the key of G minor (and its parallel key Bb major). Identifying similarities both within parts and between parts can be fruitful in order to convey an ingenious/insightful interpretation of the whole piece. On one hand, the lack of variation in the core material has its advantage in that every part relates satisfactorily to the other parts, however its main disadvantage is precisely the same. In this case, procedural memory and mindful placing of performance cues may come to good use to avert an unwanted wrong progression from one variation to another. So what happens if it all goes awry? First of all, there is a difference between forgetting something, and not having memorised it. If a piece of information is properly encoded and retained, there should also numerous associative cues able to retrieve it.

If the wrong keys are struck during a performance, it is important that the pianist has other strategies to rely on than motor memory alone. In this situation, the auditory input does not match up with what is expected, and the kinaesthetic feedback is incorrect - felt by the fingers due to the asymmetry of the black and white keys on the keyboard. In accordance with the aforementioned model, that still leaves two backup solutions. Visualising the correct keys to play, aided by a theoretical and/or analytical overview of the piece enables the pianist to continue by playing the right keys.

5.
A Multimodal Approach

«There is no inherent meaning in information. It is what we do with that information that matters» (Lotto 2009)

Preface

Does the act of memorising music involve an unnecessary amount of work? Naturally, practising for perfection leads to some amount of tedious exercises, whatever the music, and whatever the goal may be. As the hours of practise sum up, however, much of the musical information will consolidate on its own, based on exposure, based on implicit learning, and based on the previously mentioned basic knowledge of piano literature that most pianists acquire through their formative years. Should all pianists consider learning memorisation techniques? Does it remove the pleasure of playing music to have the piece undergo such an amount of analysis? In accordance with some music analysts opinions, a thorough analysis may unveil details that might otherwise remain hidden within the piece (Cook 1987), and may thus provide the pianist with the ability to emphasise particular elements s/he may have remained oblivious to. In the case of performers who are untrained in reading music, auditory analysis can still bring a lot to the table. In the opposite case, pianists who are more skilled in reading music than playing by ear may benefit from the visual input they receive through repeated reading of the score. In both cases an effort should be put into thoughts of how to shape the music, as this spatial exercise provides a sort of abstract overview of the music regardless of its particular sound. Many pianists, myself included, often speak of how the music 'takes turns here and there', how it 'goes up, and then down, and then after a short break shifts to this or that' etc. These are already metaphors relating to musical contour, and as such they are forcing a sort of visual association onto the music.

When practising pivotal points of a piece, extramusical movements and activities have been found helpful in aiding the pianist to express his/her intentions when playing. On numerous recordings, powerful breathing can be heard in certain - often momentous - places throughout a piece, as if the musician wants to express the very act of not playing, or, to demonstrate the gravity of the specific situation s/he is in at that particular time and place. This heavy breathing can be traced both in circumstances where the musician feels the loudness capacity of the instrument has reached its full potential, and in phrases where s/he wants to make a point out of stretching the musical time, as in a *molto ritardando* or similar. This way of symbolising both to oneself and to an audience where the musician places particular emphasis is obviously more common in wind instruments and among singers, where lung capacity has a natural influence on phrasing and playing technique. Nevertheless, active use of the breathing, even among instrumentalists relying mainly on manual dexterity, may invigorate both the music and the musician. Furthermore, the breath itself may become an incorporated part of the piece for the performer, thus adding yet another element for the memory to accomodate.

Another element that can be heard among some professional solo pianists is a type of singing, and not really one that does the music any good. Glenn Gould, for instance, was renown for his keen sense of detail related to his personal practice performance, yet in his famous recordings he can be heard singing and humming along with his own playing. Possible explanations for this phenomenon are provided both by himself and others:

> «The three-year-old Glenn Gould, with his then small hands and his big musical ideas, was perhaps compelled, while experimenting at the piano keyboard, to sing or hum notes which he could not reach, or which he could not combine, because of his undeveloped hands. [...] Gould has given two different explanations of his own. One is that his singing might have been an unconscious attempt to compensate for the mechanical deficiencies of the piano he was playing, an attempt to produce the kind of mechanical articulation he hears in his imagination and wants to hear from the piano, but which the piano cannot produce. The other explanation is equally dependent upon his mental images: "I think there's a wishful thinking aspect … THAT is the way I would like my phrases to be made, and I'm never able to do that at the keyboard"» (Payzant 1992:81).

It is possible that Gould's automatic singing reflects a certain wish for interpretive nuances that are impossible to achieve on the piano, as there are many hinders in the extensively mechanic instrument. It is also very much likely that due to his mental practising technique of memorising the score in its entirety away from the piano, his level of processing has been at the deepest levels, and he may have subvocalised single-voiced structures and melodies from the music all along, only to become sound once he starts playing.

On the origins of memorised performance

Seeing as how memorised playing became widespread through the Romantic piano virtuosos, it seems natural to try to explain how this may have come about in the first place. According to historical anecdotes, pianists like Chopin regularly incorporated more improvisation in his public performances than his peers. As the aesthetics of the Romantic period was predominantly concentrated around tonal music, and technical expertise was highly appraised, Chopin's artistry, use of fast tempi, arpeggios, chords and mix of diatonic and chromatic movements made him widely renown as a *genius* of his time. The elements became both part of his compositional palette as well as his playing style, and also reflect some of the aesthetic ideals of the still developing era, especially on solo instruments such as the violin and the pianoforte. An interesting conjunction of a number of events made the latter became the most sought after instrument in first decades of the 19th century. Even though the pianoforte had existed for approximately a full century and was highly popularised by the time of Mozart, Haydn and Beethoven, it was relatively expensive and had an inappreciable dynamic range, leading to an inevitably innovative generation of pianos being constructed around the turn of the century. As a result of the industrial revolution in the late 18th century, machines made construction much easier, and innovations were made both in the production of strings and the iron cast frames. Among the benefits of the innovations were a larger range of dynamics, and an expansion from the pianoforte's five octaves, providing pianists and composers with many new expressive possibilities on the instrument. Expressivity, another key ingredient in the music of the 19th century, was seen as the physical manifestation of genius. With production rate going up, the prices went down, allowing a whole new group of music aficionados to own their own instrument.

Impressive as they may sound, arpeggios reaching across several octaves on the piano keyboard ultimately require the ability to recognise and play it in any one octave, as the keys within all octaves are identical. Thus, triggering a motor programme for playing an arpeggio stretching over several octaves is much the same as playing the same arpeggio in only one octave - the difference being the difficulty in placing the hand in the subsequent octave within an acceptable amount of time. Once an appropriate opportunity to add an arpeggio emerges - for example replacing a half note chord - a fitting rhytmical pattern is chosen, e.g. sixteenth notes, and the notes of the chords can be played in succession, as in what is known as a broken chord. Furthermore, extending the arpeggio across octaves as described above presents a relatively moderate problem for an adept pianist, owing to the fact that this very issue (breaking chords) normally has been dealt with during several rehearsal sessions. One approach to learning classical pieces is to play variations of the presented material, so as to familiarise the fingers with their positioning regardless of preceding or succeeding notes. Similarly, chords are practised in every possible position, and scales are practised both in ascending and descending patterns. Varied practice is suggested to strengthen the motor programmes that will later constitute the basis of a musical performance

(Jørgensen & Hallam 2009). Since the key signature determines which notes are appropriate, triggering any of the motor programmes associated with either a scale figure, a chord structure, or an arpeggio is likely to be a straightforward exercise.

Extra-musical experiences

Sounds in the environment can easily be perceived as musical features. There is, for example, a reason why it is called whale and bird song. There are recognisable patterns in their calling, both rhytmic and melodic. Even if the exact pitch classes of such 'singing' would fall outside of the Western equal temperament, it is still hard to argue against the periodicities and the resemblance of musical contour. A reason why these sounds may come across as musical is that even though the details fall outside of typical human musical culture, the overall features fit inside our schematic model for music on a general basis. Another example is the rhythmic patterns emerging when the wheels on the train are running across the rails. The thumping noises arising when the train is keeping a steady pace makes a good physical example of a strict rhythmic pattern, due to the identical spacing of the wheels on the bogies underneath the wagons. I mention this because repetitions and patterns in one domain are easily transferred crossmodally to domains within which we have considerable experience. Relating to music specifically, musically trained and untrained individuals differ in their aural acuity. The ability to quickly distinguish between a major and minor chord, for example, or discern the particular differences between a 2/4 march beat, 3/4 waltz beat, a 4/4 rock beat or a 7/8 fusion beat. Furthermore, musicians identify scales and modes, genres, instruments, and on a detailed level hear the difference between different composers and even different musicians. Developing these abilities is a tedious task, but they are in fact merely a mix of multiple elementary musical skills. Furthermore, learning the basic components of a scale and the tonal combinations that constitute minor and major chords is expected from one who plays a tonal instrument, and even more so if the instrument is a typical polyphonic instrument. A pianist would be expected to be better at recognising chord progressions than a saxophonist, who would again be expected to have a better ear for microtonal variations than a drummer. On the other hand, drummers develop rhythmical skills rarely called for among most tonal instrumentalists. Thus, whilst an experienced drummer would pick up the microscopic difference between a 32nd triplet note and a double-dotted sixteenth note, the saxophonist would be more concerned with microtonal variations such as quarter tones, due to their need to intonate while playing.

Mnemonics revisited

In addition to the mnemonic devices mentioned earlier, other techniques use similar approaches. Pegging and linking are two other methods that can be used for memorising large quantities of information (Higbee 2001). Pegging involves a number/letter code in which a number is associated with a phonetic replacement, so that a combination of numbers will be associated with a combination of the phonetic replacements (D'Arcy 2013). For example, if associating the number 1 with a d and the number 7 with a k, the number 17 would be replaced by dk, which when pronounced could sound like 'duck', and can thus be associated with the animal (ibid.). Note how this is a one-syllable word, with a simple association which can easily be visualised. Replacing the number 7 with 8, whose phonetic replacement is a v, the number 18 would be replaced with dv, or dove. Thus, 17 and 18 have been replaced by 'duck' and 'dove'. With this system, D'Arcy continues to explain how larger strings of numbers can be visualised as combinations of the imagined 'pegs' (ibid.).

The most interesting point about introducing mnemonics in this thesis is that even though they may at first glance seem completely unrelated to music, their processing methodology may not be. Notice how all mnemonic strategies employ a systematic approach to understanding conceptual categories, and constructing associations between formerly unrelated entities, or at least entities that may not come across as related until they are pointed out. Once a mnemonic device is mastered, memorising large quantities of information becomes a task of grouping, not single entity processing, very much in line with how pianists do not memorise musical pieces on a note to note basis, but rather on a phrase level, before an even larger structural level. Retrieval of information learnt with mnemonic strategies are based on definite cues, decided on beforehand. Again, this is mirrored in many classical pianists, where performance cues can be based on literally anything they may decide to focus on as a trigger. In addition, many mnemonic strategies have an ability to incorporate chaining devices in order to both memorise and retrieve material in the correct order. Once again, in line with the long-term working memory performance model illustrated previously, there seems to be many similarities between memorising information with the aid of mnemonics, and memorising music.

6.
Concluding remarks

The sizable body of literature in the three main topics of this thesis provides a number of different ways to approach the core question of how pianists memorise music. The focus has been on illuminating the relations between how music-theoretical issues concerning musical structure and analysis aid instrumental and mental practising in preparations for a memorised solo performance. Furthermore, theories on memory have been introduced on the basis of a general psychological framework leading up to an understanding of musical memory in particular. Theories of musical memory have been compared to theories on practising techniques, bearing in mind how the many-faceted structures of music relate to the construction of comprehensible associations that lead to a strong, functional memory. Lastly, theories on human motor control, herein motor memory and mental simulation, have been compared to evidence from brain plasticity. This has again been related to the formation of a multi-modal musical memory, consisting of implicit, procedural motor programmes, music-theoretical frameworks that allow a pianist to monitor performance in real-time, and finally how this complete package enables pianists to perform remarkably long musical sequences without the aid of a musical score.

Performing music from memory requires more mental activity than meets the eye. Focussed practise establishes technical proficiency on the instrument and enables students to structure schematic knowledge of music internally. With prolific schematic representations of music, the cognitive capabilities for storing musical information increase. Over time, associations between the visual representations of written music, inner auditory representations of sound, and motor sequences needed to perform solidify, and musicians are thus equipped with an arsenal of potential triggers for reproducing visually, aurally, or internally represented sound. Cognitive processes involved in monitoring music performance depend on visual, aural, and kinaesthetic feedback in order to ensure the performance unfolds in accordance with the mental representations of the music. With experience the mental representations are able to incorporate increasingly more details, and the cognitive load associated with performing these details is reduced when the motor programmes are properly consolidated, and the retrieval schemata employed for triggering the motor programmes have been sufficiently practised.

Analysing novel musical information helps to identify patterns in the music that may be concealed within the musical structures, and may also give hints to where familiar performance techniques can come in handy when rehearsing. Furthermore, an analytic approach to visual representations of the music, i.e. the notes or contours, adds information to the overall mental schema relating to the music. This information provides a safety net during performance in addition to the automatised motor programmes and the mental representation of the aural material.

Learning how ones memory is structured and how our perceptual abilities function can lead to a more efficient approach to how music is studied and practised. This includes limiting practising time, limiting amount of novel information introduced per practise session, understanding how information is learnt through conscious repetition in order to form coherent elements or chunks, and learning how these chunks can be systematically retained in long-term memory. When practise time is limited, making the most of the time available is paramount.

Consciously monitoring the process of constructing new motor memories, with focus on how a minimal amount of muscular activity can produce the optimal output leads to a relaxed approach to musical performance. Too much tensioning of the muscles in the hand and arm prevents fluent and controlled performance, and will also lead to undesireable physiological issues. I mention this because of two reasons. First, being in pain when playing may naturally impede performance, and it will also disturb the memory by occupying much mental workspace. Second, a physically strained performance is rarely a good performance, as expressivity will be severely handicapped. Remembering from earlier, expressive cues are occasionally important performance cues, and their absence can jeopardise certain aspects of the performance. Motor memories consist of practised motor programmes, carefully prepared sequences of movement which produce the desired end result by manipulating the surroundings in the most effective way available. Relating to piano playing, meaningful memorising of motor movements is based on musical knowledge concerning not only structure and form, tonality, harmony and rhythm. It also depends on extensive knowledge of how the instrument works, and on how the fingers interact with and control the keys.

On the basis of this thesis, further research is suggested to look into melodic memory in pianists through investigating pianists' metaphorical terminology in relation to musical form and structure, to look for possible relations to existing evidence supporting contour models. Knowing whether pianists are talking about 'up' as a combination of both higher up in the register, i.e. to the right on the piano keyboard, and higher up on the staff notation, in *addition* to internal visualisations either in support of existing contour models or other graphical means, may provide useful insights for pedagogues to consider when teaching music *without* musical notation.

As a proposed answer to one of the initial questions regarding whether the mind is in control of the automatised motoric actions in pieces that are memorised; yes, and no. Yes, our procedural memory controls the execution of motor programmes, with potential regulations offered by feedback through the auditory and visual senses. And no, because our implicit memories are largely unavailable to us, and as is illustrated by the aforementioned centipede's dilemma; thinking of the physical manifestation of performance may inhibit the performance altogether.

We have no access to our physical world other than through our senses. All of our sensory modalities receive input through organs anchored to our heads, except for the sense of touch which receives input from everywhere on our bodies. The hands are our only organ through which we can reach out and interact with our physical world.

Our fingers play the instrument,
our brain performs the music.

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Interview

Riisnæs, A. E., Assistant Professor, University of Oslo, Department of Musicology, 12.04.2013