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System for determining stages of development using music

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Abstract

Music is a domain with an infinite number of variables, ranging from instruments that express a variety of moods to tunes ingrained in each culture to rhythms that immediately induce dancing and a joyous disposition. Music signal processing is one of the most complex types of signal processing. Many signals are merged and received by a single sensor and can be deconstructed into diverse variables. By comprehending how humans can process music signals, we can make conclusions to implement in engineering fields.

The objective of this work is to comprehend how music is learned. We approach this issue by understanding how any domain knowledge is acquired. One of the most widely acknowledged models of reasoning is Piaget's four-stage hypothesis of cognitive development in children. However, even Piaget recognised that despite being influential, his hypothesis required expansion. This was one of Michael Commons' assumptions when he discovered Piaget's theory. Michael Commons established a mathematical validity based on Piaget's formulations that defined stages for the development of reasoning in any subject. The Model of Hierarchical Complexity (MHC) provides a framework for assessing degrees of reasoning in any subject area and across cultures. The scoring is not based on the topic or participant inputs, but the mathematical difficulty of the hierarchical structure of information.

After presenting a general music description and the cognitive developmental theory, we realise that music variables could be structured hierarchically according to the MHC's principles. We propose separating musical variables into five subdomains to achieve this. From these five subdomains, we suggest the integration of some defined variables into three orders of hierarchical complexity (OHC), which are the stage definitions of the hierarchical structure variables. Learning through a structured hierarchical complexity approach has proven successful and more efficient than standard practices[1]. It was developed an instrument for assessing in a 163 population if learning music through the premises of the Model of Hierarchical Complexity is more efficient than a non-structured approach. The elaboration of this test allows a first step in collecting pieces of evidence that music variables, such as tempo or measures, are hierarchically structured and are non-cultural dependent.

The 30-minute test introduced learning on the subjects, resulting in a 60% improvement in stage performance in both groups. The structured approach, the one following the premises of the MHC, made the subjects answer the final exercises in half the time as the other group, allowing to conclude that it was the most efficient approach. In addition to validating the hierarchical structure of one of music's subdomains, the data allowed for a deeper understanding of the structurality of the stages proposed and the good development of the exercises.

Keywords: Music, Hierarchical Complexity, Teaching strategies, Subject testing

Resumo

A música é um domínio com um inumeras variáveis, desde instrumentos que expressam emoções, a melodias enraizadas em cada cultura ou até ritmos que nos levam imediatamente a dançar. O processamento de sinais musicais é extremamente complexo, sendo que através de um só sensor é captado um sinal onde diversos estão combinados. Através da compreensão de como os humanos fazem este processamento poderemos tirar conclusões para implementar no mundo da engenharia.

O objectivo deste trabalhp é compreender como se aprende música. Esta questão é abordade compreendendo como é adquirido conhecimento de qualquer domínio. Um dos modelos de cognição mais amplamente reconhecidos é a teoria de Piaget, ques estabelece quatro patamares de desenvolvimento cognitivo nas crianças. No entanto, Piaget reconheceu que a sua hipótese, apesar de ser determinante, exigia desenvolvimentos. Este foi um dos objectivos de Michael Commons quando descobriu a teoria de Piaget. Michael Commons estabeleceu uma validade matemática baseada nas formulações de Piaget que definiram patamares para o desenvolvimento do raciocínio em qualquer assunto. O Modelo de Complexidade Hierárquica (MHC) fornece um base para avaliar graus de cognição em qualquer área e em todas as culturas. A avaliação não se baseia no assunto , mas na dificuldade matemática da estrutura hierárquica da informação.

Após apresentar uma descrição do domínio musical e a teoria do desenvolvimento cognitivo, apercebemo-nos de que as variáveis musicais podem ser estruturadas hierarquicamente de acordo com o MHC. Propomos a separação das variáveis musicais em cinco subdomínios para o conseguir. A partir destes cinco subdomínios, sugerimos a integração de algumas variáveis definidas em três ordens de complexidade hierárquica (OHC), que são as definições dos patamares das variáveis numa estrutura hierárquica. A aprendizagem através de uma abordagem de complexidade hierárquica estruturada provou ser bem sucedida e mais eficiente do que as práticas padrão [1]. Desenvolvemos um instrumento para avaliar, numa população de 163 pessoas, se a aprendizagem de música através das premissas do Modelo de Complexidade Hierárquica é mais eficiente do que uma abordagem não-estruturada. Este foi um primeiro passo na validação de que as variáveis musicais, tais como tempo ou compassos, são hierarquicamente estruturadas e aculturais.

O teste de 30 minutos introduziu a aprendizagem sobre os temas, resultando numa melhoria de 60% no desempenho médio dos sujeitos. Além disso, o grupo de sujeitos que fez o teste estruturado, criado apartir do MHC permitiu que estes executassem a última parte de perguntas em metade do tempo dos sujeitos do outro gupo, permitindo concluir que aprender pelas premissas do MHC é um método mais eficiente do que o standard. Para além de validar a estrutura hierárquica de um dos subdomínios da música, os dados permitiram uma compreensão mais profunda da estrutura dos patamares propostos e a confirmação do bom desenvolvimento dos exercícios.

Keywords: Música, Complexidade Hierárquica, Estratégias de Ensino, Teste em sujeitos

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A toda a minha família e amigos que me acompanham e fazem que eu seja quem sou.
Por fim, a Deus.
Obrigado

Hugo Mesquita Vasconcelos

*"The music is all around us,
all you have to do is listen."*

August Rush

Contents

List of Figures

Abbreviations

MHC	Model of Hierarchical Complexity
OHC	Order of Hierarchical Complexity
AI	Artificial Intelligence
ML	Machine Learning
mpeg	Moving Picture Experts Group
jpeg	Joint Photographic Experts Group
FFT	Fast Fourier transform
DSP	Digital Signal Processor
CD	Compact Disc
IQ	Intelligence Quotient

Chapter 1

Introduction

José Hugo Mesquita Vasconcelos developed this work presented throughout his dissertation with the supervision of Professor António Ramos Silva and co-supervison of Drª. Sofia Leite. This disseetation was written to obtain the Masters in Mechanical Engineering. A system to determine the cognitive stages using music is established and tested.

1.1 Framing

With today's rapidly evolving technologies, sensors have emerged as an integral aspect of modern life, especially in the fields of robotics or automotive. Sensors monitor the state of their immediate physical surroundings and relay that information in several ways. Energy in the form of motion or temperature is delivered to the system, and in turn, the sensors output signals. Processing these signals is a domain of vast importance in mechanical engineering that is in evolving [3].

When we learn, we are processing signals understood by our senses, which are our sensors and collecting data to be stored in our brains. The knowledge of the cognitive learning process allows a better understanding of how the teaching method should be done. Piaget brought an opposite idea in an IQ-dominated developmental psychology tradition that created a discriminatory framework where each person is placed on an unchangeable and predetermined scale of intellectual capability. In his eyes, each human mind is independent, curious and an active creator of its mental structures and is allowed to develop at a non-determined pace or time. While the individual nature of each subject to Piaget is central to the development of each state, his theory allows capturing the common qualities of thought and its development that occur regardless of the particular cultural and socioeconomic circumstances. "The developing mind was supposed to make its way ineluctably toward mature thought regardless of gender, cultural context, historical period, nutritional input, training, or even biological variations unless they proved to very extreme indeed."[4, 5]

From the idea of stages of developmental cognition in children, a vast range of theories was elaborated. The Model of Hierarchical Complexity (MHC) is a neo-Piagetian model as it utilises the idea of hierarchical stages but enriches it and develops further mathematical foundations to develop 16 stages of development for any domain to be used in any subject or domain.

Fundamentally the idea of hierarchical complexity is built upon the sense of vertical complexity as opposed to horizontal complexity. On vertical complexity, a more complex task is built by associating two or more lower stage tasks, while horizontal complexity is correlated to how complex a task is without deconstructing it in other smaller stage tasks.

1.2 Objectives

Learning more efficiently is a target to try to achieve constantly; therefore, knowing how the human mind captures and assimilates new knowledge is immensely needed. In the present work, we try to understand how the human brain learns music so that we can create a better approach to teaching music more efficiently.

After understanding how to teach music through the premises set above, it is proposed to elaborate a test where we asses if the method proposed is better than the traditional method. This test will be done on a population where half will have the traditional music learning approach and the other the newly proposed method.

1.3 Methodology

To understand how the music learning process happens, we first initiate our work by presenting a general definition of music. Explaining through the analysis of the sound waves into frequencies and pitch as well as rhythm or timbre. We introduce why and how music exists, and sounds are possibly pleasing. We present many music variables and the way our brain interacts with them.

Cognitive development theories are significant to people who teach as it enables them to understand how to reach better subject development. These theories have helped to construct the notion of learning as not something linear and depository but rather as an element that must be understood, leading to a comprehension of why each subject learns at their own rate.

Cognitive learning is an active learning approach that focuses on teaching how to maximise the brain's potential. The ability to deepen memory and retain knowledge is improved since it is simpler for you to link new information with previously held beliefs.

It is searched through cognitive development theories, the most appraised by the scientific field, to better comprehend how any domain is learned. From the music definitions and learning theory for any domain, we present a construction of said theory for the domain of music, elaborating a new approach to teaching music.

The method proposed brought the idea that music had five different subdomains. The test developed only tested the learning method on one of the subdomains due to restrictions on subject times test. In order to comprehend if the newly proposed method for teaching music had better results than a standard way, a test with two parts was developed. The elaboration of the structure of the test, followed by the creation of the exercises and the deployment of the system, was done.

1.4 Structure

This dissertation presents two submitted articles corresponding to the two different parts of the methodology submitted to the British Journal of Musical Education and presented in appendix A and appendix B. It is presented in chapter 2 a brief exposition on why the work was developed as a master thesis of Engineering as it relates deeply to a new approach in the domain of signal processing and Artificial intelligence.

The first article is the formulation of the method to be used on the test, while the second is the elaboration and results of the test. Starting with a detailed definition of music, followed by an explanation of how the MHC appears, why it is valid and its premises for the elaboration of the orders of hierarchical complexity (OHC). The first article was built as a solid basis for elaborating the three proposed OHCs. The MHC states that variables are capable of being structured hierarchically due to their complexity. The OHC are the explicit stacking of the variables. The first article sets the theoretical approach that music variables are also stackable through the presentation of three OHCs.

With the OHCs proposed, the elaboration of the test was simplified and set on a robust theoretical basis. It was necessary to perceive which OHC to use and how to formulate the questions. Develop the platform, check user usability and correctness of answers, collect subjects data, create first a local version of the test and eventually migrate it to an online website and eventually find the population to test upon. After it, the analysis of the results was done.

Final remarks are given where some details of the work developed are explained. These final mentions were not considered critical to the article's work as they did not correlate to essential developments to their premises.

Chapter 2

Signal Processing

In a world that is becoming ever more automated, it is through sensors that engineers can digitally visualise the changes happening physically. These sensors produce signals that can be read and analysed to understand what is happening. Simply from a thermometer that measures a room temperature, and therefore the heater should be turned on. To a more complex accelerometer that can sense when a machine is malfunctioning or even give an alert before it malfunction allowing for a preventive maintenance.

2.1 Definition

Signal processing involves the representation, modification, and manipulation of signals as well as the information they carry. For instance, we may wish to isolate specific or more signals that have been mixed by an operation, such as addition, multiplication, or convolution, or we might wish to improve a signal component or estimate a signal model's parameter. In communications systems, pre-processing, such as modulation, signal conditioning, and compression, are typically required before transmission through a communications channel. These are followed by post-processing at the receiver to recover a replica of the original signal [6].

Signal processing's illustrious past and promising future result from a powerful synergy between increasingly complex applications, fresh theoretical advancements, and constantly developing new hardware designs and platforms. Signal processing applications include leisure, communications, space exploration, medical, archaeology, and geophysics, to name just a few. In several systems, signal processing methods and hardware are prevalent, from highly complex military systems and industrial uses to inexpensive and mass-produced consumer devices. Although the fantastic performance of multimedia systems such as high-definition video, high-fidelity audio, and interactive games is commonly taken for granted, these systems have always relied significantly on cutting-edge signal processing. Advanced digital signal processors are the central component of all modern cell phones. MPEG audio and video and JPEG image data compression standards heavily rely on several signal processing principles and techniques. New solid-state memory and high-density data storage devices increasingly rely on signal processing to provide consistency and durability to otherwise fragile technology.

Prior to the 1960s, signal processing technologies were nearly completely analog and continuous-time. The rapid development of digital computers, microprocessors, and low-cost chips for analogue-to-digital (A/D) and digital-to-analog (D/A) conversion has resulted in a continuous and significant transition to digital technologies. Numerous significant theoretical advancements, such as the fast Fourier transform (FFT) algorithm, parametric signal modelling, multi-rate techniques, polyphase filter implementation, and new ways of representing signals, such as wavelet expansions, have supported these technological advancements. As an illustration of this trend, analogue radio communication systems are transforming into re-configurable "software radios" that are virtually solely implemented with digital processing.

Instead of functions of a continuous independent variable, discrete-time signal processing is based on the processing of integer-indexed numeric sequences. In digital signal processing (DSP), signals are a sequences of numbers with finite precision, and processing is carried out by a digital computation. The more inclusive phrase discrete-time signal processing encompasses digital signal processing as a specific case, as well as the possibility that sequences of samples (sampled data) could be treated with other discrete-time technologies. Since both discrete-time signal processing and digital signal processing are concerned with discrete signals, the distinction between the two terminologies is often of minor significance. This is especially true when employing high-precision calculation. Although there are numerous instances in which the signals to be processed are intrinsically discrete-time sequences, the vast majority of applications utilize discrete-time technologies to handle continuous-time data. Typically, a continuous-time signal is converted into a sequence of samples, or a discrete-time signal, in this instance. In fact, the invention of low-cost A/D, D/A converter chips based on differential quantization and noise shaping was one of the most crucial factors in the broad adoption of digital signal processing. The output sequence is transformed back into a continuous-time signal following discrete-time processing. Oftentimes, real-time functioning is required or desired for such systems. As the speed of computers has improved, discrete-time processing of continuous-time signals in real-time has become widespread in communication systems, radar and sonar, audio and video coding and enhancement, bioengineering, and many other applications. Applications that are not real-time are also typical [7].

CD and MP3 players are examples of asymmetric systems that only process an incoming signal once. Initial processing can occur in real-time, at high or low speeds. The processed form of the input is recorded (on a compact disc or solid-state memory), and the final processing for reassembling the audio signal is performed in real-time when the output is played back. The CD and MP3 recording and playback technologies rely on a number of the signal processing principles.

Sensors generate signals as the output, while the energy in the form of movement, temperature, or sound serves as the input to the system. The result of the calculation expressed as a unit of time or frequency, is eventually transmitted through a series of specialised transmitters to a computer or machine. Through the analyses of the signal, we can separate a single signal into many parts allowing us to visualise the past of what that sensor was measuring and therefore have better data to work from.

Take gait analysis, as depicted in 2.1 flowchart, as an example. In this context, a patient's movements are observed using accelerometers and gyroscopes while undertaking simple tasks, such as walking at the patient's desired pace, jogging, or standing still. The purpose is to quantify gait characteristics objectively. The resulting signal is described as a series of non-overlapping segments, each of which corresponds to a distinct gait activity. Identifying the temporal limits of segments containing homogeneous phases allows for the extraction of informative characteristics[2].

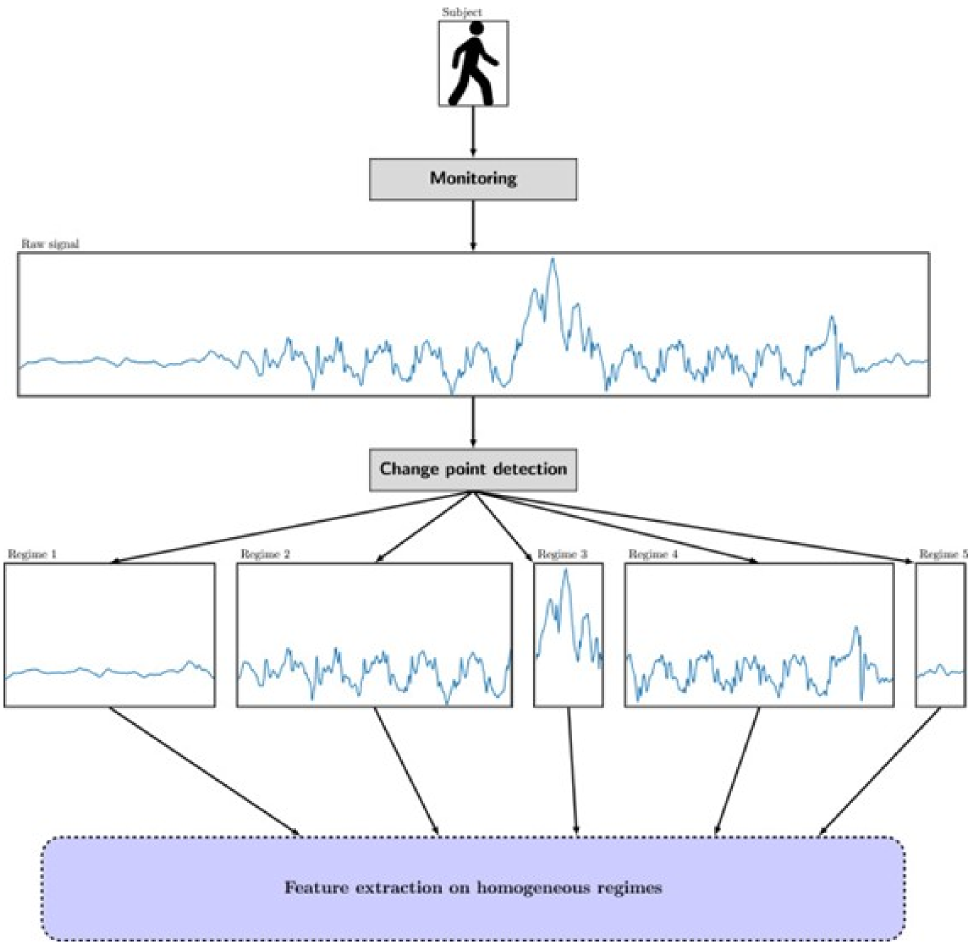

Figure 2.1: Flowchart of a study scheme, for gait analysis [2]

2.2 Music signal processing

The use of signal processing for musical signals is not a novelty. It might be suggested that it is the origin of the theremin, a 1920s device in which the capacitance of the player's hands near the antennas controls an oscillator. In the 1940s and 1950s, the advent of advanced signal processing led directly to the first wave of electronic music, in which composers like Karlheinz Stockhausen used signal generators, ring modulators, etc., drawn directly from electronics laboratories. Soon after the introduction of general-purpose digital computers in the 1960s and 1970s, pioneers such as Max Matthews and John Pierce began using them to synthesize music. Experimental music has been a consistent source of novel uses of signal processing and has created a substantial corpus of sophisticated techniques for creating and altering sounds [8].

Signal processing for music analysis is a dynamic and fast-expanding area of study that can enhance the broader signal-processing community with novel applications and challenges. Music is perhaps the most complex and meticulously produced of all controlled sound signals. Therefore, extracting information of interest to listeners necessitates the use of specialist techniques that can account for music-specific properties such as pitches, harmony, rhythm, and instruments.

> "While, for the moment, human listeners remain far superior to machines in extracting and understanding the information in music signals, we hope that continued development of automatic techniques will lessen this gap, and may even help to clarify some aspects of how and why people listen to music." [8]

Music signals are, most of the time, an addition of signals that come from different instruments that an experienced listener sorts. This process can be analysed as processing a complex signal into its parts. Besides the multiple instruments, music has repeating patterns and structures that make it pleasing that are perceived easily by humans from a non-obvious signal. Therefore, understanding how humans learn to process this signal can tremendously impact the development of future signal process techniques to apply to music and other engineering fields.

2.3 Artificial Intelligence signal processing

Artificial intelligence (AI) is set to revolutionize sensor processing for embedded computing in industrial applications. Machine learning is a subset of artificial intelligence (AI) that allows computers to acquire knowledge without being explicitly programmed. Machine learning concentrates on creating computer algorithms that can self-teach in response to exposure to new data.

The sub-field of computer science known as machine learning originated from the research on pattern recognition and the notion of computational learning in artificial intelligence. In 1959, Arthur Samuel described machine learning as a "Field of study that gives computers the ability to learn without being explicitly programmed". Machine learning is the study and development of algorithms that can learn from data and make inferences. Instead of strictly static computer instructions, these algorithms construct a model using an example training set of input observations to produce data-driven predictions or decisions expressed as outputs. The primary objective of machine learning research is to automatically derive models, such as patterns and rules, from the training data it examines. Several machine learning methods have been implemented in various sensor network applications, including activity recognition, health care, security, defect and event detection, enhancing the efficiency of complex systems.

Although Artificial intelligence is revolutionizing the world, it has two main problems blocking its full potential. The first problem is that the areas where AI exceeds only exist through immense data to train, and the tasks done happen in a very deterministic/controlled environment. For example, the best AI system playing chess needed 44 Million games to perform at a top human level. Considering a chess game with an average of 10 minutes, it will take a human 837 years of continuous play to perform at this level[9]. A computer can simulate the 44 Million games faster, but it represents the enormous amount of data required to train the algorithm. Besides this large amount of data, this system, capable of beating humans playing chess, can not walk or understand the mining of a text. This relates to the second big AI problem, the lack of commonsense reasoning.

Commonsense is the type of basic knowledge that we assume most people to have, such as "People do not like losing money," "You can store money in your wallet," "You can keep your wallet in your pocket," "Knives cut things," and "Objects do not vanish when covered with a blanket." We would all be startled to see a dog carrying an elephant or a chair transforming into a television. The great irony of common sense, as well as AI itself, is that it is something that everyone knows, yet nobody appears to know what it is or how to build machines with it.[10].

This commonsense reasoning is lacking in AI and is fundamental in more generalized tasks. This knowledge possibly will open many opportunities for AI to enlarge, and the way to achieve it is possible by trying to understand how we humans have our developmental process, as mentioned by Gary Marcus and Ernest Davis.

> "The discoveries of the cognitive sciences can tell us a great deal in our quest to build artificial intelligence with the flexibility and generality of the human mind. Machines need not replicate the human mind, but a thorough understanding of the human mind may lead to major advances in AI."[11]

Chapter 3

Final Remarks

3.1 Discussion

It is proven that music education, even minimal, translates to the production of new neural networks [12]. Music is a part of our lives, from movies to concerts or many other random encounters that we have with “the organised sounds”. Some of us are more musical; others prefer to dance, but learning music is a fantastic cognitive tool for development as much research proves it and is used in most national teaching programs in developed countries [13, 14].

Music has many variables, as defined in the first paper, Structuring music according to the Model of Hierarchical Complexity. These variables were shown to be capable of integrating Orders of Hierarchical Complexity (OHC). From the three proposed OHC (Timbre, Tonal and Tempo/Measures), it was necessary to choose one on which to create the test and which interaction (Listening/Comprehension, Playing or Composing).

When first thinking of musicality, a typical thought is the ability to play music. This would lead to the first teaching test created to access the apprentice of music to be on playing music. Playing music is a construction of several subdomains of music. When playing, for instance, the violin, it is needed to master the timbre produced, the pitch played and the rhythm inside of the specific measure. It would perhaps be easier to access a piano player’s level as the timbre production and pitch playing are hierarchically less complex. The order of hierarchical complexity of playing the piano was already developed in the first article. Nevertheless, the possibility of getting a group of people that were in a low stage of piano and that could get to higher stages on playing the piano on a 30-minute interval test would be challenging to grasp, and with the fewer results obtained, the conclusions would not be as broad and trustworthy. Therefore playing music was not the best interaction to test knowledge learning.

The composition interaction with music is an association of the various subdomains; therefore, its test was not ideal. It was perhaps faster to teach comprehension subdomains of music in the window of time available with each subject and correlate the findings on other sub-domains of music and interactions. The test was first thought to be answered in a controlled room with standardised speakers, microphones, and outside sounds isolated. These would be fundamental if creating a test for assessing the development of the playability of a music player, which we already ruled out.

While the interaction of the subject with music was already selected, the subdomain was lacking on which to test. For that, we understood that loudness, correspondent to the amplitude of the sound heard, although with some vertical complexity, the stages are not well determined, and the stage advancement would not be as evident as in other subdomains and it is very dependent on auditory subject capabilities and not music reasoning. The tonal and pitch part of music would be a fascinating subdomain to test as it is one of the most fundamental parts of music. These are very dependent on the culture used to teach. Western classical music utilises a system of notation that is predominantly dispersed throughout the world but getting familiar with it is a time-consuming process that does not sometimes correspond to music knowledge. In fact, sometimes, the subject comprehension is on the notation system and not the music that lives upon it.

Timbre perception would be a perfect subdomain of music to test as it has some vertical complexity that can be thought of in the time frame we first set for each test. In fact, in the development of the test, we thought of testing two subdomains on one of the iterations, and timbre was the second. This route was the second choice due to a perception that the other remaining subdomains are of more importance in music and would translate to a better conclusion due to that fact. Rhythmical comprehension has much of the same problems as the tonal or pitch subdomain as it is particular to the notation used, and the acquaintance with the system of notation in use can be time-consuming.

With all these, we understood that music's tempo/measures subdomain was the right choice to develop the instrument for determining cognitive stages of development using music as it is not as cultural as pitch or rhythmical subdomains. It is one of the subdomains with an OHC well determined with stages proposed that are easily reached and others only for highly capable subjects. The five stages of hierarchical complexity of the sub-domain of measures are velocity, beat, strong beat, measures and irregular measures.

The development of the different exercises is already explained in the second article, Test for determining cognitive stages of development using music. Nevertheless, it is essential to state the iterative method utilised to obtain the final version presented in the second article. The test started as a locally built platform that run on LABVIEW®. After developing three exercises for each of the three middle stages, we submitted two subjects to them to understand how they would interact with the platform, how the questions were asked, and the answers were given. These subjects

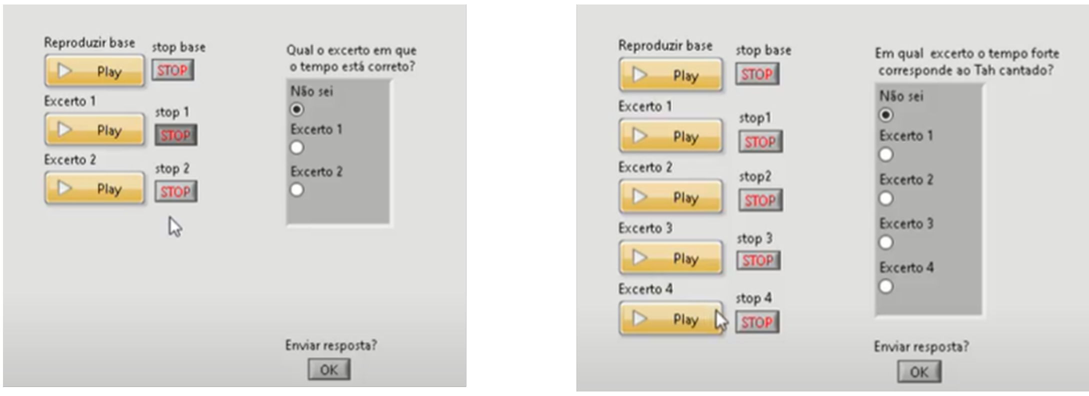

Figure 3.1: Tempo and strong beat perception pages from LABVIEW® test

were specifically chosen as the first had some knowledge of music and would probably be in the fourth stage of the OHC, and the second would perhaps be in the second stage. The first subject easily completed the second and third stages but only got two answers correct in the fourth stage. The second subject interacted perfectly with the test platform but could not answer any questions correctly.

We rapidly developed the first stage exercise page presented in the article with the results obtained. After running it on our two alfa users, they were both capable of using the interface and got it correctly. Examples of exercise pages from the local version of the test are presented in figure 3.1.

After performing these two tests and with further discussions, we conclude that the questionnaire could be presented online instead of the version created locally. Through that, it could be available to a lot more people allowing a more solid understanding of the premise that learning through the MHC is more efficient and vaster correlations with the asked variables at the beginning of the test. An example of a fifth-stage exercise from the web version test is presented in figure 3.2. Moving the test from the local platform to the online introduced an opportunity to improve the usability allowing a more straightforward interaction of the subject with the test.

The learning part was created upon the development of the exercises. Although this was one of the essential parts of this work, it is possible to say that it was perhaps not given the proper attention in the final result. When we understand that from a three-part test where the objective was to analyse types of learning, the subjects took the same time learning as in the other two parts, we visualise this discrepancy. As well as the exercises, the learning part suffered various iterations until we got to the final version presented on the online test. Nonetheless, the iterations were more drastic than the ones done on the exercises.

Figure 3.2: Fifth stage exercise webpage(Portuguese-from top to bottom: Exercise 2; to hear the excerpt press the button. Press again to stop.; Red button with the excerpt; Which is the base measure of this excerpt; 3 beats, 4 beats, 5 beats, 7 beats, don't know; Does this excerpt have any irregular measures? If so, what are the beats per measure of said measure?; All of the measures are the same, 3 beats, 4 beats, 5 beats, 7 beats, don't know; button to continue)

The first iteration was the elaboration of a video. In order to explain the concepts, a video was developed with a recorded voice over a spectrogram displaying an example music. The concepts were presented in compliance with the OHC, and the examples given in each stage followed an increase in horizontal complexity, as the MHC proposes. For instance, to explain the second stage, beats of a music/tempo, we first used an electronic rhythmical instrument that only played a rhythm with the 1st 2nd 3rd beat and on the 4th there were two notes played, in a 4 beats per measure repetitive structure, this corresponds to a straightforward rhythm that is only used for explaining porpuses. After the simple rhythm, we introduced other rhythms, and afterwards, other instruments increasing the horizontal difficulty of comprehending the beat of a music. When explaining strong beats perception, the third stage, it was visually perceptible that the wave on the spectrogram was higher when the beat was louder. The introduction of the concept was developed upon the previous notion of beat and, again, the difficulty constructed horizontally with increasingly difficult song, starting again from a simple rhythmical instrument. In the Fourth stage, the idea of how many beats per measure were introduced with the same rhythmical pattern used in the second and third stage and afterwards, a song excerpt from a Valsa was shown where a 3 beats per measure is used.

When transforming the local version into a website, we realised that the initial learning video, although built with the MHC in mind, did not follow its premises. The subject had to follow the timing of the video and could not learn at their own speed. Although manipulation of the concepts existed during the first exercise of each stage, it was not in the learning part of the questionnaire.

Figure 3.3: Video explaining the concepts (on the top, there were subtitles for the voice-over and on the bottom a spectrogram)

The concepts were first presented and only after being experienced by the subject. Through that, we are not allowing the subject to autonomously ascend through the stages, affecting the learning process.

The second iteration of the learning part dropped the video's idea and only displayed the solutions to the exercises answered by the subject. After doing a preliminary test with 11 subjects, where only one rose in stage performance after finishing the test, we comprehended that we needed further explication and manipulation from the subjects. This was achieved through the learning part explained in the second article.

When developing both tests learning parts, it was always a concern to utilise the same excerpts of music. However, these were prepared structurally, so even the non-structured test may have underlined structure, which can correlate to the results obtained. This was nonetheless difficult to modify as if the excerpts utilised were different, we would not be able to compare both tests' structures because the different excerpts could heavily impact the learning process.

The system was utilised by 163 subjects that finished it, but during the iterative process of developing it, many more subjects took it, some of which are mentioned in the above test. Other subjects took the test in a local environment and were not integrated into the final results. From these, we mention one subject. Although done on the final version of the system, this test was ruled out of the results as the presence of the test creator profoundly altered the interaction with the system.

This presence was needed as the subject was visually impaired and needed help browsing and using the test. An example of a webpage of the test is displayed in Appendix A. Through this manoeuvring of the website test, some concepts were talked about, and while explaining the placement of the buttons, some hints of how the test was constructed happened. This subject was presented with the structured test. However, as the interaction with the learning part was optional and did not have answers to give, the subject asked to go directly to the final exercises. This corresponded to a far diminished learning part that correlated to him not developing when evaluating the subject performance between the first and final parts of the test. This subject had average reasoning in music and performed at the fourth stage, which corresponds to a good test assessment. Although impaired, he had piano lessons and played other instruments while hearing commonly diverse genres and some complex music. This test allowed us to visualise the richness of an interview survey conducted as many done by Piaget. Nonetheless, the results obtained are not as robust as this format is so derivative of the interactions between interviewer and subject, one of the common criticisms of Piaget's work and one of the reasons for the development of a system that did not had an interviewer [15].

3.2 Future works

Timbre perception is also another important subdomain of music and with an Order of Hierarchical Complexity perception proposed [Tonal vs Rhythmical Instruments, Wind vs String Instruments, Woodwind vs Brass Instruments, Single instruments(trumpet vs trombone) and Different sounds on an instrument(staccato)]. Further tests built on other subdomains of music will allow a broader knowledge of music cognitive stage development. Besides the other subdomains instruments, this Tempo/measure perception instrument could be reformulated by having a restricted time for the exercises part of the test and with the subject's thoughts on the test gathered to further analyse the cognitive stage development.

It will also be necessary to elaborate more OHC for the other subdomains and even for specific instruments, test their validity and try again to prove that teaching through the premises of the MHC gives better results than a non-structured approach.

The conclusion that humans improve the answering time by half if following a structured approach was one of the first steps in a long process of recreating a new approach to training and teaching artificial intelligence systems. Therefore this structured approach should be first utilised in AI with music and, after concluding its efficiency gain, used in other areas of signal processing. It is always essential to remember that music signal processing is one of the more complex types of signal processing; Consequently, extrapolating knowledge from this domain into others will revolutionise this field.

3.3 Conclusion

The knowledge of the cognitive reasoning process is essential for better teaching practice. The developments in the cognitive sciences by Piaget brought a very insightful way to how children reason and create associations of concepts. Children develop reasoning in stages, which can be related approximately to age but are non-limited to it, and each child has their development rate [5]. Most of Piaget's findings were done in an interview approach, which allowed Piaget to collect much data but introduced variability in the results that are now contested [15].

The developments introduced in the cognitive sciences by Piaget are non-contestable, but even Piaget realised that although his theory was capable of being important in the future should be worked upon [16]. Michael Commons introduced a mathematical proof to Piaget's theory that allowed further developments and the elaboration of a new model for cognitive development. The model of hierarchical complexity is a formal theory and a mathematical psychology framework for scoring how complex a behaviour is [17]. In terms of information science, it quantifies the hierarchical complexity of a task based on the mathematical underpinning of how information is arranged. It describes the stages for each of the 16 orders of hierarchical complexity for any domain and across cultures. According to the MHC, task sequences and task behaviours create hierarchies that become ever more complex [18].

Music is a construction of many variables, from different instruments to melodies or dependent cultural rhythms [19]. By defining these variables, we could see that most of them were dependent on each other and could be organised into five subdomains. These subdomains are tonal, where every pitch-related variable belongs, from single notes to scales to melodies and harmonies. Tempo/ measures is related to the measures where the base of the beats per measure is the beats in itself, which relates to the tempo and other related variables. Although rhythms could be thought of as being related and a variable from the tempo/measures subdomain, it is analysed as a separate subdomain as it has its own complexity and variables in it, from how long a song is played and how it repeats and is played with other sounds. The Timbre subdomain is associated with the sound profile of each sound, corresponding to why a guitar has a different sound from a clarinet. Per last, loudness aggregates all amplitude-related differentiation of the sound produced. It is necessary to state that loudness is mainly associated with the amplitude of the sound wave produced, but this amplitude can also influence the note's pitch, as stated by Levitin [20].

Music is an art that can be interacted in three different ways. The first is listening; however, in the present work, we focus on the comprehension of the heard sound. The second one is playing; although the five subdomains exist separately most of the time, the usage of the five subdomains is associated with developing the best-sounding music. The last interaction is composition. Composing also integrates the five subdomains; however, vast knowledge of each of the five subdomains is needed to understand which instrument to choose or what part to play, for example.

By deconstructing music into these five subdomains and each interaction, we can visualise the structuring of the music variables. This stacking of the variables allowed us to elaborate on three OHCs for tonal piano playing, timbre and measures comprehension. Tonal piano playing starts with pressing each piano key and consequently playing any note. So this was the first stage proposed corresponding to the primary stage of the 16 stages of the MHC. From the note, it is expected to play scales, melodies, and harmonies. The timbre OHC starts from the perception of the difference between tonal and rhythmic instruments, and increasingly complex reasoning tasks are set until the comprehension of different technics in each instrument is possible. The final OHC elaborated was the measures comprehension, where a subject is capable in the first stage of knowing if a song is fast or slow, afterwards comprehending the song tempo, followed by the comprehension of the strong beat and the beats per measure. A final stage was introduced of knowing if a song has irregular measures.

From the proposal of the three OHCs, it was necessary to test if their construction was valid and if music variables were indeed stackable in orders of hierarchical complexity by analysing multiple subjects on their stage performance and comprehending their dispersion through the stages. After this evaluation, it was possible to analyse whether teaching through the MHC premises was more efficient than a normal approach.

For these two purposes, a test was built to be utilised by a population where half would have a structured test compliant with the MHC premises and the other half a non-structured test. The test was set to be a proximal 30-minute test, and with that, only one of the subdomains was chosen to be tested. The subdomain chosen was the measures OHC, a non-cultural subdomain with non-notation associated, and musical knowledge is not associated with classical constructions. As this is one of the more important subdomains, the findings could be well related to other subdomains.

During the elaboration of the test, many iterations happened. With preliminary tests implemented on smaller populations, the structurality of the measures subdomain OHC was starting to be visible. Through the final results, it is possible to visualise the dispersity of subjects' stage performance that correlates to a good elaboration of the OHC.

The elaboration of the exercises was a time-consuming process as a standard method of evaluation was tried to be achieved between the five stages while only interacting in one neurological sense. As the test was to be available online and subject answers would be individual, and without interaction of the test creator, good user usability was thought and tested. Besides the type of exercises and how they would be answered, a profound search of multi-cultural songs was done as well as with diverse genres.

Although with different tests, the exercises parts of the test were equal for the entire population with the same presentation of the exercises in the same order. This allowed a better comparison between the learning part and more robust data on how the exercises were answered collectively and the stage performance of more subjects. Through this analysis, we can conclude that the five stages are hierarchically stacked and that the placement on the 16 stages of the MHC is possibly correct as the average subject performed on the Concrete stage of the MHC correspondent to the tempo stage.

Regarding the learning aspect of teaching music in accordance with the MHC, we propose diverse methods while ending with applying a close to exercises method. We started the exposition of the concepts with a video but rapidly understood that not allowing the subjects to experiment and manipulate the concepts was not corresponding to the premises established by the MHC. From the structure of the exercises, we presented examples that, from the third stage onwards, had an explication of the process to get to the answer. The examples had the solution present upon a button pressed by the subject. The examples were shown in the structured test in a structured manner, starting from the lowest stage and going hierarchically complex, and the subject did not have any time constraint or was obligated to manipulate every example. On the non-structured test, the examples were presented in random order while utilising the same excerpts prepared for the structured test only to analyse the placement of a structured vs a random placement of the examples and not the validity of the concepts.

The test could teach the population the concepts, as there was a 60% increase in stage performance when comparing the subjects' entrance and final stage performance. Nonetheless, this increase was viewed in both tests. This result may have occurred due to the non-structured test being built from the structured test. Visualising and comprehending the different stages and subliminally the structure while taking the non-structured test is possible. Therefore, the non-structure of this test was not sufficient to relate to a worse stage performance increase. The non-structured test could be viewed as a less structured test, and this difference was not sufficient to visualise the results first thought.

However, the subjects that took the structured test answered the final 15 exercises almost half the time as the non-structured test subjects. Therefore, we can say that the first group performed better, as the time metric is an essential aspect of the reasoning process assessment. Allowing us to conclude that learning through the MHC premises leads to a better and more efficient strategy.

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Appendix A

Structuring music according to the Model of Hierarchical Complexity

Structuring music according to the Model of Hierarchical Complexity

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Abstract

Music is a domain with endless variables, ranging from how loud a piece of music is to harmonies mathematically composed or cultural rhythms that transport us to their respective cultures. An approach to a definition of the reasoning method of learning music is not well defined.

We approach this problem by first presenting a general definition of some of the most important music variables. Afterwards, we try to understand how any domain is learned through theories developments in cognitive developmental science field.

Piaget's four-stage theory of cognitive development in children is one of the most commonly accepted models of reasoning. However, even Piaget recognised that despite being highly significant, his theory required development.

Michael Commons constructed a mathematical validity based on Piaget's formulations that described stages in the development of reasoning across all domains. The Model of Hierarchical Complexity (MHC) provides a framework for assessing levels of thinking across all domains and cultures. The scoring is not based on the topic or participant responses, but the mathematical complexity of the hierarchical information structure.

Through the premises of the MHC and the definition of music we propose a division of music into five different subdomains and present the integration of some variables into structures of hierarchical complexity for three different subdomains.

Introduction

Even minimal exposure to music education as a child produces neural circuits for music comprehension that are improved and more efficient than those of untrained individuals. Music lessons enable us to listen more attentively and accelerate our capacity to recognise structure and shape in music, enabling us to determine what music we appreciate or not. (Jaschke Id et al., 2018)

Music is a domain with infinite variables, from different instruments that convey different emotions to melodies engraved on each culture or rhythms that immediately take us to dance and have a festive mood. We will start this work by presenting a general scientific definition of music. From the sound waves to the definition of some of the music variables and how they entwine and work together. It is also presented some neuroscientific discoveries about how music is perceived on a neurological level.

Our goal is to understand how music is learned. We approach this problem by understanding how any domain is learned. One of the most accepted theories of reasoning is the one presented by Piaget, a child's four stages developmental cognitive theory. Nonetheless, even Piaget understood that although his theory was influential, it should be developed. This was one of the premises of Michael Commons when he stumbled upon Piaget's theory.

Through Piaget's formulations, Michael Commons introduced a mathematical validity that granted a definition of stages for all reasoning development in any domain. The Model of Hierarchical Complexity (MHC) establishes a framework for evaluating levels of reasoning in any topic and across cultures. The scoring is not dependent on the subject matter or participant submissions but rather on the mathematical complexity of the hierarchical structuring of information.

The MHC is a quantitative behavioural developmental theory that posits that task sequences create hierarchies that get more complex instead of explaining behaviour variation over age due to mental structures or schema formation. This explains the developmental changes observed since less complicated tasks must be completed and practised before learning more complex tasks.

After explaining the music definition and the cognitive developmental theory, we understand that through the premises of the MHC, music variables could be hierarchically structured. To accomplish this, we propose dividing music variables into five subdomains. From these five subdomains, we propose the integration of some defined variables into three orders of hierarchical structure, which are the stages definitions of the hierarchically structured variables.

Defining and decomposing music

When asked how the cognitive process of learning music occurs, it is essential first to understand what music is. Searching through the academic research in musical cognition, we encounter several definitions presented forward.

Reflecting upon the philosophical approach to understanding music, Mazzola defines music as the characteristic art of time, more so than dance, as its embodiment depends not only on physical bodies.(Mazzola et al., 2020)

One of the most famous definitions of music is from the French composer Edgar Varese: "music is organised sound". Music can be described as language organised in a system of rules that makes all parts work together. Said parts are rhythm, melody and harmony.(Jauset Berrocal & Soria Urios, 2018) Or intensity, pitch, timbre, tone duration and rhythm. (Jarvela, 2018) Another definition considers music's effect on the listener, stating that "music is the organised and structured sound in time, destined to be an aesthetic experience". (Patel, 2017) Immediately, one can argue that although some music has rules, nowadays, we can hear contemporary western classical music as non-ruled sounds that try to be unruled opposing classical western music. The aesthetic experience can sometimes be corrupted, depending on the listener. Although these definitions are relevant, they do not present a scientific and engineering perspective on what music is.

Music is sound thaperceived by hair cells in the inner ear. The sounds are transmitted as electrical signals through the midbrain to the auditory cortex, where the first steps of listening, perception and analysis of tones happen. Music is acted upon by other brain parts. From the motor cortex, which allows us to dance, foot tap, and play an instrument, to the sensory cortex, where we feel the tactile feedback from dancing or playing a piece of music. The prefrontal cortex, where our expectations of where the harmony is going are related allowing us a sense of realisation or satisfaction, to the cerebellum that is engaged seemingly as the motor cortex but is also responsible on emotional responses to music and the visual cortex when reading notation or looking to a performer. (Jarvela, 2018; Levitin, 2006)

A. How to characterise sound

Sound is a set of vibrations that travel through a medium such as solid, gas or liquid. Mainly it is a type of wave, where a wave is defined as motion or energy that moves along (or propagates) by itself. In particular, sound is a compression wave, which means that the direction of propagation aligns with the direction of motion. The effect of these vibrations passing through a given point in space can be characterised as the displacement of the said point from its normal position as a function of time.

If the vibration is regular and repetitive, it is possible to characterise sound frequency. Vibration frequency is defined by how many cycles of upward and downward movement occur per unit of time, usually measured per second. A standard unit of frequency is Hertz (abbreviated Hz), equal to one vibration per second, e.g. 200Hz = 200 vibrations per second.

The human ear often hears sound waves ranging from 20Hz to 20 000Hz, although by the age of sixty, most adults cannot hear much above 15 000 Hz due to stiffening of the hair cells in the inner ear. (HOWARD, 2010) Frequency usually is related to the listener's perception of a "high" or "low" sound. In a piano, the lower frequencies notes are on the left side, and the frequency increases from left to right. This happens as the strings on the piano are bigger on the left side and decrease in size on the right side. Frequency is related to the length of the part that produces sounds, from strings, to pipes or wooden bars (xylophone). A piano's far-left key plays a string that vibrates with a frequency of 27.5 Hz. Instead of using the term frequency, musically we use the term pitch.

B. What is a single note, and why do instruments sound differently?

A note is the fundamental part of music. It consists of a sound with a specific fundamental frequency (pitch), duration and timbre. Notes are usually played on an instrument, being the human voice an instrument, as well. Instruments define the shape of vibration produced when played, called timbre. Timbre is uniquely correspondent to an instrument when talking of acoustic instruments. The wave pattern produced by a non-electronic instrument is always a sum of multiple sine waves. Virtually obtaining a pure sinusoidal sound is a simple task.

When analysing a spectrogram of any sound produced by an instrument, it is possible to decompose them into sums of sine waves, where the frequency of each sine wave vibration is a multiple of the frequency of vibration, visually perceptible in figure 1.

The frequency itself is called the fundamental frequency, and all the other multiples are called harmonics frequencies or simply harmonics. It is possible to decompose an arbitrary note into harmonics by attributing an amplitude and phase to each sine wave component. This can be achieved through Fourier Analysis and is a possible path to understanding how the human brain captures and understands music sound and describe why some notes are more appealing and others create dissonant sounds.

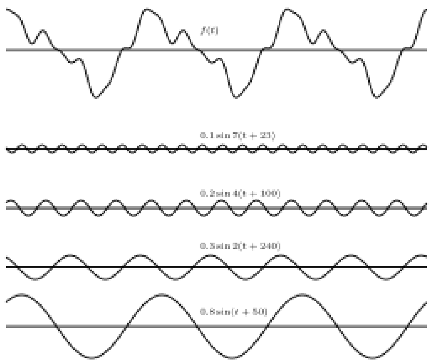

Figure 1-f(t) is an example of a sound produced by an instrument with the decomposition in sine wave functions below,

C. Why do two different pitch notes are different?

When two notes are analysed and have different pitches/frequencies, we can perceive it as a ratio of frequencies, which correlates to the difference between two pairs of notes being considered the same if the ratios are the same. For example, the interval between two notes with frequencies of 100 Hz and 200 Hz is the same as the 120Hz and 240 Hz since the ratio is 1 to 2 in both cases. It is vital to salient that when talking of these frequencies, we use the fundamental frequency of the note.

From analysing these intervals, it is crucial to understand that when hearing two frequencies separated with a ratio of 2, as in the example given, those notes are psychologically perceived to be similar. This ratio is commonly referred to as an octave, originating from the word eight, and derives from the western scale.

The psychological sense that the two notes are separated by a ratio of two in frequencies comes from the sequence of harmonics obtained through the spectrogram or dividing a vibrating string into integer sizes. When a piano string is hammered, it produces the fundamental frequency, for example, 220 Hz, and a sequence of infinite other frequencies in smaller importance/volume each. The first harmonic is two times the fundamental frequency(2ff), 440Hz, the second one 3ff, 660 Hz, the fourth 4ff, 880Hz and onward until harmonics that are not discernible even to the most trained hear and only perceived on the spectrogram. These harmonics are deeply connected to the development of music as we know it and to the appearance of the western musical scale. Historically western musical culture has deep roots in Christianity, and music was viewed as sacred and played in big churches or to please the king in big halls. It is in this configuration of a room that we encounter reverberation. This effect happens when a sound is reflected and causes other reflections until the sound wave loses its energy. This reverberation created two phenomena: First, a note that would be played or sung would be reminiscent for longer, which makes singing other notes while the first is still audible need to be in congruence with the first one and not dissonant. The second effect is that a single note sang would allow through the reverberation to listen the harmonics of it. The first phenomenon was fundamental to the 12 semitones western scale organisation. The harmonics of a note start with the octave, then a relative fifth (five notes from the fundamental), then another relative octave and a relative third(three notes from the fundamental). As intervals and the relation between notes relate to ratios, the logarithmic scale is typically used to represent musical note frequencies.(Burns, 1999)

D. Melodies and Harmonies

The concept of relative pitch values is immediately apparent in how we talk. Culturally, we raise a sentence's final word's pitch to ask a question, however not to a specific frequency. It is sufficient to complete the phrase with a slightly higher tone than what began it. In linguistics, this is known as a prosodic cue and is a convention in most western languages. Similar conventions exist for music composed in the Western tradition. Specific pitch sequences suggest tranquilly, while others evoke enthusiasm. We all have the intrinsic ability to absorb the language and musical nuances of the culture into which we are born. Exposure to the music of that culture alters our neural pathways such that we eventually internalise a set of principles characteristic of that musical tradition. (Flagge et al., 2021)

When notes are played sequentially, it forms organised sounds. Melodies are defined by the pattern or relationship of successive pitches over time; most people have little issue identifying a melody played in a higher or lower key than the key they have previously heard. In truth, many melodies do not have a "proper" starting pitch; instead, they simply float in pitch, beginning anywhere they like. Consequently, one way to consider a melody is as an abstract prototype created from specific combinations of key, tempo, instrumentation, etc. A melody is an auditory entity that retains its character despite alterations. So, for instance, if a piece of music is played louder than usual, it is still recognisable as the same tune. Similarly, alterations to the song's absolute pitch values are permissible so long as the relative distances between them remain the same.

When a melody is played or sang and a second voice joins it (voice in this context can refer to the human voice or other sound produced by any melodic instrument) and does not sing an octave higher or lower, harmony is formed. Harmony is the relationships between the pitches of different tones and the tonal contexts that these pitches set up. These tonal contexts ultimately lead to expectations for what will come next in a musical piece, expectations that a skilled composer can either meet or breach for artistic and expressive purposes. Harmony is the study of the relationships between the pitches of different tones. A secondary melody that runs in tandem with the primary melody (as when two singers harmonise) or a chord progression (clusters of notes that form a context and background on which the melody rests) can be called harmony.

E. What are the time related underlying structures of music

Time is one of the essential concepts in music. First, every note has frequency and frequency is defined by how many cycles of upward and downward movement occur per unit of time. Second, a note in most instruments can be played for a specific amount of time. Third, the precise moment a string is strummed or a note sang correlates to time.

The third and second aspects of time refer to the rhythm. It is the relationship between the length of one note and another and is essential to transforming sounds into music. Some rhythms prevail in our western society and the rhythm known as "shave-and-a-haircut, two bits," which is occasionally utilised as the "secret" knock on a door, is one of the most well-known in our society. The first known instance of this rhythmic pattern is found in Charles Hale's 1899 album "At a Darktown Cakewalk." We hear a series of notes in "shave-and-a-haircut" that are both long and short, with the long notes being twice as long as the small ones: long-short-short-long-long (rest) long-long. The reason it grew found in our society is unknown, but it has been broadly used in tunes, cinema, and everyday life. Two reasons can be connected to its popularity: First has a question and answer type of formulation, has section A, until the rest can be viewed as a question and the answer falling it after. The second is the sense of realisation of expectation when hearing the last two notes. This is a vital aspect of music—the management of expectations by the composer or performer. The "shave and a haircut", got its name from a tune written in 1939 by Lee, Shapiro and Berle where they utilised the rhythm, if it does not have the last two notes, the listener will feel a non-satisfying sense and if the rest is prolonged to a particular time the feeling of enjoyment in hearing the last two notes will increase. (Levitin, 2006)

Most of the music we listen to has rhythms that are rarely that straightforward. A particular arrangement of rhythms can suggest music from a particular country, style, or idiom, much like a specific arrangement of pitches—the scale—can. Even though most of us cannot mimic a sophisticated Latin rhythm, we can instantly tell that it is Latin rather than Chinese, Arabic or Western. We establish tempo when we arrange rhythms into strings of notes with varying lengths and emphases.

Tempo refers to the pace at which a musical work develops rapidly or slowly. The speed of a piece of music can be determined by how quickly or slowly the listening subject taps his foot or snap his fingers in time to it. If a song is imagined as a living, breathing thing, its tempo could be compared to its gait—the speed at which it moves—or pulse—the speed at which its heart beats. The basic unit of measurement in a musical composition is denoted by the word beat. Most frequently, this is the natural time to clap your hands, tap your foot, or snap your fingers. Due to varying neural processing methods across individuals as well as variations in musical training, experience, and interpretation of a composition, people occasionally tap at half or double the beat. Even accomplished musicians often disagree on the ideal tapping rate. However, they always concur on the tempo or the underlying speed at which the work is developing; disagreements only concern the subdivisions or superdivisions of that underlying pace. (Levitin, 2006) Nowadays, written music will have a notation of the tempo in bpm, beats per minute. This accurately states the composer's thought tempo for that music. Everyone can quickly grab a metronome or search the internet for a reference making the specific unit available easy to understand. In the past, the tempo of a classical piece was written in specific Italian words; through that, a performer could try to interpret the tempo that the composer thought of the music. Some examples of these time signatures are Largo, Adagio, Andante, Allegro and Presto. The time imprinted by each of these words correlates to their meaning in Italian. Largo will be a plodding rhythm (40-60 bpm), each beat slower than a second, Andante means walking, and it says that each beat should match each footstep when a person is walking (76-108 bpm), Allegro means happy, cheerful and correlates to a faster time than Andante and Presto is a speedy tempo as the Italian word means fast.

Tempo is a crucial element in communicating emotion. Generally, songs with quick tempos are considered joyous, whilst songs with slow tempos are considered melancholy. Although this is an oversimplification, it holds in a wide variety of settings, across numerous cultures, and throughout an individual's life and could be related to the heartbeat and its emotions, as when a person is feeling sad, the heartbeat decreases and when happy and cheerful it rises.

The ordinary individual possesses an excellent recall for tempo. In a 1996 experiment conducted by Perry Cook and Daniel Levitin, participants were asked to sing their favourite rock and pop songs from memory, and the researchers were interested in how closely they matched the actual speed of the recorded versions of the songs. As a baseline, they determined that the average person can perceive a difference in tempo of four per cent. Most participants in the study could sing songs within 4% of their nominal pace. (Levitin & Cook, 1996)

The cerebellum, which is considered to include a system of timekeepers for our daily life and to synchronise with the music we hear, is likely the neuronal basis for this remarkable precision. This indicates that the cerebellum can remember the "settings" it uses to synchronise to music when we hear it and retrieve them when we want to sing a song from memory. It permits us to synchronise our singing with a recollection of the last time we have sung. The basal ganglia are probably also involved in producing and shaping rhythm, tempo, and meter.

How pulses or beats are clustered is referred to as meter or measure. When tapping or clapping along with music, we tend to sense certain beats more than others. It appears that the musicians are playing this rhythm louder and with more force than the others. This louder, heavier, stronger beat is perceptually dominant, and the beats that follow it are perceptually weaker until another powerful beat appears. There are patterns of strong and weak beats in every known musical system. The most frequent pattern in Western music is for strong beats to appear every four beats: STRONG-weak-weak-weak. STRONG-weak- weak-weak. Typically, the third beat in a four-beat pattern is somewhat stronger than the second and fourth. There is a hierarchy of beat strengths, with the first beat being the strongest, followed by the third, and then the second and fourth. In another frequent measure, the strong beat occurs once every three in what coud be called the "waltz" measure: STRONG-weak-weak. STRONG-weak-weak. Typically, we also count to these beats, emphasising the strong beat: ONE-two-three-four, ONE-two-three-four, or in the "waltz" ONE-two-three, ONE-two-three. (Levitin, 2006)

The cognitive developmental reasoning process

Cognitive learning is an active learning approach that focuses on teaching how to maximise the brain's potential. The ability to deepen memory and retain knowledge is improved since it is simpler for you to link new information with previously held beliefs.

According to cognitive learning theories, both internal and external influences can affect a person's thought processes to support learning. Learning can take longer than expected or be more challenging when cognitive processes are not functioning consistently. These include activities like paying attention, observing, retrieving information from long-term memory, and categorising. Cognition is the capacity of the brain's mental functions to take in and hold onto knowledge gained through experience, the senses, and thought.

Cognitive development theories are significant to people who teach as it enables them to understand how to reach better subject development. These theories have helped to construct the notion of learning as not something linear and depository but rather as an element that must be understood, leading to a comprehension of why each subject learns at their own rate.

A. Piaget's theory- Introduction of stage reasoning

". Piaget indicated that intellectual changes do not happen suddenly, but are gradual developing changes that suddenly reach consciousness (when a new mental structure is formed); Piaget (as cited in Piaget, 1961) called this seizing of consciousness."

In an IQ-dominated developmental psychology tradition that created a discriminatory framework where each person is placed on an unchangeable and predetermined scale of intellectual capability, Piaget brought an opposite idea. In his eyes, each human mind is independent, curious and an active creator of its mental structures and is allowed to develop at a non-determined pace or time. While the individual nature of each subject to Piaget is central to the development of each state, his theory allows capturing the common qualities of thought and its development that occur regardless of the particular cultural and socioeconomic circumstances. "The developing mind was supposed to make its way ineluctably toward mature thought regardless of gender, cultural context, historical period, nutritional input, training, or even biological variations unless they proved to very extreme indeed (e.g., Down's syndrome)." (Feldman, 2017)

One of the essential theories of reasoning in developmental psychology is the one developed by Jean Piaget. He defined learning and thinking not as an act of contemplation but as an act of dynamic transformation within an interaction with an object. For him, the learning process can be described as comprised of two parts: the first one being the formal viewpoint and the second one being a dynamic aspect. The formal viewpoint implies and begins with the already defined reasoning aspect of contemplation through mental imagery or imageries, and the dynamic aspect involves the physical phenomena of manipulating an object. For Piaget to comprehend and learn how a machine works, it is needed to manipulate and interact with it so that it is possible to understand its causalities. To create a more profound logical development, it is needed first to understand and already master the more basic logical structures meaning that to develop, one must coordinate already gathered information.(Piaget, 1961)

In the example given by Piaget in 1961, a child from 4, 5 to 18 months is capable of recognising that an object that was first in his field of view and is then obstructed by an opaque wall continues to exist when he persists in recovering said object that as escaped is field of view. This realisation allows concluding that at this age, the child has already built his first invariant, which Piaget defines as the schema of the permanent object.

Through this conclusion, Piaget presented four stages of a child's development. The first is the sensorimotor stage, where the toddler will experience and collect information in the world through manipulating objects in a sensory experience. This is usually related up to 18 months of age. The second stage is called the preoperational stage, where the foundations of language development appear, and words and pictures symbolically represent objects. This stage correlates to a child under seven years of age, and it is possible to conclude that he or she is building complete cognitive structures deficient in logic. To illustrate this deficient in logic at the Preoperational stage, one of the most used examples is the incapability of understanding the concept of volume of water when presented with the experience of transposing a glass of water that is wider to a slimmer and taller glass, the level of water will increase, and the child will state that the volume of water has increased. When the child matures and riches seven or eight years, he or she can understand complete dynamic structures, relations, numbers, and classes. These dynamic structures refer to an actual object that can be manipulated or imagined; therefore, we can state that these structures are concrete in nature. At this stage, the child will understand that the volume of water has remained the same in the two-glass experience as they start to think logically about concrete events. This stage is called the Concrete Operational stage and is typically associated with 7 to 11 years old. Although logical thinking is more developed than in the previous stage hypothetical and abstract concepts are still difficult to grasp. That development appeared in the Formal Operative stage, the final stage of Piaget's theory, where the adolescent is capable of developing multiple potential solutions to problems. He or she thinks abstractly and reasons about hypothetical problems. When a child reaches 11 or 12 years, it typically becomes capable of utilising logic or even hypothesising. This process is different from learning a concrete nature structure as the logical structures are built on other more basic logical structures or even on concrete structures.

The tests used by Piaget to evaluate reasoning ability did not have time constraints. Therefore, logic and reasoning skills are essential for performing well on a Piagetian test, although the amount of time required to complete the activity is mostly irrelevant. Piaget would only deem an answer correct if the participant could sufficiently explain why it was chosen as the correct response. Items in a Piaget test are ordered hierarchically.

"It is my conviction, illusory or otherwise—and the future alone will show which part is truth and which but simple conceited obstinacy—that I have drawn a quite clear general skeleton, but one still full of gaps of such a kind that, in filling them, one will be led to differentiate its connections, in various ways, without at the same time altering the main lines of the system. When one theory succeeds another, the initial impression is that the new one contradicts the old and eliminates it, whereas subsequent research leads to retaining more of it than was foreseen. My secret ambition is that the hypotheses one could oppose to my own will finally be seen not to contradict them but to result from a normal process of differentiation" (Jean Piaget inBringuier & Piaget, 1989).(Feldman, 2017)

As cited here, we can see that Piaget comprehended that his theory was not final and that the development of the proposed stages should be worked upon.

B. Model of Hierarchical complexity

The Model of hierarchical complexity (MHC) presented by Michael Commons in 1982 is a "framework for scoring reasoning stages in any domain as well as in any cross-cultural setting." (Commons, 2007) It is called a neo-Piagetian model as it utilises the idea of stages developed by Piaget and builds upon it. The MHC is a quantitative behavioural developmental theory that posits that task sequences create hierarchies that get more complex instead of explaining behaviour variation over age due to mental structures or schema formation. This explains the developmental changes observed since less complicated tasks must be completed and practised before learning more complex tasks.

As Michael Lamport Commons and Patrice Miller say, "Tasks are defined as sequences of contingencies, each presenting stimuli and requiring behaviours that must occur in some non-arbitrary fashion". (Commons, 2007)

When analysing task complexity, it is common to assess its horizontal complexity. For example, in a school, when a class has learned multiplication and the teacher wants to understand the level of each student will ask more challenging multiplication questions increasingly, and although this complexity exists, this all correlates to horizontal complexity. The number of stimuli that must be addressed (individually) within a task and the number of response types necessary to complete it are examples of horizontal complexity. One way to quantify horizontal complexity is to count the informational components of an activity, the number of bits embedded in a task. Horizontal complexity can be objectively assessed and quantified. No horizontal complexity mechanism considers the varying difficulty of various task types.(Commons & Chen, 2014)

Another property of a task that is more interesting for understanding the cognition process is the property of vertical or hierarchical complexity. Recursion is the method used in which the higher-order action's input is formed from the output of the lower-order actions. The number of recursions the coordinating actions must carry out on a group of primary elements serves as a measure of the vertical complexity. Concatenation is the process of "nesting" two or more lower-order tasks inside of higher-order ones. In the hierarchy, each new task-required activity is one order more complex than the task-required activities it is based on. (Commons et al., 2008)

The idea of vertical complexity is presented in Piaget's Theory, even though it is perhaps not explicitly stated. Formally, a task must satisfy two conditions in order to be more hierarchically complex than another. First, two or more less hierarchically complex tasks and their required actions are used to describe a higher-order action. This makes the higher-order action include the lower ones and impose a hierarchical nature. Second, the more hierarchically complex task organises or coordinates two or more activities that are less difficult; in other words, the more complicated action describes how the more uncomplicated actions should work together, making it more robust. (Commons, 2007)

In the definition of hierarchical complexity of tasks, Commons agrees with the first two premises of Piaget's work but adds a third one:" Higher order of complexity actions organise those lower order actions in a non-arbitrary way" (Commons, 2007). This development in the work of Piaget became possible through a mathematical approach and the idea that although Piaget developed his thesis on a Logic domain, it could be applied to any domain. "He did not like the logical framework that Inhelder and Piaget employed in their model because it was based on a form of rationality (i.e. logic). Logic is too restrictive." (Commons & Chen, 2014)

The Model of Hierarchical complexity identifies 16 orders of hierarchical complexity and due to the previously explained premises, it has a tree-like structure, figure 2. It is developed to approach personal development throughout a lifetime. Humans, their biological systems, social organisations, non-human animals, and machines, including computers, are examples of entities that organise information. Its extensive applicability comes from a straightforward mathematical approach to defining tasks, and tasks may contain any information. As a result, it can be used in any situation because it just uses quantitative concepts. As a result, there is no longer any need for mentalistic, cultural, or other contextual explanations, which makes it possible to perform a standard quantitative study of hierarchical complexity in every situation.

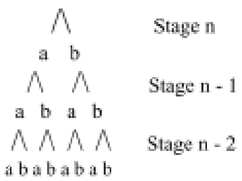

*Figure 2-Order of Hierarchical Complexity Tree. Each higher order action organises two or more lower order actions(*Commons, 2007*).*

From the first publication, where four stages were added to Piaget (Commons et al., 1982), MHC has long developed, reaching 16 stages, represented in Appendix A. The first five stages (0-3) can correlate to the first stage of Piaget, sensorimotor, generally associated with an infant's development, 4-6 correspond to Piaget's Preoperational stage and 6-8 to Concrete operational and finally, 9-11 to the formal operational stage. The last stages are not represented in Piaget's theory as it was formulated upon child development and because MHC's highest stage represents successful performance on the most hierarchically complex task rather than intellectual maturity. (Commons et al., 2007)

The MHC has been applied to vast areas and shown to account for performance in a variety of different domains. Perhaps one of the more straightforward examples is mathematics and the complexity of the distributive law versus simply adding or multiplying. The task of a+(b+c) is no more complex then (a+b)+c as the organisation in addition is arbitrary. On the contrary, ax(b+c) requires a non-arbitrary organisation of addition and multiplication. In modern algebra, the non-arbitrary coordination of addition and multiplication leads to the definition of rings, and the expressions in ring theory are usually more complex than the expressions in group theory (which involve only one operation(Commons et al., 2008). Apart from the distributive law being a higher stage, as multiplication is the repeated addition of groups of equal sizes, we can state that in the mathematical domain the order of hierarchical complexity of the three concepts is: Addition, Multiplication and Distributive Properties.(Duran et al., 2018; Li et al., 2014; Ross & Commons, 2008)

Structuring music according to the MHC

It is known that music activates multiple parts of the brain instead of an early idea of a "musical part" of the brain to process every aspect. Besides this development, there was a time when neuroscientists believed that only the right part of the brain dealt with musicality and that the left took care of the linguistic processing. (Levitin, 2006) Tonotopic maps have an organization of pitches between bass and treble that have some proximity to the layout of the piano keyboard. Different timbres are processed in well-defined regions of the brain. Tempo and rhythm may activate oscillators in the cerebellum and basal ganglia. A network of neural circuits stretching from the brain stem and inferior colliculus to the temporal lobes processes loudness. A network handles the localisation of sounds and the perception of distance cues by attending to (among other cues) variances in interaural time of arrival, changes in the frequency spectrum, and changes in the temporal spectrum induced by reverberation. One can achieve world-class skill in one of these subcomponents without necessarily accomplishing it in the others. (Levitin, 2012)

Evidence suggests that persons with amusia do not have difficulties that extend beyond the musical realm into the verbal domain. (Ayotte et al., 2002) It was found that people with congenital amusia suffer from a domain-specific musical impairment, consistent with the modularity view of music processing, as their participants were unimpaired in a broad range of linguistic tasks, including the processing of human prosody. (Peretz & Coltheart, 2003)

Through this idea of different neurological brain parts interacting with different music variables and even the constructions of the different definitions of these variables, we propose a formulation of five subdomains of music where each music variable is to be attributed.

These five subdomains are Tonal, Rhythm, Tempo/Measures, Loudness and Timbre. Timbre corresponds to all variables associated with the "quality" of sound, or production of a specific sound, like *staccato*(a technique used on string instruments) or choice of a specific instrument. How a note or passage is played in terms of intensity is an example of a variable of the loudness subdomain. Tonal takes in all of the fundamental frequencies related variables, such as scales, melodies or harmonies. Measures/Tempo and Rhythm subdomain are both related, although rhythm is when and how long a sound is played, and Tempo/Measures is more of a structure subdomain where rhythm is built upon. Although the subdomains exist separately, they tend to cohabit and be learned together as they are, in fact, what constitutes music in itself. A better representation of how the division of music exists into these five subdomains in figure 3 is presented.

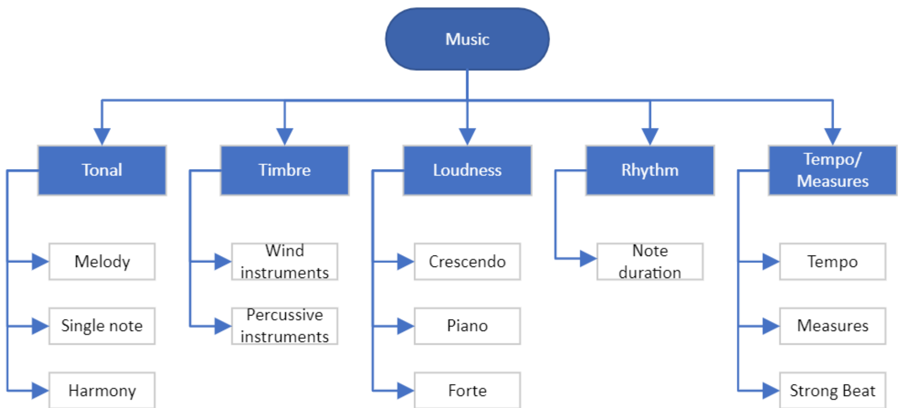

Figure 3- Example of music variables sorted through the five subdomains

When applying the concept of the Model of Hierarchical Complexity to music, it is interesting to apply it to each music subdomain: rhythm, timbre, tonal (melody and harmony), loudness and tempo/measures. Besides, as we interact with music in many ways, from listening/comprehending to playing or composing, it is also necessary to develop the stages for each interaction. Developing these OHC and theorising about them, it is necessary to perceive that perhaps playing one instrument is different from playing another, and the hierarchical complexity proposed will not be unrelated to each instrument.

Tonal playing OHC

Presented with the idea of theorising the hierarchical stages for music, the first thought was to start organising the tonal part of music. Therefore, the first assumption was based on the piano as it is an instrument that the quality of timbre produced by the music player is not as hard to obtain as other instruments. On the piano, a player strikes a key, and the hammer will play the string producing a pleasing sound. That does not happen as easily on the violin as the learning violin player will need many conjugate movements to produce a "beautiful" or pure sound first. This differentiation corroborates the idea that each instrument probably has different hierarchical complexity orders but allows us to utilise the piano learning process as an example, as the playing is somewhat distanced from the sound quality produced. This is substantially true, but as the learning process evolves, the piano player will master a better timbre and sound quality.

In the piano, each note is easily perceived as it corresponds to each key, which also helps in the learning process as the piano player does not need to worry about the pitch frequency he is producing as a trombonist would do in order to play in tune. Therefore, considering a single note as a starting point for a possible order of hierarchical complexity would be congruent with the Model. I am not stating that playing a single note on the piano is stage 0 of the piano playing process but defining it as a starting point to developing an order of hierarchical complexity (OHC)to the motor skills of playing the piano. By comparing it to other proposed OHC(Ross & Commons, 2008) and asserting to the definitions(Commons et al., 2007) it is possible to suggest that it correlates to a Primary stage development.

Thomas Elbert's studies on violinists indicate that the brain region responsible for manipulating the left hand — the hand that demands the most precision in violin playing — enlarges with practice. We do not yet know whether the tendency for growth is innate in some individuals but not in others(Elbert et al., 1995)

The 10,000-hour theory is congruent with the knowledge of how the brain's cognition processes happen. Assimilation and consolidation of information in brain tissue are necessary for learning. The more we experience something, the deeper the memory/learning trail expands. Even if the time it takes individuals to integrate knowledge neurally varies, it remains true that additional practice results in more significant neurological traces, which can be combined to produce a more robust memory representation. Memory strength is proportional to the frequency with which the original stimulus was encountered.(Levitin, 2006)

If playing a single note is the starting lower stage of the OHC when we play a non-arbitrary sequence of close pitch notes, we play a scale, that will correlate to the second stage of the OHC. When learning scales, it is common to start with playing one octave of the C scale, as in the piano, it corresponds to pressing only the white keys. Only after other scales are learned with black keys, considered harder. This process is congruent with the MHC, but this author perceives this complexity as a horizontal complexity, not a hierarchical or vertical one.

After playing scales, the player will learn to skip some notes and not play some consecutive notes producing a melody and establishing the dominance of another vertical stage. As a scale can be viewed as a melody, it is necessary to develop MHC instruments to assess if this learning process has two different vertical stages or the same stage.

Afterwards, two voices will be played simultaneously, or chords added to help the melody gain colour, creating harmony. Therefore the last proposed stage is playing harmony. The four stages presented are set to be a simple example of the applicability of the MHC to the music domain: Note, Scales, Melody and Harmony. This theoretical work will need instruments to prove them, but they are not the focus of this work.

Upon the development of these four stages, they were presented to a series of professional players and music teachers(n=9) who tended first to defend that perhaps harmony was not hierarchically more complex than melody. After a brief discussion and while playing a new song, we rapidly concorded that the theorised stages would probably be correct, as while playing an intricate part, it is necessary to first practice and learn the melody and only subsequently add the harmony, a straightforward representation of the MHC working. These discussions were realised in a presential interview setting.

The proliferation of guitar students and players is a non-obvious subject to address. Nevertheless, the author presents one theory associated with the MHC. According to the MHC is easier and necessary first to master lower stage to progress to a higher stage. Although the OHC presented above was developed for the piano, only looking for the pitch aspect of guitar playing, not the rhythmical and rest, the guitar has been, nowadays, thought through chords fixed hand gestures. This corresponds to the guitar player comprehending his action as playing a single note("melody") while the sounds produced by the instrument are harmony. With this simplification of the harmony stage, the apprentice of the harmonic stage is facilitated because it is melodic learning. This is not the only reason for the proliferation of guitar players and should be viewed as a mere representation of the OHC. The guitar OHC seems to be different from the piano and should be worked on afterwards.

Tempo and Measures comprehension OHC

On a neural level, playing an instrument requires the coordination of regions in our primitive, reptilian brain, such as the cerebellum and brain stem, as well as higher cognitive systems, such as the motor cortex and the planning regions of our frontal lobes. The cerebellum, considered to include a system of timekeepers for our daily lives and synchronising with the music we hear, is likely responsible for people's ability to accurately remember a song's tempo. This indicates that the cerebellum can remember the "settings" it uses to synchronise to music when we hear it and retrieve them when we want to sing a song from memory. It permits us to synchronise our singing with a recollection of the last time we sang. Rhythm, pace, and meter are almost certainly generated and shaped by the basal ganglia, which Gerald Edelman calls "the organs of succession." (Verschure & Edelman, 1992)

While the interaction with music has three main aspects: Playing, Listening and Composing. Listening is better understood as comprehending the music that is being listened. Any sound can enter our inner ears; therefore, music in any degree of complexity can be heard by anyone. This profoundly affects the notion of the OsHC of listening interaction when compared to the other two OsHC based interactions of a subject with music because on the other two, the subject's music is the threshold, and here the music can be limitless, and their comprehension of the subjects is what set them apart.

In this regard, it would be possible to characterise a new OHC regarding notes or tonal aspects of music. However, another approach was taken as we analysed the OHC with measures in eyesight. Exploring a different way to obtain the OHC, we propose that the meter in music is a higher hierarchical complexity stage than something and started to unravel from the top to the bottom until we get the OHC perception of the meter of music. When talking of the meter or measure, we are referring to the capability of stating the number of beats in a bar of music. The definition of the lower stage from the one set is obtained from the measure's definition. The number of beats in a bar is determined by the number of beats between two strong beats. The comprehension of the strong beat is the second highest stage. Before knowing what beat is the strong beat, knowing where each beat stands needs to be mastered, being the third highest stage. In musical terms this is commonly called knowledge of the tempo of a song.

Moreover, the lowest stage comes from the tempo aspect of music as before knowing the beats of a music, a subject will capture if a song is fast or slow. With this, the four stages of the comprehension of the number of beats in a measure are set: Speed of a Song, Beat localisation (tempo), Strong beat perception and knowing the number of beats in a bar.

Typically song excerpts constantly have the same measure to give a sense of repetition and predictability. A higher stage can be theorised correlated to using different meter bars on a single piece of music. Exemplifying a song with all bars with 4 beats and in the middle the composer utilises a 5 beat measure, and if the subject can comprehend this, he is in this higher stage.

It is essential to pay attention to the non-cultural importance that the MHC has. With that in mind, an abstract idea was proposed: Any number of beat measures would be considered in the same hierarchical complexity, all horizontal complexity. This is perhaps an abstract and debatable idea, as in Western Culture, almost all music has 4 beats per bar, and therefore while testing a subject, if he states that a song has 4 beats per measure, would most of the time be correct. It is vital to reiterate the importance given by Piaget to the capability of the subject to explain profoundly the answers given, which is another reason for the idea of any number of beats in a measure being a horizontal complexity. That said, the capability of understanding even non-common measures like a 7 beat bar is considered horizontal complexity, although this idea needs post-confirmation.

ORDER OR STAGE		PIANO TONAL PLAYING	MEASURE COMPREHENSION	TIMBRE PERCEPTION
6	Preoperational			Tonal vs Rhythmical Instruments
7	Primary	Single note	Velocity	Wind vs String Instruments
8	Concrete	Scales	Tempo	Woodwind vs Brass Instruments
9	Abstract	Melody	Strong beat	Single instruments(trumpet vs trombone)
10	Formal	Harmony	Measure	Different sounds on an instrument(staccato)
11	Systematic		Irregular	

Table 1- Orders of Hierarchical Complexity Proposed

While understanding measures and knowing the tonal complexity is of vast importance in music, it is also important to perceive which instruments are playing, called timbre perception. As mentioned before, timbre is associated with each instrument and as each instrument can produce a unique sound, the capability of understanding which instrument is playing is a cognition process. Therefore we present the third OHC on timbre discrimination.

The first and easiest stage is the ability to differentiate between a percussive instrument and a melodic one. A percussive instrument is mainly focused on the rhythmical aspect of music. The notes played have a frequency and therefore pitch, but most of the time, the rhythmical aspect of the notes played is more important. On the contrary, the melodic or harmonic instruments relate more importance to the tonal part of music. Melodic instruments mainly play melodies, although they can sometimes play harmonies, and harmonic instruments do the opposite. A guitar, although considered a harmonic instrument, can also play a melody.

Afterwards, the ability to understand between wind and string instruments can correlate to the second stage of hierarchical difficulty. Wind instruments often have a resonator that, through the vibration of hair along it, produces sound, the variation in the size of the resonator shifts the pitch of the note. String instruments have a string that vibrates, and the sound gets amplified with the help of a shell. The size of the string determines the pitch played. These two types of instruments produce very different timbres.

A stage higher from these would be to understand the difference between the two types of instruments that exist on wind instruments: brass and woodwind. The difference is associated with the material used on the tube that is the resonator and correlates to a vast difference in timbres. Afterwards, the comprehension of single instruments is one stage higher on this OHC of timbre perception when by earing a sound, a subject can determine if it is a trombone or a trumpet, both instruments of the same family. Ultimately, the highest proposed stage in the perception of timbres is the knowledge of specific sounds produced by each instrument when played in determined ways. The sound can be long, muffled, short and direct(staccato), or in a Viola played over the scale, producing a very thin sound(sul tasto). These techniques can sometimes profoundly alter the sound played or insert only a slight variation to the standard sound; however, as the capability of knowing which instrument is doing playing a sound and the technic used is all the same hierarchical complexity stage.

Future Work

The work developed presents theoretical structures in three subdomains of music, timbre perception, tonal piano playing and tempo and measures comprehension. It is necessary to prove them through test to validate their sane development. The OHCs proposed were constructed upon the definitions of the music subdomains and variables, therefore, they should be correct, although the positioning on the stages of MHC may not be. Upon developing the tests and analysing the responses obtained mathematically, the correctability of these OHCs can be confirmed.

Appendix A- MHC Stages definition(Commons et al., 2007)

ORDER OR STAGE		WHAT THEY DO	HOW THEY DO IT	END RESULT
0	Calculatory	Exact-no generalisation, computer computations	Human made program manipulate 0, 1 None	None
1	sensory or motor Discriminate	Discriminate in a rote fashion, stimuli generalisation, move	Move limbs, lips, eyes, head. View objects or move	Discriminative and condition stimuli
2	circular sensory-motor	Form open-ended classes	Reach, touch, grab, shake objects, babble	Open ended classes, phonemes
3	Sensory-motor	Form concepts	Respond to stimuli in a class successfully	Morphemes, concepts
4	Nominal	Find relations among concepts Use names	Use names and other words as successful commands	Single words: ejaculatives & exclamations, verbs, nouns, number names, letter names
5	Sentential	Imitate and acquire sequences. Follows short sequential acts	Generalise match-dependent task actions. Chain words	Pronouns: my, mine, I; yours, you; we, ours; they, them
6	Preoperational	Make simple deductions. Follows lists of sequential acts. Tell stories	Count random events and objects. Combine numbers and simple propositions	Connectives: as, when, then, why, before; products of simple operations
7	Primary	Simple logical deduction and empirical rules involving time sequence Simple arithmetic	Adds, subtracts, multiplies, divides, counts, proves, does series of tasks on own	Times, places, counts acts, actors, arithmetic outcome from calculation
8	Concrete	Carry out full arithmetic, form cliques, plan deals	Does long division, follows complex social rules, takes and coordinates perspective of other and self	Interrelations, social events, what happened among others, reasonable deals,
9	Abstract	Discriminate variables such as Stereotypes; logical quantification; (none, some, all)	Form variables out of finite classes Make and quantify propositions	Variable time, place, act, actor, state, type; quantifiers (all, none, some); categorical assertions (e.g., "We all die")
10	Formal	Argue using empirical or logical evidence Logic is linear, 1 dimensional	Solve problems with one unknown using algebra, logic and empiricism	Relationships are formed out of variables; words: linear, logical, one dimensional, if then, thus, therefore, because; correct scientific solutions

11	Systematic	Construct multivariate systems and matrices	Coordinates more than one variable as input Consider relationships in contexts	Events and concepts situated in a multivariate context; systems are formed out of relations; systems: legal, societal, corporate, economic, national
12	Metasystematic	Construct multi-systems and metasystems out of disparate systems	Create metasystems out of systems Compare systems and perspectives Name properties of systems: e.g. homomorphic, isomorphic, complete, consistent, commensurable	Metasystems and supersystems are formed out of systems of relationships
13	Paradigmatic	Fit metasystems together to form new paradigms	Synthesise metasystems	Paradigms are formed out of multiple metasystem
14	Cross-paradigmatic	Fit paradigms together toform new fields	Form new fields by crossing paradigms	New fields are formed out of multiple paradigms
15	Meta cross paradigmatic	Reflect on various properties of cross-paradigmatic operations	Explicate the dynamics of, and limitations of, cross-paradigmatic thinking	The dynamics and limitations of cross-paradigmatic thinking are explained as they are recursively enacted

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Appendix B

Test for determining cognitive stages of development using music

Test for determining cognitive stages of development using music

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***Abstract*—Learning through a structured hierarchical complexity approach has proven successful and more efficient than standard practices.**[1] **In this work, we develop an instrument for assessing in a 163 population if learning music through the premises of the Model of Hierarchical Complexity is more efficient than a non-structured approach. The elaboration of this test allows a first step in collecting pieces of evidence that music variables, such as tempo or measures, are hierarchically structured and are non-cultural dependent. The teaching method introduced learning on the subjects in a 30-minute test, developing a 60 % increase on stage performance. Nonetheless, it made no difference between the non-structured and MHC structured tests. The results obtained allowed more profound information on the development of the stages and the exercises while confirming the hierarchical structure of one of music's subdomains.**

Keywords—Music, Learning evaluation, Subject testing

I. Introduction

The Model of Hierarchical Complexity (MHC) establishes a framework to structure the levels of reasoning in any topic and across cultures. The scoring is not dependent on the subject matter or participant submissions but rather on the mathematical complexity of the hierarchical structuring of information.

The MHC is a quantitative behavioural developmental theory that posits that task sequences create hierarchies that get more complex instead of explaining behaviour variation over age due to mental structures or schema formation. This explains the developmental changes observed since less complicated tasks must be completed and practised before learning more complex tasks.

When analysing task complexity, it is common to assess its horizontal complexity. For example, in a school, when a class has learned multiplication and the teacher wants to understand the level of each student will ask more challenging multiplication questions increasingly. Although this complexity exists, this correlates to horizontal complexity. The number of stimuli that must be addressed (individually) within a task and the number of response types necessary to complete it are examples of horizontal complexity. One way to quantify horizontal complexity is to count the informational components of activity and the number of bits embedded in that task. Horizontal complexity can be objectively assessed and quantified. No horizontal complexity mechanism considers the varying difficulty of various task types.[2]

Formally, a task must satisfy three conditions in order to be more hierarchically complex than another. First, two, or more, less complex tasks, and their actions, are used to describe a higher-order action. This makes the higher-order action include the lower ones and impose a hierarchical nature. Second, the more hierarchically complex task organises or coordinates two or more activities that are less difficult; in other words, the more complicated action describes how the more uncomplicated actions should work together, making it more robust. Third," Higher order of complexity actions organise those lower order actions in a non-arbitrary way" [3]

The Model of Hierarchical complexity identifies 16 orders of hierarchical complexity, and due to the previously explained premises, it has a tree-like structure. It is developed to approach personal development throughout a lifetime.[4]–[6] Humans, their biological systems, social organisations, non-human animals, and machines, including computers, are examples of entities that organise information. Its extensive applicability comes from a straightforward mathematical approach to defining tasks, and tasks may contain any information. As a result, it can be used in any situation because it just uses quantitative concepts.

First and foremost, it is important to define what music is and then explain the process of developing the test we utilised to assess if learning through the MHC was beneficial. In the words of the French composer Edgar Varese:" music is organised sounds", sounds perceived by our air cells in the inner ear that are transmitted over electrical signals through the midbrain to the auditory cortex.[7] Music can be described as language organised in a system of rules that makes all parts work together: rhythm, melody, harmony, intensity, pitch, and timbre [8] We consider that music has infinite variables (scales, melody, harmony, types of instruments, measures…), but these can be arranged in five subdomains: Tonal, Timbre, Loudness, Rhythm, and Tempo/Measures. This idea is better shown in Fig. 1. According to the MHC, all these dimensions can be divided into levels of hierarchical complexity. Apart from the multiple music variables, a subject can interact with music in three ways. First, when we think of music, we create a visual image of a person playing an instrument, corresponding to the interpretation of music. Playing music is the first interaction with music. The second is the first approach, anyone, not deaf, has with music, hearing it, yet in this work, we are interested not in the earing part but the comprehension of the eared sounds. Anyone can hear the most complex music, but few can fully comprehend the harmonies, the rhythm and measures used or the instruments selected for each part. The third and final interaction is its creation. In order to exist, music needs to be composed.

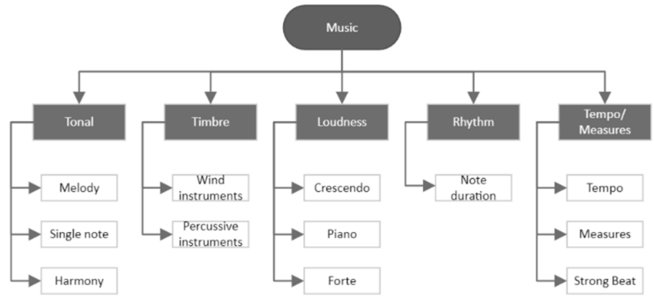

Figure 1-Examples of music variables sorted through the five subdomains of music.

The subdomain of tempo/measures comprehension was chosen as it is better correlated to a non-associated notation required and a non-cultural assessment of musical comprehension knowledge while still significantly impacting the perception of musical cognitive stage development.

Time is one of the essential concepts in music. Tempo refers to the pace at which a musical work develops rapidly or slowly. The speed of a piece of music can be determined by how quickly or slowly the listening subject taps his foot or snap his fingers in time to it. If a song is imagined as a living, breathing thing, its tempo could be compared to its gait—the speed at which it moves—or pulse—the speed at which its heart beats. The basic unit of measurement in a musical composition is denoted by the word beat. Most frequently, this is the natural time to clap your hands, tap your foot, or snap your fingers.

How pulses or beats are clustered is referred to as meter or measure. When tapping or clapping along with music, we tend to sense certain beats more than others. It appears that the musicians are playing this rhythm louder and stronger than others. This louder, heavier, stronger beat is perceptually dominant, and the beats that follow it are perceptually weaker until another powerful beat appears. There are patterns of strong and weak beats in every known musical system. The most frequent pattern in Western music is for strong beats to appear every four beats: STRONG-weak-weak-weak. STRONG-weak- weak-weak.

Tempo/measures subdomain of music comprehension can be hierarchically ordered in five stages. According to the MHC, these correspond from the primary to systematic stages. This order of hierarchical complexity (OHC) starts from knowing the velocity of a song (Fast vs Slow), followed by tempo perception, strong beat recognition, beats per measure, and identifying irregular measures.

The last stage, called Irregular measure perception, is, in fact, a subject's capability to comprehend if a song has any measure different from the others. For example, typically, a 4 beats per measure song, has 4 beats measures throughout the entire song. An Irregular one will have an irregular pattern of beats. For example, the song American Tune by Paul Simon, a 4 beats per measure song, has 5 beats measure on the "Smiled reassuringly" part.

II. Methodology

A. Elaboration of the test

A two-test instrument was prepared and is available online where half of the population would learn via a structured test and the rest through a non-structured test. [9] This means, half of the population has a test formulated according to the MHC premises, and the other half has a non-structured test. Subject's distribution between tests was made randomly upon entering their data.

The instrument has three distinct parts: i) initial stage assessment, ii) structured or non-structured teaching, and iii) new stage assessment. The first and last parts are similar on both tests. In the beginning, through 10 exercises, the stage at which each subject enters the instrument is assessed. In the second part, the learning process happens, constructed firstly from the solutions of the 10 first exercises. Secondly, the different part of the instrument occurs. On the structured test, a stage-by-stage explanation of the concepts is performed. On the non-structured test, the same explanations but in random order are viewed. in Appendix A and B the detailed flowcharts of each test. In figure 2 an overview of the flowchart is presented. After the learning part, the subjects are evaluated with exercises, for both tests.

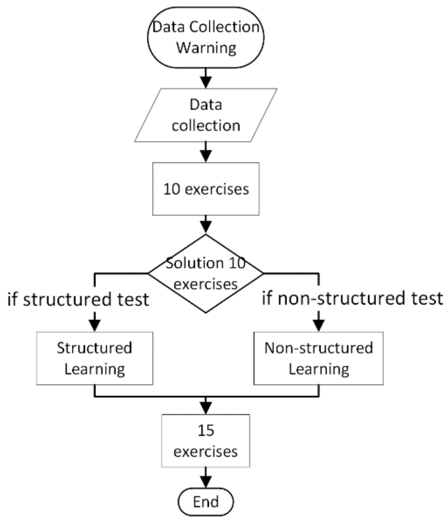

Figure 2- Test Flowchart simplified

B. Exercises development

The first stage of the OHC of Tempo/measures is the comprehension of the velocity of a song. Velocity exercises had a primary button with a song, and the subject is asked if the song was fast or slow. It where only chosen songs with 40-75 BPM as slow ones and over 120 BPM as fast songs. The variation in tempo perception was challenging for the first stage's exercise formulation as sometimes a subject can perceive double or half the beats. This occurrence is already mentioned in Levitin's work[7]. As this was the first stage, it was not supposed to analyse the tempo but the song's feeling through the tempo. This is a one-stage lower question from tempo's, and the choice of clearly slow or fast songs was taken into consideration for better results.

The second stage evaluation, tempo perception, was done by comparing two overlapped excerpts of the same song: one with the tempo correctly and another incorrectly sang. In order to only have differences in the sang tempo and not in vocal cues or different intonations, the same sang recording was used while altering a 10% recording speed computationally without altering the pitch. The comparison approach of formulating the question was made to approximate the third and fourth exercise formulations. The choice of songs followed a multicultural and multi-horizontal difficulty. This horizontal complexity was based on the first two levels of the three proposed in Velautham work, where it is proposed three increasing levels of difficulty in perceiving the tempo of songs[10]

Strong beat or “downbeat” is the foundation where measures lie, and although easily perceived by any amateur musician, it is not a common question to be asked. This was the base for the third stage exercises where the subject from a series of excerpts with overlapped beats sang would need to identify on which the strong beat was sang

In the formulation of the stages, the idea of horizontal complexity was proposed upon non-typical measures and non-cultural complexity. It is not the same complexity to identify a 4 beats per measure or a 7 beats per measure song, but this difficulty correlates to horizontal complexity, not vertical/hierarchical.

This horizontal difficulty was utilised in the choice of the songs on all stages but especially on the third, fourth and fifth. The fourth stage is the comprehension of the beats per measure of a song. Although this is one of the most straightforward questions to be asked, it was introduced in its formulation an approximation to the third stage. Besides the original excerpt, four overlapped excerpts were presented with the tempo sung while counting the four main used measures (3, 4, 5 and 7 beats per measure). By comparison, the subject would need to choose what was the beats per measure used on the original unaltered excerpt. This approach allowed for an approximation to the third stage and neutralisation of the double or half-beat perception that was mentioned in the stage one formulation.

The final stage, Irregular Measures exercises, had an unaltered song excerpt, and the subject would need to answer correctly to the regular used measures and perceive if any of the measures were different and, if so, which was it. The exercises for the final stage were prepared from a selection of songs, including an explicitly composed for this instrument with a 7 beat per measure base and a single 4 beats measure.

C. Learning part

The only differing part between tests is the learning part initiated by a demonstration of the solution for the 10 first exercises while displaying the subject’s answer. This solution presentation was equal for both tests.

After the first 10 exercises, the structured test assessed in what stage the subject was and displayed accordingly examples of a stage higher. For example, a subject performing at stage 2 was first presented with examples of the third stage.

These examples were prepared through a similar process to the exercises, as having the same page structure and questions. The answers options were provided for the user, but the responses given were not registered. Furthermore, solutions were provided if the subject requested them.

In the three higher stages, apart from the exercise alike formulation, a deconstruction of how to get to the conclusion through the stages was presented before the solution was given.

For example, in the fifth stage examples, subjects were presented with a primary button with a different song excerpt from the exercises, and the two same questions were asked, although the answers given were not retrieved. Beneath the questions options, there was an explanation area where the excerpt would initially have the tempo sung over, then another button where the strong beat was prominently sung, followed by the counting of the regular measures and finally the counting of the regular measures and irregular measure. Only after this hierarchical deconstruction of the question, the solution was displayed if the subject required it.

Any subject that took the structured learning process started from one higher stage than what he was performing on the first 10 exercises but passed through all the other stages. For example, the subject that performed at a second stage was presented with the five prepared examples of the third stage, then the five prepared examples of the fourth stage and finally, the five prepared examples of the fifth stage.

The subject could hear the examples and explications as often as he wanted, experience the five examples pages, or pass to the following stage examples. Each example was presented individually on a single page.

The non-structured learning was elaborated from the excerpts prepared for the structured test. This was done as the exercises, although randomly presented, were formulated to ask each stage concept; therefore, the learning process would need to have the same concepts teached.

So, the non-structurality of the non-structured test is more of a random display of the excerpts prepared.

Here, the subject’s performance on the first 10 exercises did not count for the examples presented. Each of these subjects was presented with the two twenty random examples prepared pages. These pages counted with some same examples as the structured test, specifically for the first two stages, but on the last three stage examples, the explication part was separated from the examples. The same excerpts were shown, although not organised.

Again there were prepared two 20 example pages that the subject could interact freely, and at the end of the first page, there was the possibility to continue to the following 20 examples or go directly to the last 15 exercises.

D. Subjects stage performance evaluation

According to the MHC to truly assess a subject’s stage performance, he will need to answer correctly to one same stage question. Nonetheless, the answer needs to be conveniently justified, and a subject would be deemed to perform on the question stage with the single correct justification of a question asked. The instrument was built with only right or wrong questions, not open-ended answers. Therefore, having only one correct answer does not directly state a subject stage performance as opposed to what is suggested by Piaget and Commons. [3], [11]

The definition of a subject stage performance was developed to be three correct answers on said stage. A subject that answered correctly to three exercises of the measures stage was considered to be on the measures stage. The stage performance was evaluated sequentially from the highest stage to the lowest.

The final part of the test with the 15 exercises has 3 same stage questions therefore, the subject stage performance is easily obtained.

The initial evaluation part of the test only has 10 exercises, 2 of each stage. This corresponds to an evaluation that happens on the test. At the end of the 10 questions, it sequentially analyses the two higher stage correct answers given by the subject and presents an additional question of that stage to enable the subject to have three same stage questions correct. For example, if a subject only got one exercise right of the measures stage, none of the irregular stage and the strong beat two exercises correct, an extra strong beat question would appear and the answer to that question would set the subject stage performance. If it were correct, the subject would be performing in the third stage if it was wrong, it was considered to be performing in the second stage.

The subtraction of one question of each stage was due to the decrease in time, frustration and consequently, more subjects finishing the test. During the test, the subjects would acquire ease of interaction with the platform and answering times would decrease, allowing a 15 exercise last evaluation part.

The assessment of subject development was done by comparing the stage performance on the initial 10 questions to the stage performance obtained on the last 15 exercises. The learning evaluation of each subject was shown by the developmental stage performance between the first and last exercises.

III. RESULTS

The instrument is available online. At the beginning of the analysis, 467 persons started it and 163 concluded it, 83 on the structured test and 80 on the non-structured test. Their mean age was 27.4 years old with a standard deviation of ± 11.2 for the structured test and 27.9 years old with a standard deviation of ±10.5 for the non-structured test. The instrument took an average of 38 minutes and 10 seconds on both tests without significant variation between them.

Before answering the first 10 exercises, the subjects replay an anonymous survey, namely the: age, gender, academic degree, and musical knowledge. Figure 3 illustrates the distribution of the subjects from a self-evaluation musical knowledge perspective. Here the possible answers are: Professional, Semiprofessional or amateur music player, music lover or non music lover. The vast majority indicated a strong taste for music (amateur musician or music lover). The structured *VS* non-structured distribution presents some imbalance, thus note significative.

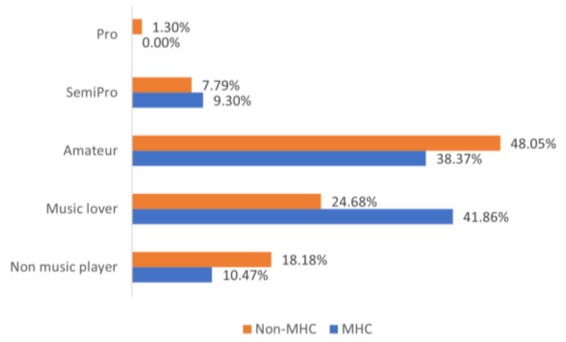

Figure 3-Answers to the question: “Do you consider yourself to be?”- distribution between the two tests

Besides the musical knowledge, it was also asked literacy subject-related questions. With this information, it was possible to visualise the stage distribution through the literacy levels and capacity of learning presented in Figure 4 and Figure 5.

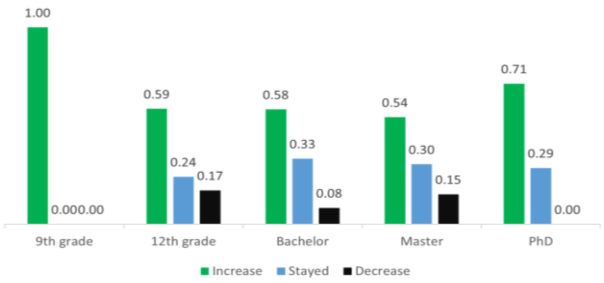

Figure 4- Distribution of average stage performance by literacy level

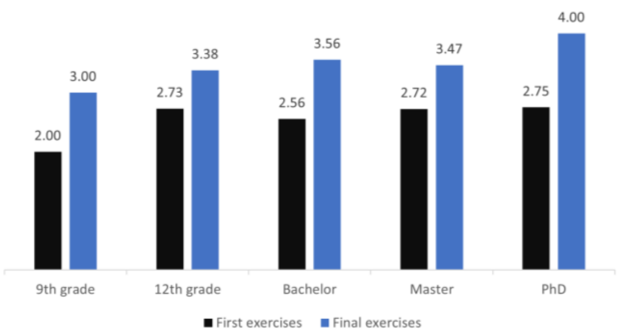

Figure 5- Evaluation of stage improvent- distribuiton through literacy

When analysing the separate areas of the tests, the learning part of the structured test subjects took 6 % longer and 5% longer on the first exercises, while subjects on the non-structured test took 83.5% longer on the final stage of evaluation. Of the 163 subjects, 14 were on the highest stage upon the first 10 exercises.

The stage evaluation was done by assessing the highest stage sequentially where the subjects had 3 correct answers. Figure 6 sows the number of subjects at each level after this diagnose phase. In black are the results obtained with a criteria of three correct answers and blue with two. This last criteria helps the analysis if the last exercise since this only had three questions.

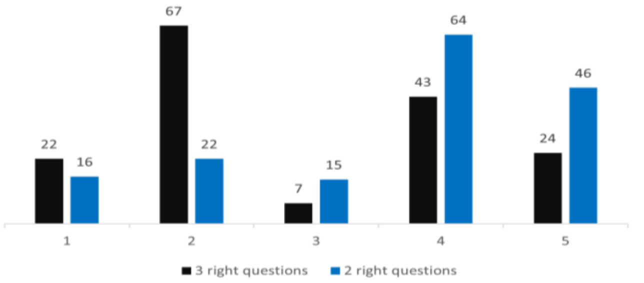

Figure 6- Count of final stage subject obtained on both tests using 3 right questions vs 2 right questions answered

With these final stage performances and through the analyses of the stage obtained in the first part of the exercises, we can understand the subjects that learn music by visualising the ones that got a higher evaluation on the final exercises. These results are presented forward in Figure 7. Here are presented the stage variation (decrease, same or increase stage) when compared with the initial results of that same subject. The four elements correspond to the structured/non-structured tests (in black and blue, respectively) and the changed evaluation of two correct answers for the structured and non-structured tests(in red and green, respectively)

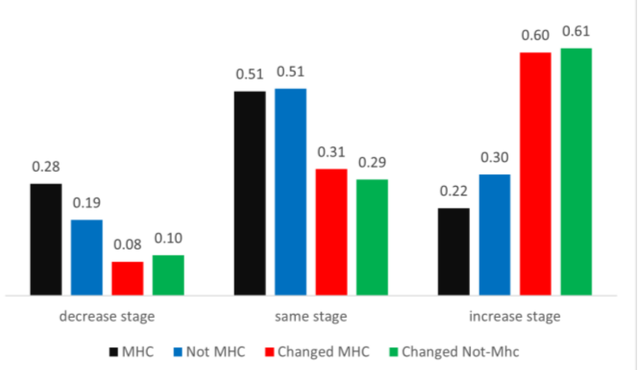

Figure 7- Relative subject performances on both test. The 3 right questions and 2 right questions(changed) final exercise evaluation

The assessment of each exercise's correct responses on both instruments is presented in Figure 4. It included all responses obtained even from non-finished subjects.

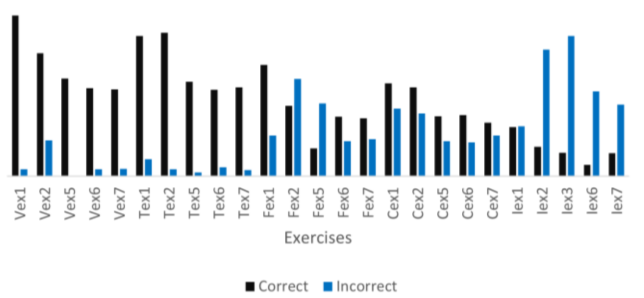

Figure 8-Correct vs incorrect answers on each exercise (Vex- Velocity exercises, Tex- Tempo exercises, Fex- Strong beat exercises, Cex- Measures exercises, Iex- Irregular Measures exercises

IV. Discussion

The tests were randomly assigned, yet we visualised a similarity in both number and subjects' capability as the results on the first 10 exercises were merely identical. The average stage a Non-MHC test subject reached on the first instrument part was 1% higher than the MHC test subject with a 6% standard deviation difference.

The evaluation of subject development was done by comparing the stage performance on the initial 10 questions to the stage performance obtained on the last 15 exercises. The definition of a subject stage performance was developed to be three correct answers on said stage. A subject that answered correctly to three exercises of the measures stage was considered to be on the measures stage. The stage performance was evaluated sequentially from the highest stage to the lowest.

According to the MHC to truly assess a subject's stage performance, he will not only need to answer a question correctly but conveniently justify said answer, and with the single correct justification of a question asked, a subject would be deemed to perform on the question stage. The instrument was built with only right or wrong answers, not open justification answers. Therefore, having only one correct answer does not directly state a subject stage performance as suggested on Piaget and Commons. [3], [11]

Initially the proposed evaluation was 3 right exercises to try to correct the effect of randomly answered correct answers. The evaluation of the population stage performance on the last 15 exercises led to an assessment of a new definition of stage performance where two correct answers would set the subject stage performance. The differences in both evaluation methods are shown in Figure 2. This difference correlates to a higher stage performance of the subjects, as expected.

Through the 2 correct answers, there is room for a non-comprehended question or a more horizontally complex question out of the 3 asked for each stage. The analysis of perhaps more difficult questions to answer on the same stage will be done later.

The learning evaluation of each subject was shown by the developmental stage performance between the first and last exercises. The first stage evaluation method of the 3 right questions led to a 22% increase in stage performance for the MHC subjects and 30% for the non-MHC. Although these are good learning results the majority of the subjects, by this evaluation standard, remained on the same stage. Nonetheless, through the 2 correct answers evaluation, a 60% increase was seen in both tests, correlating to a better understanding of the learning process as we have more subjects that are considered to have learned and, therefore, more data.

Prior to the final instrument, some preliminary tests took place both online and locally. The preliminary tests mainly searched the exercises' performance and the subjects' dispersity through the stages proposed and not the time spent between test parts. As stated by Piaget and followed by M. Commons, there should not be a time constraint on the subject learning.[11], [12] The idea of a non-constricted timeframe for the learning part of the instrument was also taken to the exercises. As the webpages where the exercises were displayed were specially developed for this instrument, non-prior knowledge of user usability was known, and time to get familiarised with the page and how the exercises were constructed was estimated.

Although with a higher than 60% increase in stage performance, cognitive development occurred. The elaboration of this instrument was not intended to be the best teaching method in the 30-minute window of the interaction of the subject with the platform but as an instrument to compare two different approaches to the learning process. This comparison is heavily influenced by the 83.5% more time the Non-Mhc test subjects spent on the final exercises since prolonged exposure to the exercises can possibly lead to better results.

It is viewed in Figure 5 that there were subjects with more musical knowledge on the non-MHC test, particularly amateurs, which can correlate to a better predisposition to recognise and better learn the variables' concepts.

It is interesting to visualise that individuals with higher education got higher stages. However, it does not seem to correlate with the learning capabilities as the three middle education levels, which were also the most considerable, got identical learning values, as seen in figure 7.

The exercises were developed through an iteration process where the middle three stages' exercises had a primary button with a sample not altered music and other secondary buttons with the same excerpt with computationally overlapped sounds. Underneath, a question about the heard sounds is asked. The first and the final stages' exercises only have the primary button and the questions. Although previously tested through preliminary tests, the distribution of exercise answers obtained was the first representative population distribution. Through it, we see a dispersion of results through the five stages in figure 3, relating to a good assessment of the hierarchical structurality of the proposed variables and good elaboration of the exercises.

This idea is visible as in each of the first exercises of each stage, the proportion of right questions vs wrong decreases. There are, however, some discrepancies. Mainly on the third stage, strong beat perception. This can be associated with two reasons: non-typical concept to be asked, and Fex2 (Strong beat exercise 2) was the first presented exercise on the instrument while having a non-usual measure, 7 beats per measure.

Strong beat or "downbeat" is the foundation where measures lie, and although easily perceived by any amateur musician, it is not a common question to be asked.

In the formulation of the stages, the idea of horizontal complexity was proposed upon non-typical measures and non-cultural complexity. It is not the same complexity to identify a 4 beats per measure or a 7 beats per measure, but this difficulty correlates to horizontal complexity and not vertical/hierarchical.

It is possible to visualise that the usual measures(3 and 4 beats per measure) have better results. Cex7 (Measure exercise 7), a 5 beats per measure song had worse results than Cex1, a 3 beats per measure song.

We see a significant discrepancy on Fex5 answers that is not easily explained as the song used is a predominantly electronic rhythmical instrument based on a 4 beats per measure structure and was supposed to have a better correct answers ratio. It was, however, the first exercise after the learning part, and it can correlate to the same problem observed on Fex7 on the first exercise part. Nonetheless, on Fex7, a 7 beat per measure is used, and as it is a non-common measure, the low correct answers ratio is more comprehensible.

Cex5, although an Asian song, still got good correctability for stage performance in a European mainly population tested. We are inclined to state that the non-cultural complexity was well associated and that the music subdomain on which to test was well thought of as stage performance should not be culturally specific. To further corroborate the non-cultural analysis of the OHC, an Indian song was used on Tempo exercise 2 (Tex2) and also got a good correctability for stage performance.

The last stage, called Irregular measure perception, is, in fact, a subject's capability to comprehend if a song has any measure different from the others. For example, typically, a 4 beats per measure song only has 4 beats measures throughout all of the song. However, the song I Say a Little Prayer written by Bacharach, David and Warwick, a 4 beats per measure song, has a 3 beats measure on the chorus part. The exercises for this stage were prepared from a selection of songs, including an explicitly composed for this instrument with a 7 beat per measure base and a single 4 beats measure. One of the questions to be asked was if the song used had any different measure because there was the possibility of having a song with only regular measures. That was the case for Iex1 and Iex7(Irregular exercises 1 and 7), and as seen in figure 4, these had more correct answers than the other exercises of the same stage while having closer results to the lower stage.

Iex7 while having only regular measures, did not have similar results to Iex1. The song chosen was a piece of classical western music with a fast tempo, and the beats per measure could be perceived differently from the ones assumed as the correct response, although the used answer was defined by the composer and profoundly searched to prove it.

The variation in tempo perception was also challenging for the first stage's exercise formulation. Velocity exercises (Vex) had a primary button with a song, and the subject would be asked if the song was fast or slow. In order to facilitate the separation between fast and slow songs, it was only chosen songs with 40-75 BPM for slow songs and over 120 bpm for fast. This perception was often correctly done; however, in Vex2, some users comprehended the tempo as double the speed and incorrectly perceived the song as fast while it was assumingly slow. This wrongful evaluation was already warned by Levitin and taken attentively on the elaboration of the rest of all stages' exercises.[7]

When comparing the Iex1 results to the Measure stage exercises (Cex) we see a similarity in correct responses but with a slight variance where the lower stage exercises outperform the higher stage. This will probably be related to the elaboration of the fourth stage exercises as these had secondary buttons to the primary with examples of the beats per measure, while the Iex1 only had the primary button.

This study wanted to address the significant impact that the learning would be more profound by presenting a structured teaching approach. This was not viewed through the data as the non-MHC subjects presented a better increase in stage performance. We can conclude that the instrument, independent from which test the subject took, got to higher stages, yet the results are not as separated as expected and the non-MHC had even better results.

This can be associated with the time spent on the last 15 exercises that correspond to the final stage assessment and therefore have significant importance on the learning scale used. However, why was the time taken to answer the last part of the test so uneven? This will have to be related to the second part of the instrument as it is the one that differs between tests.

The learning part was also created with an iterative method. First, it was a video presenting the concepts with the support of visual spectrograms and, therefore, visual clues. After realising the non-self learning speed that each subject needs, as suggested on the MHC, and that the cognition stages should be accomplished individually by the subject and that the visual clues could interact with the visual cortex, and the association of the concepts could be related to non-auditory perception. The idea of showing the solutions was introduced. At the second stage of the learning part iteration, this was the only learning of the test, and through a preliminary test with 11 people, only one increased stage and therefore learned the concepts. The third and final iteration of the learning test part was developed. Starting with the solutions for both tests, it changes only after that.

The MHC test examples were prepared, formulated and displayed the same way as the exercises. These were shown to the subjects in a structured stage-by-stage formulation. Apart from displaying the exercises like examples with solutions to them, a deconstruction of the solution in the lower stages existed in the three higher stages. The interaction with these pages was subject-self-related, but we can analyse through the data that most of the buttons were at least utilised once. For each stage, there were prepared five different examples. Upon the first 10 exercises, the subjects were directed to one higher stage examples from their stage. On each example, the subject could select to continue to visualise the other same stage examples or continue to the following stage examples. In Appendix B, the flowchart of all the MHC test is presented, and it is perhaps easier to visualise the test structure there.

The non-MHC learning examples part was prepared from the MHC examples. The same songs and excerpts were utilised, allowing the subject to interact with them freely. It was, however, displayed differently. Two 20 randomly placed examples pages were presented without differentiation for the stage got on the first 10 exercises.

The similarity of the learning part and exercises parts on the MHC could have correlations to the results obtained where the subject could not have understood that he was on a learning interaction and therefore did not predispose himself to a knowledge-gathering experience. Furthermore, without the delimitation of the three different parts of the instrument, subjects can experience boredom and frustration as the experience with the instruments does not vary.

While collecting some feedback on the experience of utilising the instrument, frustration for the duration of the test was a constant statement. This feedback was from a small part of the tested population and not associated with any test, so it should be considered accordingly. It would be interesting to have asked a survey on the predisposition and interaction with the instrument when the end of the instrument was reached. These formulations were already done on some MHC instruments to assese stage development but with the time duration of the test and since what was being studied was the teaching through the MHC and not the stages formulation, although it ended being possibly confirmed, it was chosen not to ask those questions.

CONCLUSION

When first thinking of musicality, a typical thought is the ability to play music. This would lead to the first instrument created to access the apprentice of music to be on playing music. Playing music is a construction of several subdomains of music. When playing, for instance, the violin, it is needed to master the timbre produced, the pitch played and the rhythm inside of the specific measure. It would perhaps be easier to access a piano player's level as the timbre production, and pitch playing are hierarchically less complex. The order of hierarchical complexity of the tonal playing piano is already proposed (single notes, scales, melody and harmony). Nevertheless, the possibility of getting a group of people that were in a low stage of piano and that could get to higher stages on playing the piano on a 30-minute interval would be challenging to grasp, and with the fewer results obtained, the conclusions would not be as broad and trustworthy. Therefore, playing music was not the best interaction to test knowledge learning on this instrument but is a necessary step for better conclusions for the analysis of the structured music teaching method.

Timbre perception is also another important subdomain of music and with an Order of Hierarchical Complexity perception proposed [Tonal vs Rhythmical Instruments, Wind vs String Instruments, Woodwind vs Brass Instruments, Single instruments(trumpet vs trombone) and Different sounds on an instrument(staccato)]. Further instruments built on other subdomains of music will allow a broader knowledge of music cognitive stage development.

Besides the other subdomains instruments this Tempo/measure perception instrument could be reformulated having a restricted time for the exercises part of the test and with the subject's thoughts on the test gathered to further analyse the cognitive stage development.

The instrument developed supported the idea of vertical complexity on music variables.

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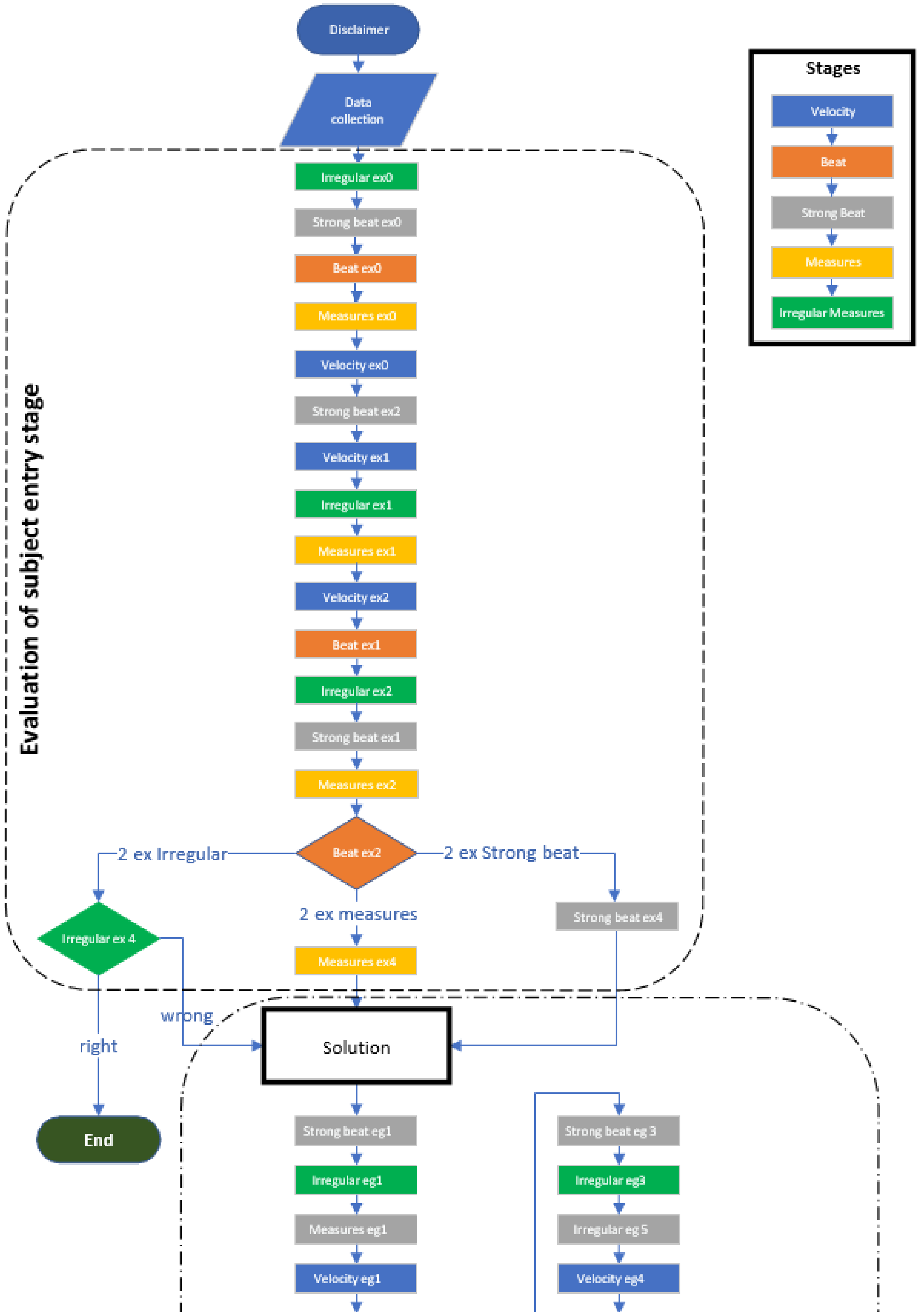
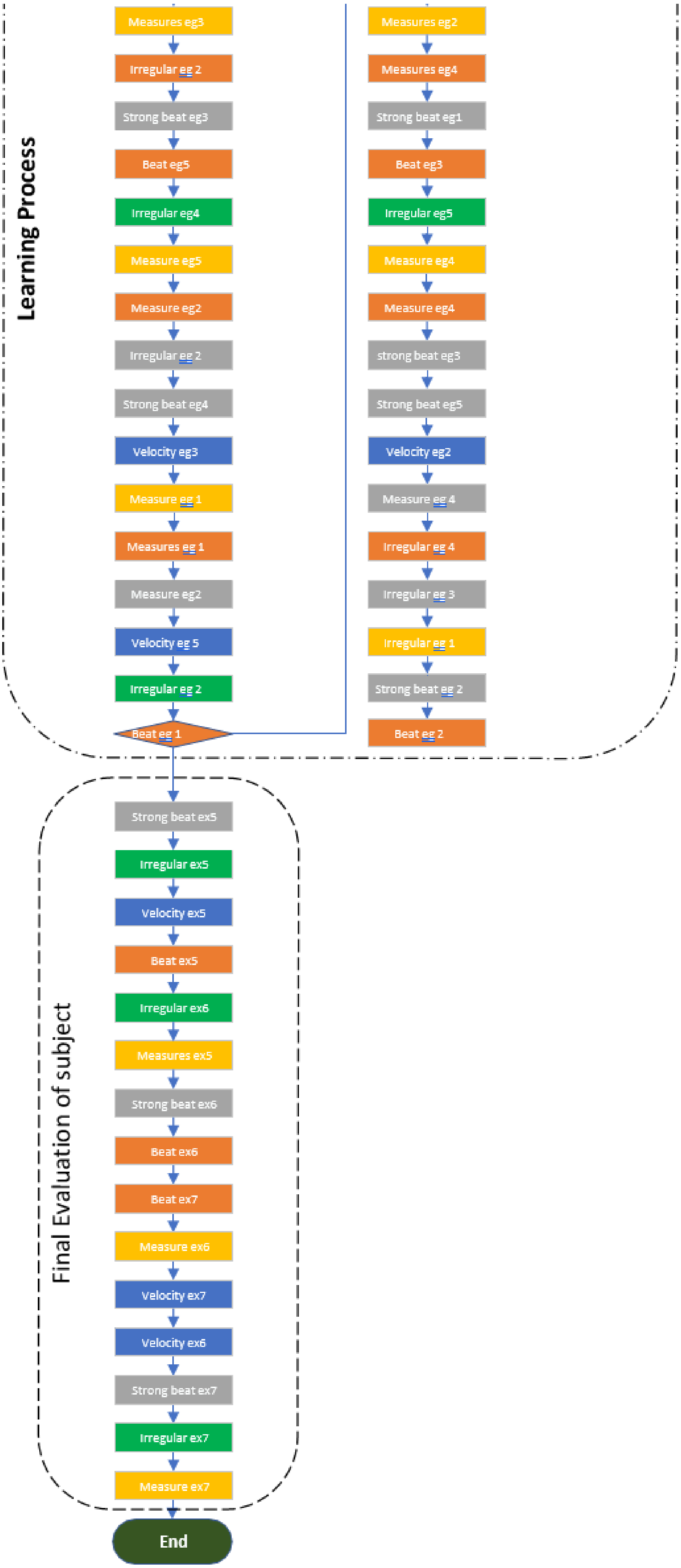
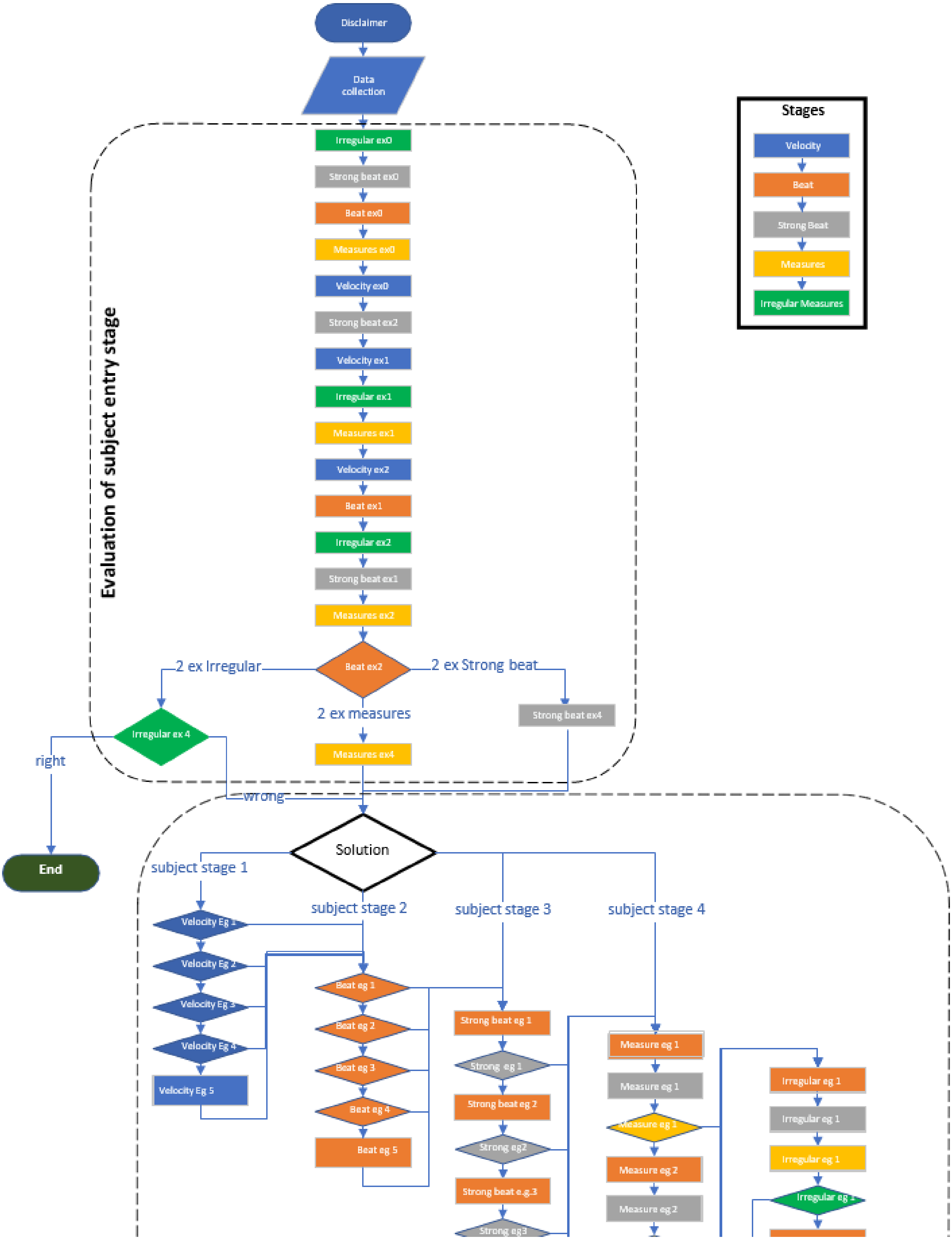
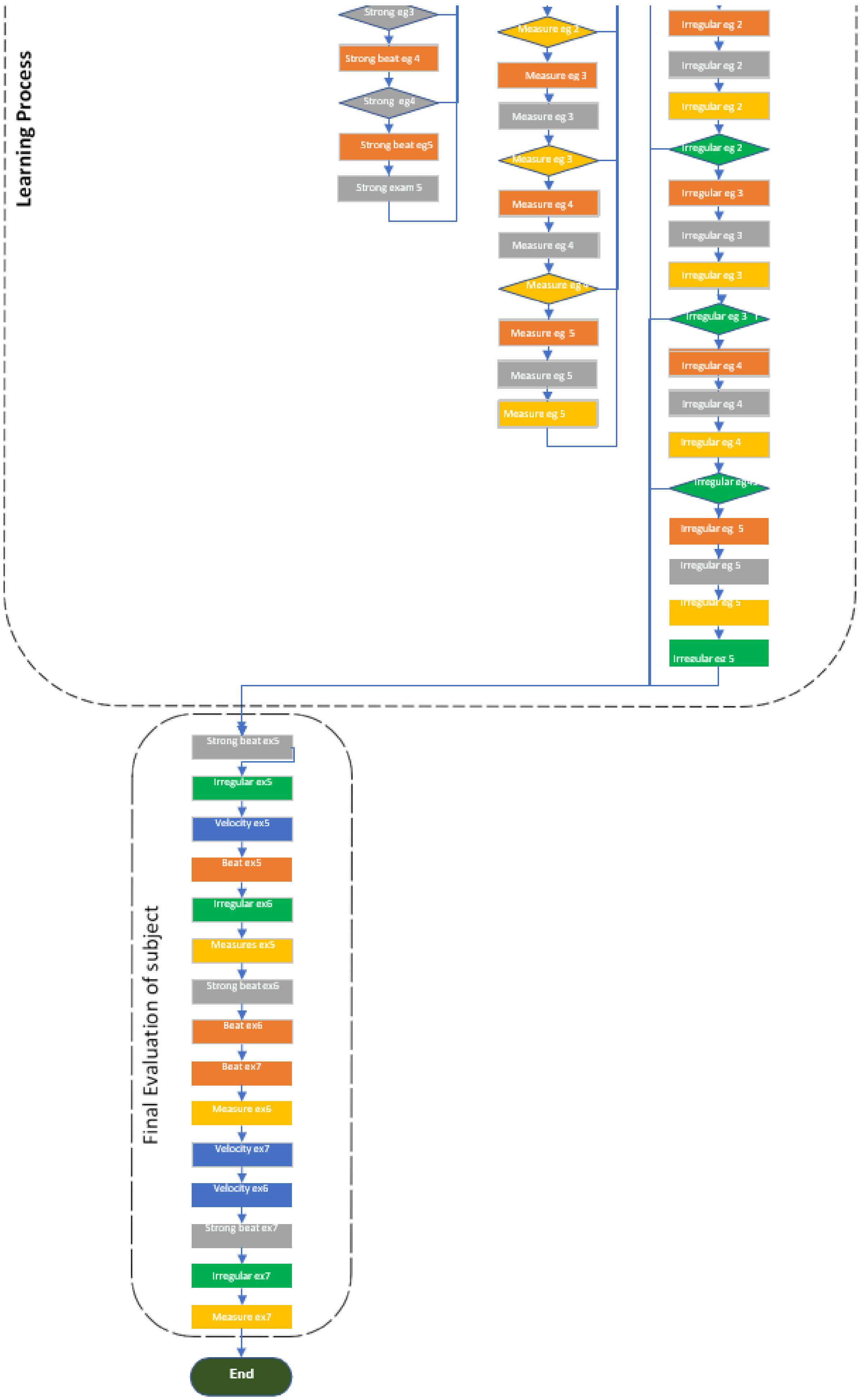
APPENDIX A- Non-structured test Flowchart with circle localisation of evaluation and learning parts




Learning Process
Measures eg3
Irregular eg 2
Strong beat eg3
Beat eg5
Irregular eg4
Measure eg5
Measure eg2
Irregular eg 2
Strong beat eg4
Velocity eg3
Measure eg 1
Measures eg 1
Measure eg2
Velocity eg 5
Irregular eg 2
Beat eg 1
Measures eg2
Measures eg4
Strong beat eg1
Beat eg3
Irregular eg5
Measure eg4
Measure eg4
strong beat eg3
Strong beat eg5
Velocity eg2
Measure eg 4
Irregular eg 4
Irregular eg 3
Irregular eg 1
Strong beat eg 2
Beat eg 2
Final Evaluation of subject
Strong beat ex5
Irregular ex5
Velocity ex5
Beat ex5
Irregular ex6
Measures ex5
Strong beat ex6
Beat ex6
Beat ex7
Measure ex6
Velocity ex7
Velocity ex6
Strong beat ex7
Irregular ex7
Measure ex7
End

APPENDIX B- Structured test flowchart with circle localisation of evaluation and learning parts




Learning Process
Strong eg3
Strong beat eg 4
Strong eg4
Strong beat eg5
Strong exam 5
Measure eg 2
Measure eg 3
Measure eg 3
Measure eg 3
Measure eg 4
Measure eg 4
Measure eg 5
Measure eg 5
Measure eg 5
Irregular eg 2
Irregular eg 2
Irregular eg 2
Irregular eg 2
Irregular eg 3
Irregular eg 3
Irregular eg 3
Irregular eg 3
Irregular eg 4
Irregular eg 4
Irregular eg 4
Irregular eg 5
Irregular eg 5
Irregular eg 5
Final Evaluation of subject
Strong beat ex5
Irregular ex5
Velocity ex5
Beat ex5
Irregular ex6
Measures ex5
Strong beat ex6
Beat ex6
Beat ex7
Measure ex6
Velocity ex7
Velocity ex6
Strong beat ex7
Irregular ex7
Measure ex7
End