MUSICAL PROFILING: TOWARDS A COMPUTER-BASED ANALYSIS OF CLINICAL IMPROVISATIONS

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Tiivistelmä – Abstract Music therapy is taught as a profession, applied in practice by clinicians and investigated by scientists, but there is still no formalised tool for the measurement of the musical processes at its core. This study determines the underlying reasons for the absence of such a tool, and establishes which musical parameters are the most relevant to the music therapy context. It is suggested that every music therapy client has their own manner of improvising that can be identified as a Musical Profile. A method is proposed for the extraction and analysis of the identified musical parameters in order to construct this Music Profile, and it is tested on clinical improvisations. The Profile consists of three parts: *Typical Performance*, *Temporal Evolution* and *Individual Tendencies*. *Typical Performance* is constructed from the descriptive statistics derived from a range of musical features. *Temporal Evolution* measures the changes of the musical material over a period of time. *Individual Tendencies* represent a set of correlations between musical features that are specific to each participant.	
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CONTENTS

1. INTRODUCTION

Music therapy is implemented into health care practices in many countries worldwide. It is potentially capable of improving clients' cognitive function, emotional development, motor and social skills, and quality of life (Bruscia, 1998). Because of such a wide range of positive outcomes, music therapy is applied in medical and psychiatric hospitals, schools, cancer centres, addiction recovery programs, correctional facilities and many other institutions. However a therapeutic intervention that is effective for a terminally ill elderly client might be completely ineffective for a client who is recovering after stroke. Consequently, the investigation and documentation of the effect of music therapy is always focused on the client population and therapeutic method applied.

During 60 years of practice, several models of music therapy have been developed, documented and implemented into training systems. These models are the result of clinical work by music therapy pioneers such as Nordoff & Robbins and Priestley (Ruud, 1998). Depending on their educational background and the area of employment, these music therapy pioneers engaged clients with a range of musical experiences varying from active music making to receptive listening. Practitioners made observations about the effects of intervention and developed methods based on their subjective qualitative examinations. These methods became the foundation of music therapy practice, but they have never been systematically investigated or compared with each other.

In order to evaluate the effects of treatment, it is important to select appropriate tools for assessment. The current study is based on the psychodynamic approach to music therapy in the treatment of depression, therefore only tools that are relevant to this area are discussed. In the treatment of mood disorders, music therapists usually apply standardised psychological measures. These measures are sensitive to changes in the client's psychological state, but do not reflect the musical aspects of the treatment. This lack of appropriate measures is a serious issue, since "musical expression and experience are the actual domains the therapist seeks to act on rather than just act through" (Aigen, 2005b, p. 48). This study seeks to establish a method of measuring dynamic musical processes in a way that would be therapeutically relevant and scientifically robust.

Several tools for the musical assessment and evaluation of music therapy have been suggested to date, but, again, none have been systematically tested for validity and reliability, or strongly implemented into practice (Baxter et al., 2007). The majority of these tools are based on the subjective point of view of the therapist, but there have been attempts to extract and evaluate musical material computationally. In order to construct a model for assessment that would formalise the process, one must explore the reasons why none of the previously proposed tools have been successful. These are the main concerns of this thesis – to investigate the reasons why none of the current tools for music therapy assessment has been formalised, and to create a model for the assessment that could have a wider applicability.

Professional recognition, the level of communication in interdisciplinary teams and the results of research depend on the assessment system (Baxter et al., 2007). However, it has been reported that more than half of music therapists working in school settings used self-created tools (Wilson & Smith, 2000). This study aims to develop a model for data extraction and presentation in an objective and meaningful way that would lead to implementation in both music therapy practice and research.

Following this introduction, four chapters are presented, exploring the following topics:

Chapter 2 outlines the theoretical background related to this study. Section 2.1 presents music therapy as a discipline, section 2.2 describes the improvisational psychodynamic approach, section 2.3 discusses the role of music therapy in the treatment of depression, section 2.4 reviews the role of assessment in music therapy, section 2.5 identifies traditional tools for assessment in music therapy, section 2.6 defines currently available computational tools, and section 2.7 describes the aims and objectives of the current study.

Chapter 3 demonstrates the methods used in order to construct and test a new assessment model – the Musical Profile. Section 3.1 describes the participants assessed, section 3.2 discusses the software tools employed in this study, section 3.3 explores musical feature selection and section 3.4 describes the construction of an individual Musical Profile.

Chapter 4 illustrates how the proposed model can be applied in practice. Six participants' Musical Profiles are presented separately in sections 4.1 to 4.6 and then compared to each other in section 4.7 in order to investigate if the profiles differ between individuals.

Chapter 5 summarises the findings of the study, acknowledges limitations and sets the direction for future research.

2. THEORETICAL BACKGROUND

2.1. Music Therapy

Music has been used for therapeutic purposes since antiquity (Wigram et al., 2002). Treatises about its healing powers like Boethius' *De Institutione Musica*, written in the early sixth century, were later included in the syllabus of medical students. However, these instances of using music as a therapeutic tool are not considered to be music therapy. Therapeutic use of music by medical professionals is defined as music in medicine (Forsblom, 2012). Music therapy interventions have to be administrated by trained music therapists. In addition to the direct effect of music, music therapists develop a musical relationship with the patient that is considered to be essential to the therapeutic intervention (Bonde, 2001).

Music therapy emerged as a profession during the 1950s in the United States, Austria and Great Britain. In 1995 there were approximately 50 countries with at least one practicing music therapist (Wigram et al., 1995). The development of the profession has been linked with cultural viewpoints with regard to music, historical events, music therapy pioneers, political and financial issues, organisation of higher education and health care approaches. In a lot of countries it became a significant part of health care systems, but has received criticism over insufficient scientific research into the effectiveness of music therapy interventions (Bunt, 1994).

Music therapy is a form of creative arts therapy in which musical experiences and client-therapist relationships provide a space for therapeutic change (Punkanen, 2011). The World Federation of Music Therapy defines it as follows:

> "Music therapy is the professional use of music and its elements as an intervention in medical, educational, and everyday environments with individuals, groups, families, or communities who seek to optimize their quality of life and improve their physical, social, communicative, emotional, intellectual, and spiritual health and wellbeing." (Kern, 2011).

During therapy musical experiences can be divided into two groups: receptive and active (MacDonald et al., 2012). Receptive music therapy employs active music listening. The listening material can originate from the client or the therapist, can be live or recorded, composed or improvised. The listening material can also be commercial music of any genre. Active music therapy, by contrast, involves making music. This can be in the form of playing and singing pre-composed music, improvising or composing original music.

Bruscia (1998) defined six main areas of practice: didactic, medical, healing, psychotherapeutic, recreational and ecological. Didactical practice focuses on learning behaviour, skills or knowledge for independent living and social adaptation. Medical practice prioritizes improving or maintaining physical health. Healing practice concentrates on restoring harmony through vibrations, sounds or music. Psychotherapeutic practice deals with psychological and psychiatric illnesses. Recreational practice emphasizes enjoyment and engagement in social and cultural activities. Ecological practice focuses on promoting health in the sociocultural community.

In addition to clinical applications, there are also a great diversity of methods employed in music therapy. These methods might be classified depending on the professions they are rooted in, e.g. approaches adapted from music education, psychotherapy, or medicine (Darrow, 2008). Other classifications are based on the psychological theories that therapists subscribe to, like psychoanalytical, behavioural or humanistic (Bunt, 1994). Further to this, some practitioners do not subscribe to a single approach and combine individual aspects from several approaches (Erkkilä, 1997). This diversity is considered evidence of the need for music therapy in a wide variety of applications, but it also causes issues in defining and regulating it.

Music therapy is prescribed for children and adults, for individuals and groups, for the treatment of physical and psychiatric disorders, neurological rehabilitation, palliative care, developmental enhancement, personal growth, social well-being, etc. (Peters, 2000). The wide range of applications result in the number of methods employed and the various therapeutic aims of the musical intervention. Considering that music therapy is a very young profession based on practical applications that are so diverse, it is only to be expected that scientific research into the effectiveness of musical interventions will encounter numerous challenges (Wheeler, 1995).

Wigram et al. (2002) categorised all the articles published in three main music therapy journals (*Journal of Music Therapy* (USA), *British Journal of Music Therapy* and *Nordic Journal of Music Therapy* (Scandinavia)) between 1998 and 2000. Clinical qualitative research constituted 8.13 %, clinical quantitative research 13.42%, and non-clinical research 17.07%. That means that 61.38% of published articles are not research based. In addition to this, 84.47 % of the quantitative research was published in one journal (*Journal of Music Therapy*). Compared to the proportion (19.64%) of both the quantitative and qualitative research during 1987-1991 (Wigram, 1993) there was a notable growth in the scientific understanding of music therapy, but it is not yet sufficient.

The scientific investigation of the methods used in, and effects of, music therapy are critical for this profession to be more widely recognised and further developed (Michel & Pinson, 2005). The main problem here is not the lack of literature, but the nature of it. The majority of studies do not address the issues in controlled settings and seek to explore rather than to prove. In consequence, there is a lack of studies that follow scientific protocol and present their results in an objective form.

2.2. Improvisational Psychodynamic Approach

Psychodynamic music therapy is based on the psychoanalytical theory of Sigmund Freud, and takes further influences from the analytical psychotherapy of Carl Gustav Jung, self-psychology of Heinz Kohut, and interaction theory of Daniel Stern (Hadley, 2003). As Austin (1996) summarises, the psychodynamic approach is “the creative process of exploring and integrating unconscious aspects of one’s psyche” which “enables the client to become the unique self he or she truly is” (p.30).

One of the core assumptions of the psychodynamic approach is that of personality as a dynamic relationship between consciousness, preconsciousness and unconsciousness. It infers that clients’ emotional disturbances are caused by conflicts that cannot be directly reached by the conscious mind. In therapy, music is used to induce transitional states between conscious and unconscious

– altered states of consciousness (Aldridge et al., 2006). Music also facilitates emotional memory through a defence mechanism called regression (di Franco, 2003), which creates space for therapeutic change.

Another important notion in the psychodynamic approach is the development of the sense of self. The role of unconscious drives and fantasies, that form the basis of Freud's theories, is no longer considered to be of the greatest importance in psychology. Stern (1985) describes the developmental process as a product of real life experiences that shapes the way of understanding the world. Implicit knowledge is unconscious and based on action, because it is attained pre-verbally, whilst explicit knowledge can be expressed in symbolic or verbal form. Developmental levels are considered as layers of maturation that do not replace each other (like in the Freudian model), but coexist simultaneously.

The primary form of experience in psychodynamic music therapy is improvisation (Wigram et al., 2002). Clinical improvisation is not perceived as a form of art, but rather a process which might result in "very simple sound forms" (Bruscia, 1987, p.5). During spontaneous music making physical, emotional and cognitive processes occur at the same time. Metaphors, associations and images that music elicits are considered a part of the musical experience (Eschen, 2002).

Music made in therapy is usually not restricted to a particular style or genre – improvisations are defined by the client's way of expressing him or herself. Improvisatory experiences, depending on the individual case, might have a diversity of clinical goals, such as self-expression, identity formation and nonverbal communication, development of perceptual, cognitive or social skills (Bruscia, 1998).

Music therapy clients are not expected to have any prior musical knowledge or skills (Wigram, 2004). The lack of musical ability is not considered to be a limitation for the purposes of expressive performance. As a consequence the musical material tends to be atonal, without clear form or metrical organisation. Since improvisations are not evaluated on aesthetic criteria any form of expression is acceptable, even those sound forms that would not be considered to be musical *per se*.

Therapeutic understanding of music has been categorised into three views: absolutist (music has no other meaning than the music itself), referentialist (music represents the emotions and ideas of those who produce it) and expressionist (a combination of both – it is an aesthetic phenomenon that shares important qualities with human experience) (Pavlicevic, 1997). The absolutist position is strongly rejected by psychoanalytical theory, because music is believed to facilitate extra-musical meaning.

Wigram et al. (2002) suggested guidelines for how musical elements and processes can be interpreted in a metaphorical way. All of the major musical parameters have been linked with clients *being in the world*. Tempo is considered to be a metaphor for flexibility, whilst modality represents basic emotion. Texture (e.g. melody with accompaniment) is a metaphor for cooperation with a leader. Rhythm is a metaphor for the independence of the entity as related to the pulse.

The clinical nature of improvisations has an influence on the musical content produced (Bruscia, 2012). The therapist might suggest a playing-rule for a particular improvisation, e.g. "try to express your fear … just the way you feel it right now" (Eschen, 2002, p. 68). If a client is playing together with a therapist in a duet, the client's improvisation may be impacted by the therapist's performance and vice versa. There are other factors that may also affect the improvisation, such as learning how to play an instrument by practicing it weekly, the client-therapist relationship quality, or the impact of medication. In summary, the characteristics of clinical improvisations can be affected by a variety of factors that are related to the therapeutic process or the disorder the patient is suffering from.

2.3. Music Therapy in the Treatment of Depression

Depression is a mood disorder that affects more than 350 million people (WHO, 2012). It is the most common disability worldwide. Due to its high prevalence and impact on a person's ability to work, depression has significant social, economic and demographic effects. At its worst, depression leads to suicide, which results in an estimated 1 million deaths per year (Ibid). It affects people of all genders, ages, and backgrounds with a variety of emotional, cognitive, motivational, vegetative and physical symptoms, delusions or hallucinations (Beck & Alford, 2009).

The causes of depression are related to various biological, psychological and social factors. Low physical activity level is considered to increase the risk of this disorder (WHO, 2012). Depression impacts the ability to represent and regulate mood and emotions (Davidson et al., 2002), which leads to persistent low mood, feelings of guilt, low self-worth, disturbed sleep or appetite, feelings of tiredness and poor concentration.

Neuroimaging data shows that, relative to healthy controls, depressed participants exhibit decreased connectivity between anterior cingulated cortex and limbic regions (Anand et al., 2005), asymmetry in the left and right hemisphere frontal lobes (Rotenberg, 2008) and an imbalance in neurotransmitter (e. g. dopamine, norepinephrine, serotonin) systems (Kalia, 2005). EEG data has revealed that depressed participants exhibit hypoactivation in the left frontal, and hyperactivation in the right frontal lobes (Allen et al., 1993). These findings lead to the hypothesis that brain asymmetry might be considered a biological marker for the risk of experiencing depression (Tomarken & Keener, 1998).

The most common forms of treatment for depression are pharmacotherapy, psychotherapy and electroconvulsive treatment (Castillo-Perez et al., 2010). Medication treatment for depression involves antidepressants (e. g. selective serotonin reuptake inhibitors, tricyclic antidepressants, monoamine oxidase inhibitors). Psychotherapy is considered to be an effective treatment in addition to medication (Greenberg & Goldman, 2009). Electroconvulsive therapy is applied for treatment-resistant, or catatonic forms of depression, but remains highly controversial because of the side effects and short-term effect (Casacalenda et al., 2002). Music therapy is applied as an alternative when other forms of therapy are not possible or insufficient (Cuijpers et al., 2009).

Gold et al. (2009) carried out a systematic review and meta-analysis of the research on the therapeutic effect of music therapy on depression. They concluded that music therapy effectively improves the global state, symptoms, and functioning of depressed clients. It has also been suggested that music is an effective medium for therapeutic purposes, because it contains various levels of structure and flexibility at the same time (Wigram & Gold, 2006).

Maratos et al. (2008) compared five randomised controlled trial studies: Hanser, 1994; Chen, 1992; Zerhusen, 1995; Hendricks, 1999 and Radulovic, 1997. Four of the five studies reported greater reduction in symptoms of depression among those who received music therapy than those in standard care conditions. Zerhuson’s study reported no difference in mental state among those randomised to music therapy compared to those who received standard care alone.

A very important aspect of the Maratos et al. study was the investigation of research methods applied to the trials. They investigated published and unpublished controlled clinical trials and identified sixteen potentially relevant studies. The methodological quality was evaluated and as a result nine out of sixteen studies were excluded. They summarised that further research with longer studies, larger samples and the allocation status of participants concealed from researchers is necessary.

Maratos, Crawford and Procter (2011) addressed another important issue in the article “Music therapy for depression: it seems to work, but how?”. They noted that clinical trials investigate the outcomes of music therapy, but not the specific processes involved. The authors suggest that in order to determine the active elements of musical intervention there should be more studies with mixed methods design, and formulate the hypothesis that the effectiveness of music therapy is based on the experience of aesthetic pleasure and physical activity – factors that are directly affected by depression.

2.4. Assessment in Music Therapy

Assessment is a process of information collection and analysis with the intention of planning and implementing an effective treatment program (TABLE 1). This process results in hypotheses about the nature and causes of a client's personality, condition, resources and potentials. Assessment is closely related to evaluation, which determines how much progress has been made (Bruscia, 1987).

TABLE 1. Forms of assessment and evaluation (adapted from Wigram, 1999).

Assessment model	**Function**
Diagnostic assessment	To obtain evidence to support a diagnostic hypothesis
General assessment	To obtain information on general needs, strengths and weaknesses
Music therapy assessment	To obtain evidence supporting the value of music therapy as an intervention
Initial period of clinical assessment in music therapy	To determine in the first two to three sessions a therapeutic approach relevant to the client
Long-term music therapy assessment	To evaluate over time the effectiveness of music therapy

Music therapy assessment is divided into three categories: initial, comprehensive and on-going (Hanser, 1999). Initial assessment focuses on the treatment goal and establishes the point at which to begin. Comprehensive assessment is advisable when the client has difficulty complying with other forms of assessment and is performed in order to examine various aspects of functioning. Ongoing assessment is administered repeatedly in order to evaluate music therapy over time.

As stated earlier, music therapy practice has developed from clinical work and the importance of the assessment has not been addressed adequately (Wosch & Wigram, 2007). Literature meta-analyses revealed that the majority of studies did not address data collection, measurement, evaluation, interpretation and reporting in a consistent manner (Sabbatella, 2004). In the literature focused on the effectiveness of music therapy, 50.27 % of studies do not have any test instrument (Gregory, 2000). This situation has resulted in a lack of standardized assessment tools and a predominance of literature based on qualitative descriptions of the process.

The majority of the measurements used in music therapy assessment do not address musical aspects at all. The methods used in order to determine the efficacy of intervention are selected based on the disorder that music therapy is addressing (Bruscia, 2005). Standardised tools for general physical, psychological, psychiatric, and cognitive examination are adopted for music therapy clinical work and research (Ruud, 2010). Guidelines for music therapy practice identify four main areas that are addressed during assessment – motor, cognitive, communication and emotional skills (Michel & Pinson, 2005).

Of 115 different instruments used, only 20 measured musical material. Within this subset, half of the measures were related to performance skills that are not considered significant in the therapeutic setting (Gregory, 2000). Wilson and Smith (2000) found that only 3 out of 41 assessment methods that evaluated musical material produced by children with disabilities were used in more than one study.

The diversity of assessment tools is caused by intrinsic factors like the therapist's theoretical orientation and extrinsic factors like the needs of the patient population. Isenberg-Grzeda (1988) identifies five parameters that determine the form of music therapy assessment tools: client population, theory / model, area of functioning / condition, technique, and response to the institution.

The meaning that is assigned to the results of musical analysis varies no less. It is possible to define two positions regarding the role of musical analysis in music therapy assessment. The first position is illustrated by the work of Loewy (2000). She claims that even though therapists understand processes through musical experience, the interpretations and evaluations are based on verbal description. According to her, "an effective way of studying the interpretation of a music therapy experience through text is to investigate assessment using a hermeneutic methodology" (p.47).

The second position is represented by the work of Smeijsters (2005). He believes that musical processes are composed of the same amodal temporal and intensity forms as psychological processes. This implies that changes in thoughts, feelings and behaviours have a musical representation. "The music therapist is the one who hears the musical process as a psychological process and makes arrangements to transform psychological processes in musical process" (p. 80).

Links between musical analysis, emotional responses, and medical conditions have been established. Luck et al. (2008) found that activity, pleasantness and strength in clinical improvisations can be inferred from computationally extracted musical features. Another study showed that prediction of the type of mental disorder was possible solely from the musical content of clinical improvisations (Luck et al., 2009). These studies show the possibilities for future research when both the data collected and the uses to which it is put meet scientific standards, and can be applied to clinical work.

2.5. Traditional Tools for the Assessment of Clinical Improvisations

The principal characteristics of any formalised system of measurement are reliability and validity (Lachin, 2004). Validity determines if the instrument is assessing the target construct. Reliability determines the overall consistency of the measure. It ascertains that the same results would be obtained across different situations (Haynes et al., 1995). A critical aspect of reliability for psychological measures is inter-rater agreement. In a music therapy context this means that data collected by different therapists would not vary significantly.

The majority of the tools used in music therapy research that assess musical content are not tested for validity and reliability. There are however several tools that, despite the lack of widespread use and methodical scientific verification, do assess musical processes systematically. Three tools will be discussed based on chronological order of origin: Nordoff-Robbins assessment tools, Improvisation Assessment Profiles (IAPs), and Individualised Music Therapy Assessment Profile (IMTAP).

Nordoff-Robbins music therapy model is based on humanistic psychology (Aigen, 2005a). The therapeutic process primarily involves active music making. Improvisations are the predominant material for analysis and interpretation. The authors also argue for the necessity of professional musical training of therapists which allows a wider range of performance skills. They have developed several tools for assessment: Indexing, Tempo-Dynamic Schema, Thirteen Categories of Response and three evaluation scales (NRES).

Indexing involves noting audio or video recordings with detailed analysis of clients' musical expressions and therapists' interventions (Mahoney, 2010). Clients' expressions are evaluated on parameters like tonal vocalizations, tempo, organisation of rhythmical responses, and melodic and rhythmic facility. Tempo-Dynamic Schema correlate emotional responses with musical expressivity and evaluate them as normal if they correspond to common musical practice, or as pathological, if they are inflexible or considered musically meaningless. Thirteen Categories of Response is a specialised tool that evaluates the drum beating of a client in reaction to the piano playing of a therapist. Both musical and behavioural reactions to musical idioms, elements and moods are assessed.

NRES are based on a Behavioural Rating Instrument for Autistic Children, but are not restricted to this disorder. Scale I – Child-Therapist(s) Relationship in Musical Activity – assesses the developmental level of the relationship. Scale II – Musical Communicativeness – assesses the child's ability to communicate through music. Scale III – Musical Response – assesses the complexity of rhythmical (for drumming) and melodic (for singing) forms.

Bruscia (1987) wrote a seminal book "Improvisational models of music therapy" in which he describes over 25 models and suggests a method of assessment based on clinical observation and musical and psychological interpretation of the client's improvisation. IAPs consist of six profiles which are separately evaluated on rating subscales from one to five on various elements.

The six profiles of IAPs are integration, variability, tension, congruence, salience and autonomy. These profiles can be applied to musical elements such as rhythm, tonality, texture, volume, timbre as well as physical (expressive uses of body) and programmatic (verbal reactions) aspects of improvising. It is suggested to focus on a particular aspect and analyse all elements within one profile (e. g. rhythmic integration, melodic integration etc.) or all the profiles within one element (e.g. rhythmic integration, rhythmic variability etc.).

IMTAP was developed primarily for paediatric and adolescent settings (Baxter et al., 2007). It is organised into ten domains that evaluate a total of 375 skills. Gross motor skills, fine motor skills, oral motor skills, sensory skills, receptive communication/auditory perception, expressive communication, cognitive skills, emotional skills, social skills and musicality are the main domains. The subdomains of musicality are fundamentals, tempo, rhythm, dynamics, vocal, perfect and relative pitch, creativity and development of musical ideas, music reading and accompaniment.

Common features of all these assessment tools are that they are based on manual and subjective evaluation of the musical material. These analyses are time consuming and rely heavily on the subjective opinion of the therapist. However, with the development of Music Information Retrieval, new possible directions for music therapy assessment have emerged.

2.6. Computational Tools for the Assessment of Clinical Improvisations

Crowe and Rio (2004) reviewed 177 books and articles in order to explore technological applications in music therapy. They investigated various forms of technology such as adapted musical instruments, recording technology, electric / electronic musical instruments, computer applications, medical technology, assistive technology for the disabled, and technology-based music / sound healing practices. Similarly to the measurement of the effectiveness of music therapy methods, the analysis of the data is typically performed using tools that are not created for music therapy purposes. For example, the most popular programs used for music therapy qualitative research such as ATLAS.ti, HyperRESEARCH2.5 and Nvivo2.0 are designed for the social sciences or other areas of research that do not specialize in musical analysis (Musumeci et al., 2005).

At the time of writing there are several tools that are designed to computationally retrieve and assess musical content relevant to clinical improvisation: Computer Aided Music Therapy Analysis System – CAMTAS, Music Therapy Toolbox – MTTB, Wiimprovisation – MAWii, The Music Therapy Analysing Partitura – MAP, and Music Therapy Logbook. None of these tools are fully developed, methodically tested or strongly implemented into practice as yet, but they all represent a step forward in the implementation of technology in music therapy.

CAMTAS is the first attempt to create a computer-based system for the organization and analysis of audio and video data produced during music therapy (Hunt et al., 2000). It allows the playback of therapists' piano, clients' instrument and video material simultaneously (FIGURE 1). Other options include piano roll for the piano data representation, and velocity analysis over a selected section of improvisation. This system does not provide a wide range of operations, but is rather designed as a database. Hunt claimed that the system had limited functionality because "computers weren't running quickly enough for what we wanted to explore" (Streeter, 2007).

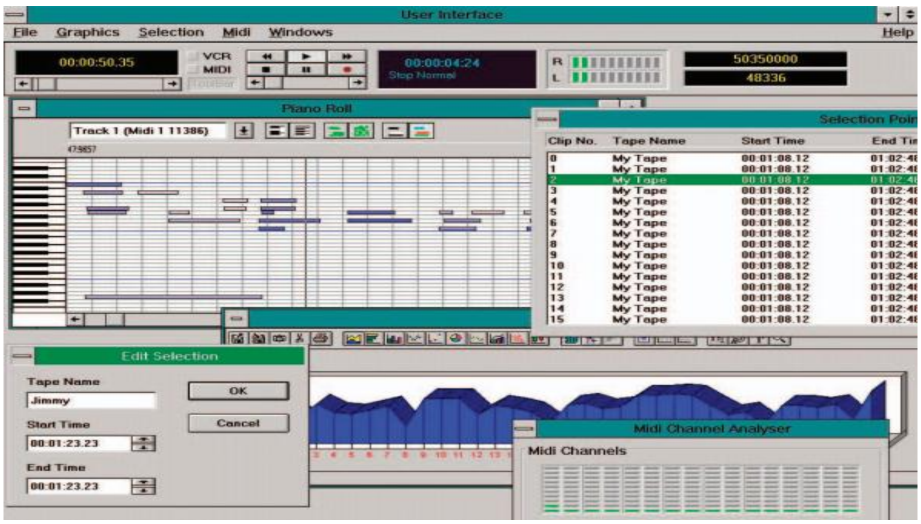

FIGURE 1. Piano roll representation of music and statistical analysis in CAMTAS software (adapted from Hunt et al., 2004).

MTTB analyses the temporal surface, register, dynamic, tonality, dissonance and pulse related features of music as well as quantifying client-therapist interaction (Erkkilä, 2007). This interaction is measured by the synchronicity of client and therapist's improvisations and is presented as an imitation diagram (FIGURE 2). The software is developed for MIDI data time decomposed analyses with a focus on client-therapist interaction on a single improvisation.

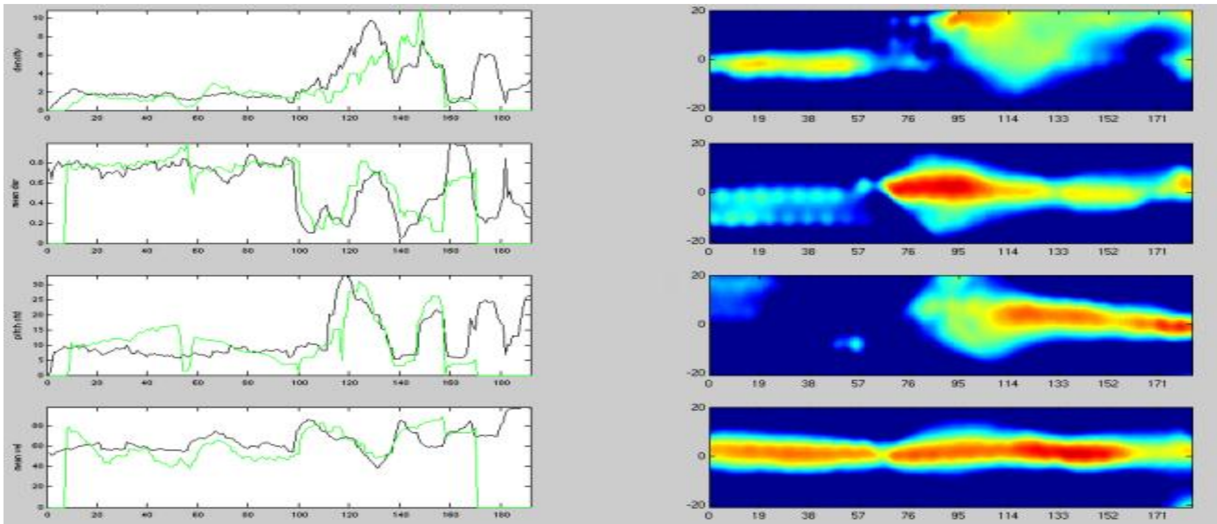

FIGURE 2. Temporal evolution of musical variables (left side) and their imitation diagrams (right side) in MTTB (adapted from Erkkilä et al, 2004).

MAWii uses Wiimote haptic devices designed by Nintendo in order to generate and measure sound (Benveniste, 2008, 2009). A computer linked to a stereo amplification system through an audio interface generates sound, triggered by downward strokes with the handheld controller. There are five levels of volume linked to the stroke force. Wiimote instrument is programmed to produce 12 sounds, choosing from three instruments: a combination of congas and djembe with two sounds each, a set of four cymbals and marimba with four pitches (C, E, G, C). MA Wii represents an alternative to traditional instrumentation and data gather techniques, but it is not yet developed for systematic analysis and assessment of the therapeutic process.

MAP describes events in music therapy based on graphical notation (Gilboa, 2012). This method enables the therapist to see the dynamics of the therapeutic process in a very concise form (Gilboa & Bensimon, 2007). Auditory material represented in notation is not limited to the music – talking, silence, crying and laughing have their own graphical codes (FIGURE 3). In MAP every client has a designated line into which the information has to be transcribed manually. Despite the systematic way of coding the material, the actual analysis is still heavily based on the therapist’s input and proves to be highly time-consuming.

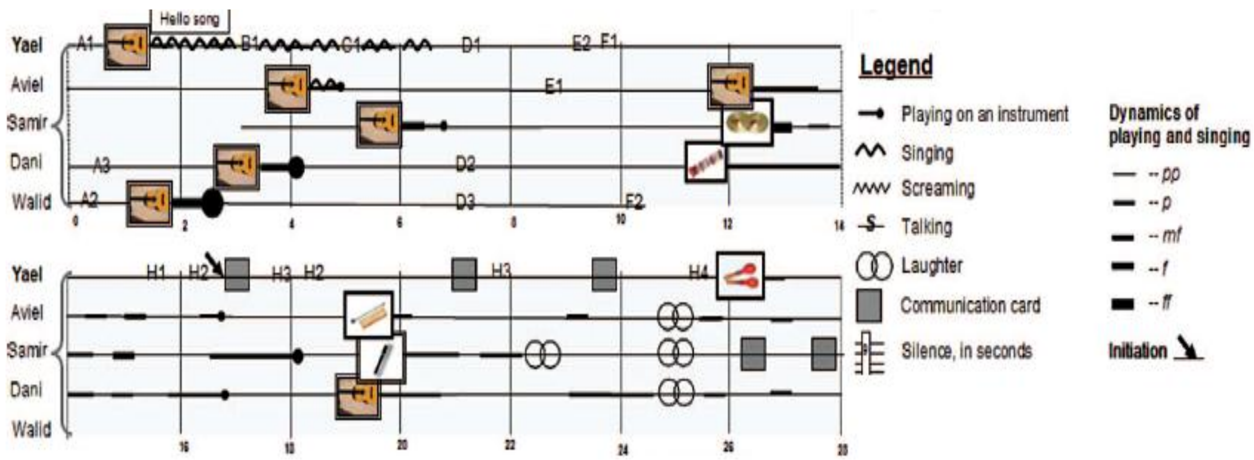

FIGURE 3. Music therapy session graphical description on MAP (adapted from Gilboa, 2012).

Music Therapy Logbook is created to perform both qualitative and quantitative analysis of acoustic and MIDI instruments. (Streeter et al., 2012). The authors stress the necessity of using a multichannel wireless digital audio recording system that would not limit the instrumentation choice or movement of the client. Music silence segmentation is performed in order to visualize the music therapy session (FIGURE 4). Other functions include time-decomposed analysis of duration, instrumentation, tempo, and interaction between client and therapist (Streeter, 2010).

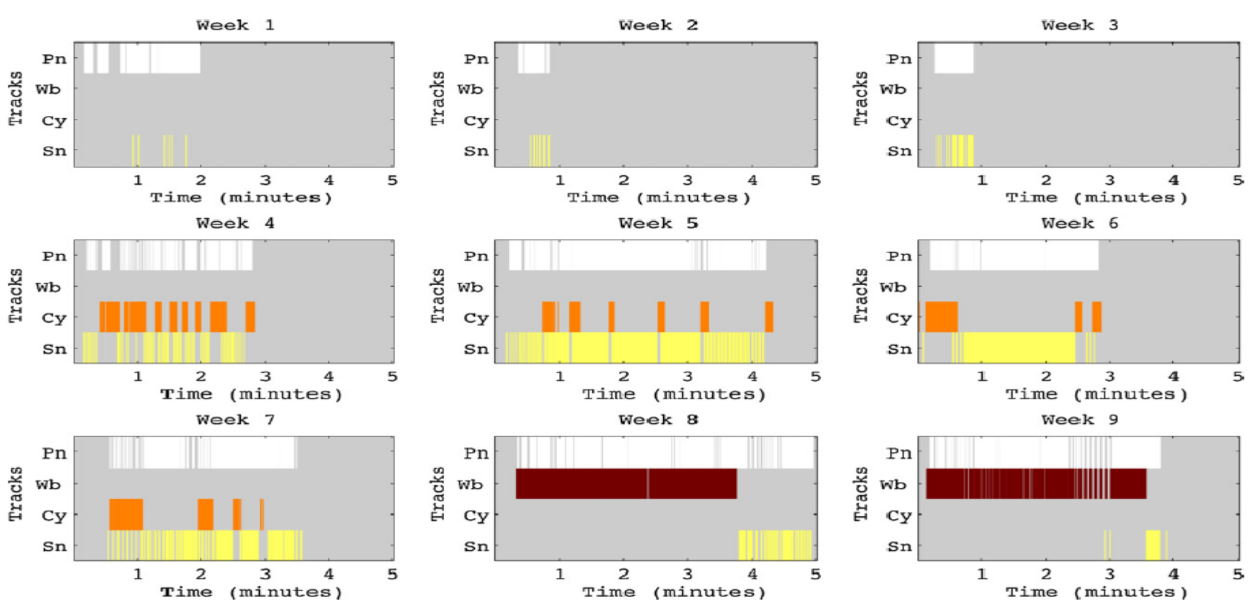

FIGURE 4. Automatic mapping of first 5 minutes of 9 therapy sessions (piano: white; wood blocks: brown; cymbal: orange; snare drum: yellow) in Music Therapy Logbook. (adapted from Streeter et al., 2012).

Hahna et al. (2012) investigated the role of technology in music therapy clinical work and concluded that the major issues with implementing computational tools into practice were financial and facility restrictions, lack of training, professional experience or interest and the belief that music technology is not appropriate in music therapy clinical work. The most alarming result of the study is that the majority of clinicians reported having no formal training in technology. The conservative approach of music therapy clinicians and educators towards the technological progress has been pointed out before (Magee, 2006) and it might explain why the development and implementation of computational tools is prolonged in the field.

2.7. The Current Study

The literature reviewed has shown that in the field of music therapy the importance of scientific research has been underestimated. The profession has advanced based on clinical work and, as a consequence, the tradition of individualised approach to treatment is still dominant. The majority of literature about the effectiveness of music therapy is based on qualitative, as opposed to quantitative observations. A formalised method of assessment is necessary in order to subject music therapy practice to systematic scientific investigation. Therefore a model for assessment that would measure musical processes in a reliable and replicable form is necessary.

Traditional tools for the assessment of music therapy are manual, therefore inefficient, and subjective, therefore unreliable, and computer-based systems are required to facilitate both the therapeutic and research processes. Several computational tools have been created, but they are neither fully developed, nor widely implemented into practise. One reason for the rejection of computational tools is a lack of technical education: the majority of music therapy clinicians' claim to have no formal training in technology. Another reason for the rejection of the computational tools is the limited functionality of the current systems.

Analysis of current assessment tools revealed that the most common musical parameters in traditional tools (Indexing, IAPs and IMTAP) were dynamics, instrumentation, pitch, tempo, texture, timbre, and tonality. Computational tools provided notably less features for assessment – the common ones were dynamics and tempo.

The aim of this study is to create a model for a computer-based assessment that would formalize assessment and be applicable across different forms of active music therapy.

The objectives of this study are:

1) To extract those features from a clinical improvisation that the literature review showed to be relevant in music therapy assessment.
2) To present the results in a comprehensible form for clinicians, but include enough detail for researchers.
3) To test the assessment model on clinical improvisations.

The current study seeks to combine both an individual approach to every client and an objective method of data gather. This model is based on the assumption that musical processes are correlated with psychological ones (Smeijsters, 2005) and changes in one process reflect changes in another. It also follows the tradition of Nordoff-Robbins approach, where every client is considered to be unique in his musical expression. The proposed method is a form of ongoing assessment (Hanser, 1999) that performs an analysis both on individual sessions and over the whole course of therapy. The adoption of this model would positively affect interdisciplinary communication, develop both clinical and research methods, improve understanding of how therapy works and reduce costs for treatment, since a computer-based assessment system would represent greater efficiency than a manual one.

3. METHOD

3.1. Participants

Data was collected in 2008-2009 by a group of researchers from the University of Jyväskylä (Erkkilä et al., 2011). A randomised controlled trial was conducted in order to determine the efficacy of music therapy added to standard care compared with standard care only, in the treatment of depression in working-age people. The overall results showed that participants who received music therapy showed greater reduction in levels of depression than those who did not.

79 participants with an ICD–10 diagnosis of depression were randomised to receive individual music therapy plus standard care or standard care only. Twenty bi-weekly sessions of 60 minutes each were suggested for 33 participants. On average, the participants assigned to the music therapy received 18 music therapy sessions (SD = 4.7, range 1–20) and created 21.8 (SD = 12.9, range 1–59) improvisations.

A clinical model that was developed at the Music Therapy Clinic for Research and Training of the University of Jyväskylä was applied in the music therapy sessions. It is a form of active music therapy with a psychodynamic approach that involves a combination of verbal interaction and free improvisation. Therapeutic musical expression was limited to a small selection of instruments, comprising a mallet instrument (a digital mallet midi-controller), a percussion instrument (a digital midi-percussion), and an acoustic djembe drum. Therapists and clients used identical instrumentation. All the improvisations created in the sessions were recorded using Pro Tools on the hard disk of a PC.

For the purposes of the current study only participants who performed on the mallet instrument for more than fifteen times were chosen (N = 6). The mallet instrument was selected because it is a chromatic pitched instrument unlike digital midi-percussion or the acoustic djembe drum. In order to facilitate subsequent statistical comparison of the Musical Profiles a threshold of no less than 15 sessions was selected (TABLE 2).

TABLE 2. Numbers in original study and number of improvisations for six participants of the current study.

Participant	Original listing	Number of improvisations
1	4	16
2	23	20
3	32	18
4	33	17
5	41	19
6	75	16

The response to treatment, which could have been either music therapy with standard care, or standard care alone, was evaluated by tracking changes in three psychiatric tests. Participants completed diagnostic questionnaires three times – once before the treatment and twice (three and six months) after the treatment. The tests included primary (Montgomery–Åsberg Depression Rating Scale – MADRS) and secondary outcome measures (Hospital Anxiety and Depression Scale – HADS, and Global Assessment of Functioning – GAF).

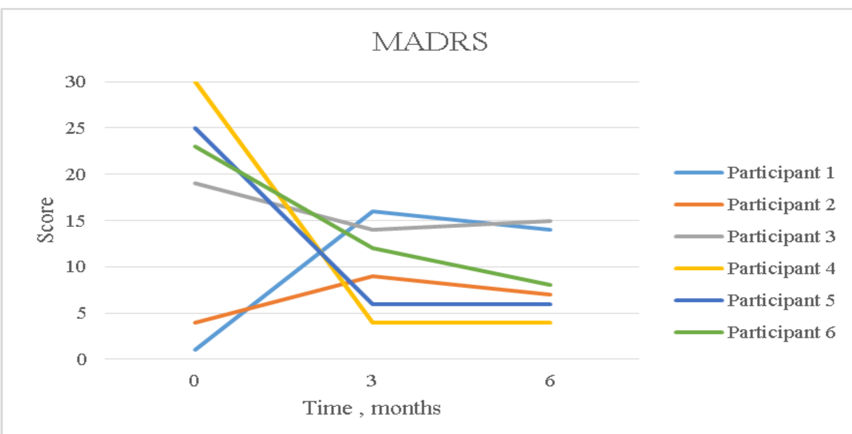

FIGURE 5. Changes in Montgomery–Åsberg Depression Rating Scale scores from baseline to 3 and 6 months.

MADRS is designed to diagnose the severity of depressive episodes. Core symptoms and cognitive features are evaluated by assessing ten items. These are apparent sadness, reported sadness, inner tension, reduced sleep, reduced appetite, concentration difficulties, lassitude, inability to feel, pessimistic thoughts, suicidal thoughts (Montgomery & Åsberg, 1979). The score ranges from 0 to 60 (60 being the most severe case of depression). Four out of six participants (No. 3, 4, 5, and 6) that were selected for the current study showed reduced symptoms after the course of music therapy (FIGURE 5).

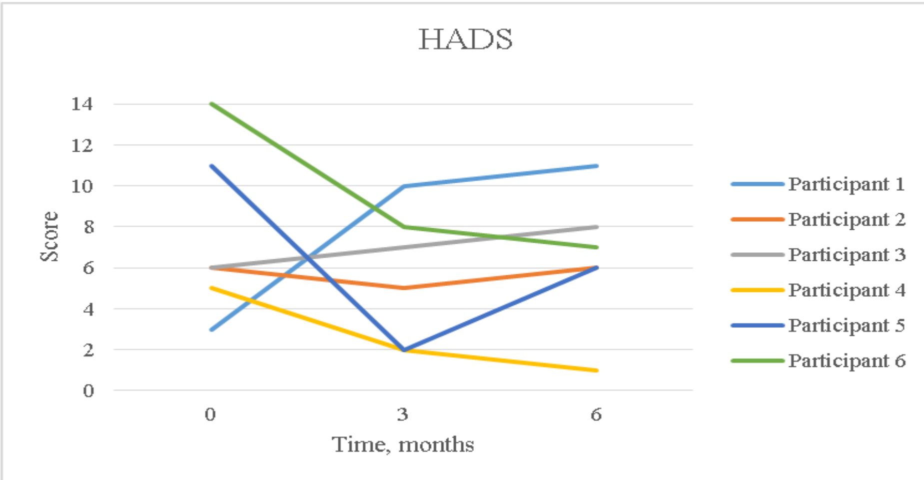

FIGURE 6. Changes in Hospital Anxiety and Depression Scale scores from baseline to 3 and 6 months.

HADS determines levels of anxiety and depression (Mykletun, Stordal, & Dahl, 2001). Seven items are dedicated to evaluate the severity of each depression (e.g. "I have lost interest in my appearance") and anxiety (e.g. "I get a sort of frightened feeling as if something bad is about to happen"). The score ranges from 0 to 21 for both anxiety and depression, where 21 is the highest level of disorder. Three out of six participants (No. 4, 5, and 6) of the current study scored lower after the treatment (FIGURE 6).

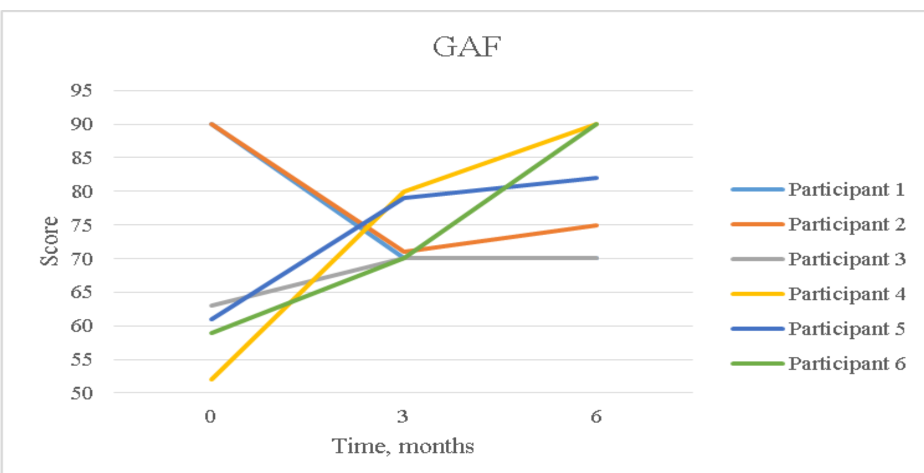

FIGURE 7. Changes in Global Assessment of Functioning scores from baseline to 3 and 6 months.

GAF is designed to evaluate social, occupational, and psychological functioning (Hall, 1995). This scale ranges from 1 ("Persistent danger of severely hurting self or others or persistent inability to maintain minimum personal hygiene or serious suicidal act with clear expectation of death") to 100 ("Superior functioning in a wide range of activities, life's problems never seem to get out of hand, is sought out by others because of his or her many qualities. No symptoms"). Of the participants in this study four out of six (No. 3, 4, 5, and 6) improved their functioning (FIGURE 7).

In the treatment of mood disorders and other psychiatric illnesses, psychological tests are the dominant measurement of the effectiveness of music therapy interventions. The most common form of psychological testing is a questionnaire administered by the medical staff. This type of assessment relies heavily on the self-report of clients which is not the most reliable source of information. In addition to this reliability issue, psychological tests assess only changes in the symptoms of the disorder rather than the process of the treatment. Therefore, the method applied in music therapy interventions cannot by directly evaluated.

3.2. Research Tools

In order to construct the Musical Profiling model, it was necessary to employ methods that precisely described the musical processes. The extracted musical features were based on the parameters discussed in the literature review as being relevant to music therapy assessment. Improvisations were imported to the MATLAB environment and subsequently analysed with different functions provided by MIRToolbox (version 1.5) and MIDI Toolbox (version 1.0.1). As a last step, the data was imported into SPSS in order to perform statistical analysis.

MIDI Toolbox, which runs in MATLAB, was developed in order to analyse and visualise MIDI files (Eerola & Toiviainen 2004). This toolbox contains functions attributed to key-finding, meter-finding, melodic contour, similarity, segmentations and some statistical analyses as well. It does not analyse as wide a range of dimensions as MIRToolbox, because of the limitations of the MIDI format. For example, timbre is not encoded into MIDI data. On the other hand, discrete pitch information is, and it cannot yet be extracted reliably from audio sources.

MIRToolbox is a set of functions developed for musical feature extraction from audio recordings (Lartillot & Toiviainen, 2007) that also runs in the MATLAB environment. Analysis can be carried out on audio files saved in .wav or .au format. Each feature is related to one of five musical dimensions: dynamics, rhythm, timbre, pitch and tonality. The toolbox also includes high-level functions for statistical analysis, segmentation and clustering. For MIR Toolbox analyses MIDI data was converted to .wav files at a sample rate of 22050 Hz, using Cubase 5 software. The same timbre (Jazz Grand Piano A from the HALionOne Virtual Instrument) was used for the conversion of all improvisations.

SPSS Statistical analysis was performed on each of the Musical Profiles individually and overall. The analysis on individual profiles was performed to describe and determine the significance of changes in the performance over the period of therapy. Overall analysis was performed to demonstrate that one individual's profile differs from another.

3.3. Feature Selection

Feature selection presented one of the biggest challenges of this study. The main goal was to represent the musical processes in a manner that would be relevant and approachable to practitioners. Therefore, the objective was to select only those features that could be meaningfully interpreted in the context of music therapy by people without extensive Music Information Retrieval (MIR) knowledge.

MIR is a young discipline with a lot of potential and difficulties still to be overcome (Downie, 2003). Some musical parameters such as rhythmic patterns are not yet retrieved with satisfactory accuracy. Furthermore some of the features that are commonly used in MIR cannot be directly described in the language of traditional music theory. An example of such a feature is an analysis called the zero-crossing rate that indicates the noisiness of a signal. Zero-crossing rate has a range of applications in signal processing (Gouyon, Pachet, & Delerue, 2000; Bachu et al., 2008), but there is no equivalent term in traditional music theory that would signify what it represents.

A pertinent connection between the extracted musical features, the perceptual qualities of the improvisation, and theoretical background in the literature were the main criteria for feature selection. Some parameters were rejected immediately, because of the limitations of the recording techniques used in the original data collection. Timbre is not encoded in MIDI data, so all features related to the analysis of overtones were dismissed. The duration of notes was fixed at 0.4 s long, so extraction of articulation was also considered not meaningful. Since the mallet instrument is played with two sticks no more than two notes are presented at any given time, so texture was rejected as a potential parameter as well.

A total of 10 features fitted the criteria and were selected for further analysis. For the purposes of consistency all the features were organised into the five classes: Activity (Duration and Note Count), Pulsation (Tempo and Clarity), Dynamics (Centroid and Variation), Pitch (Centroid and Variation), and Modality (Strength and Mode). Each of these features was extracted for every session (TABLE 3) for each of the participants (Appendix 1).

TABLE 3. A set of extracted features for Participant 1.

Session	**ACTIVITY**		**PULSATION**		**DYNAMICS**		**PITCH**		**MODALITY**	
	Duration	**Note Count**	**Tempo**	**Clarity**	**Centroid**	**Variation**	**Centroid**	**Variation**	**Strength**	**Mode**
1	1524	1680	88.27	0.03	30.84	7.86	61	5.11	0	
2	358	206	110.82	0.13	27.77	5.91	60	2.93	0	
3	172	218	117.49	0.10	24.10	0.69	66	5.28	0.12	Maj
4	252	361	164.90	0.18	30.72	6.68	60	4.08	0.14	Maj
5	290	327	93.67	0.11	35.57	10.24	62	3.90	0	
6	288	279	151.86	0.22	32.23	7.94	61	4.43	0	
7	476	328	104.97	0.06	26.90	3.99	62	5.46	0	
8	164	49	66.99	0.03	28.71	4.76	59	3.10	0	
9	380	512	127.03	0.20	35.80	10.39	63	5.33	0	
10	304	305	115.00	0.18	27.11	4.73	65	6.88	0	
11	342	561	154.22	0.11	36.25	11.65	62	5.19	0	
12	350	440	172.83	0.29	29.18	7.08	62	9.58	0	
13	172	223	126.52	0.11	30.49	6.75	60	7.45	0	
14	288	319	142.37	0.09	29.14	6.19	64	6.82	0	
15	290	192	124.64	0.10	26.63	3.69	60	5.00	0	
16	242	98	120.76	0.11	27.99	4.41	61	5.73	0	

Activity

- Duration was extracted from audio using the MIR Toolbox function *mirlength. Mirlength* returns the temporal length of an audio file in seconds.

- Note Count was extracted from MIDI using MIDI Toolbox function *nnotes*. *Nnotes* returns a count of the number of note onsets.
- Notes-per-second was calculated by dividing Note Count by Duration.

Pulse

- Tempo was extracted from audio using MIR Toolbox function *mirtempo*. *Mirtempo* returns a value of estimated tempo in beats per minute (bpm). Global tempo estimation was performed on the onset detection curve using default settings without frame decomposition (FIGURE 8).

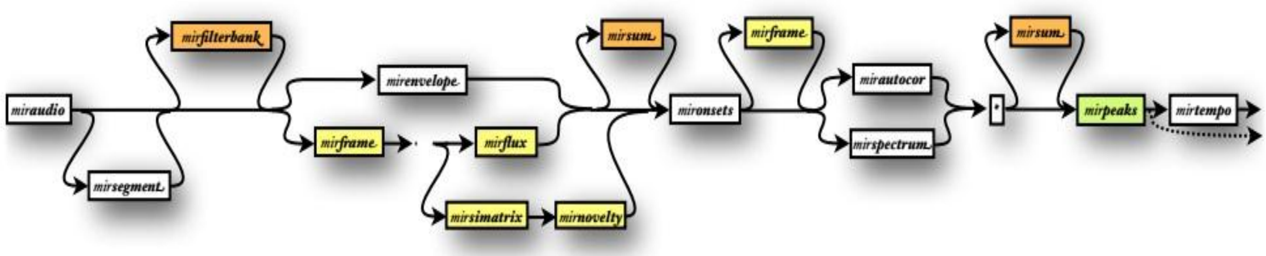

FIGURE 8. Flowchart interconnections for the MIR Toolbox function *mirtempo* (adapted from Lartillot, 2013).

- Clarity was extracted from audio using MIR Toolbox function *mirpulseclarity*. *Mirpulseclarity* returns a value of the strength of the beat, ranging from 0 to 1, where 1 is the clearest pulsation. An autocorrelation curve was calculated for tempo estimation using default settings (FIGURE 9).

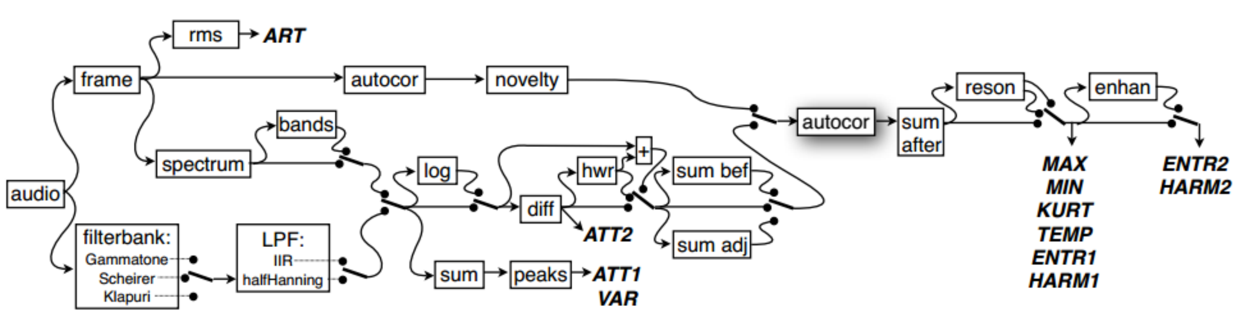

FIGURE 9. Flowchart interconnections for the MIR Toolbox function *mirpulseclarity* (adapted from Lartillot, 2013).

Dynamic

- Centroid was extracted from MIDI. Velocity is encoded in levels from 0 to 127, where 127 is the highest possible. The centroid as defined here is the mean of these values.
- Variation was extracted from MIDI. The variation as defined here is the standard deviation of the velocity values.

Pitch

- Centroid was extracted from MIDI. Pitch is encoded in levels from 0 to 127, where 0 is C-1 and 127 is G9. The centroid as defined here is the mean of these values, rounded to integer.
- Variation was extracted from MIDI. The variation as defined here is the standard deviation of the velocity values.

Modality

- Both strength and modality were extracted from audio using the MIR Toolbox function *mirmode*. *Mirmode* returns a value from -1 to 1, where -1 is strongly expressed minor mode and +1 is strongly expressed major mode. For the purposes of this study the *mirmode* value was separated into two features: Strength and Mode. A numeric value, without regard to direction, was presented in the Strength section. The Mode section indicates 'Major' when values are positive and 'Minor' when values are negative. Modality estimation based on the spectrum was performed using default settings (FIGURE 10).

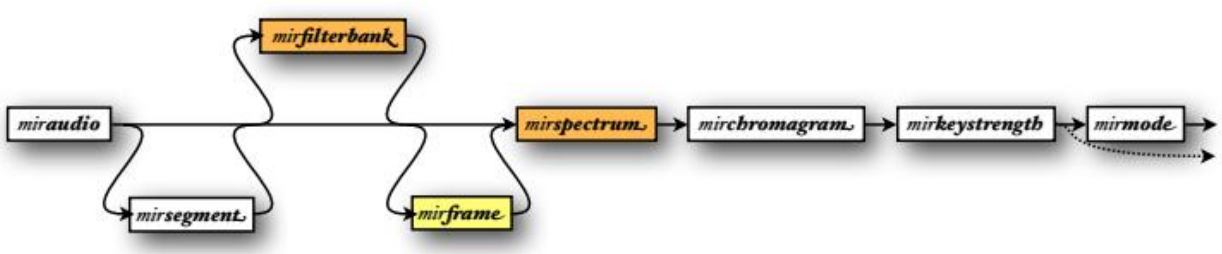

FIGURE 10. Flowchart interconnections for the MIR Toolbox function *mirmode* (adapted from Lartillot, 2013).

3.4. Musical Profile

The extracted data can be analysed in a variety of ways that reveal different aspects of the performance, all of which are presented under the collective title of the Musical Profile. This Musical Profile consists of three parts: *Typical Performance*, *Temporal Evolution* and *Individual Tendencies*. Each of the parts contains a table with numeric results or a graph and a verbal description that explains the information presented.

The current study aims to establish a model for feature extraction, analysis and presentation that would assess the musical processes occurring during the course of music therapy. The main goals are to determine therapeutically relevant content of clinical improvisations and to establish a scientific method of measuring it. A full-featured software package that functions as a database with options for automatic analysis is considered to be the next developmental stage beyond the scope of the current study. A hypothetical interface of the Musical Profile is displayed (FIGURE 11) in order to illustrate how the information would be presented to the user of this software.

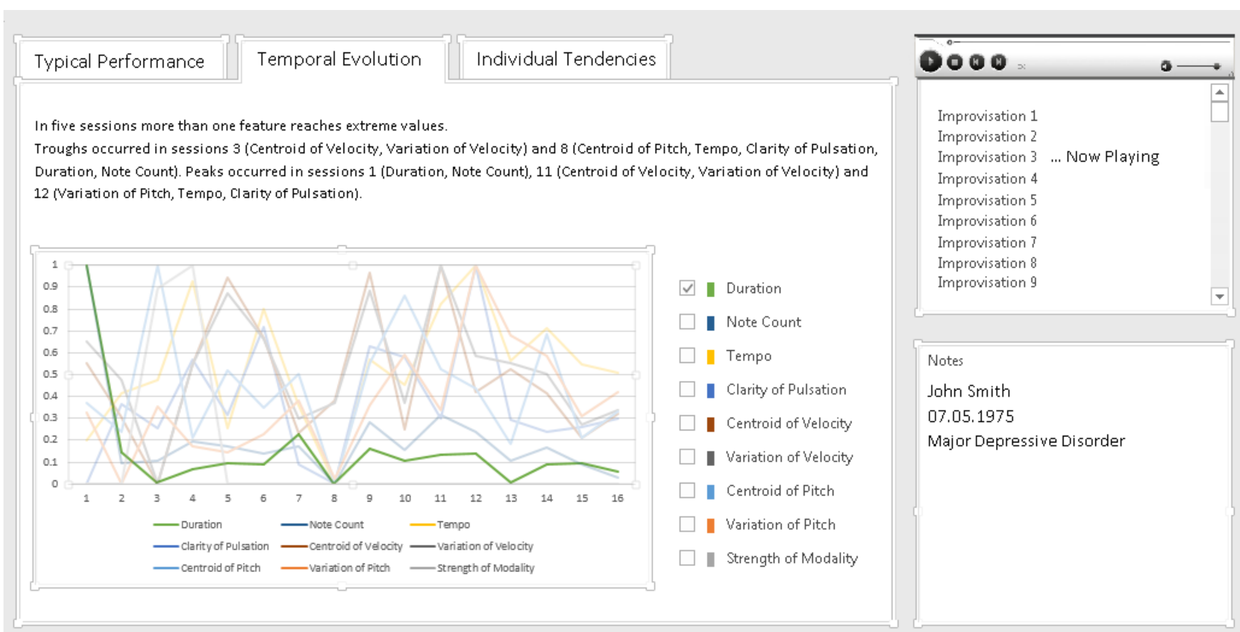

FIGURE 11. Illustration of how Musical Profile software could look like.

3.4.1. Typical Performance

Typical Performance comprises averages of nine features (Duration, Note Count, Tempo, Pulse Clarity, Dynamic Centroid, Dynamic Variation, Pitch Centroid, Pitch Variation, and Modality) and the mode (the most frequent response) of Mode. This part of the profile serves as an overall description of the performing manner. This would indicate e.g. how long the session might be expected to last or how fast the tempo might be. *Typical Performance* is a theoretical concept that is not expected to happen or to be treated as a goal to achieve. On the other hand, deviations from the *Typical Performance* are the most important indicator of events that might benefit from further exploration. Changes in the musical material might reflect the same in psychological processes.

The verbal descriptions are included for the convenience of practitioners. Opposite to the table with detailed results, the descriptions are short and clear. Gradations for volume encoded as numeric values in MIDI are expressed in terms such as ‘soft’ or ‘loud’ (Appendix 2). Tempo expressed in bpm has been reported in terms such as ‘slow’ or ‘fast’ (Appendix 2). An equivalent in musical notation such as ‘C2’ representing pitch class and height of a note has been used for the pitch data (Appendix 2).

3.4.2. Temporal Evolution

Temporal Evolution shows the changes in the musical material over a period of time. The manner of improvising might change and that change, or lack of, might be therapeutically important. This however does not mean that the change should be valued for its own sake – it is up to the therapist to decide if the client needs more challenges or stabilisation.

During the period of therapy, the manner of playing might evolve in several ways: 1) consistent (e.g. tempo is approximately 120 bpm) 2) increasing or decreasing (e.g. tempo increases/decreases approximately 5 bpm per session), 3) chaotic (tempo varies from 50 to 150 without a clear pattern). A trendline was created in order to further investigate the change. R-squared values show the goodness of fit of the trendline to the data (FIGURE 12). An individual trendline has been calculated for all of the features except Mode. The majority of these values were low and therefore not presented in the graphs (TABLE 4).

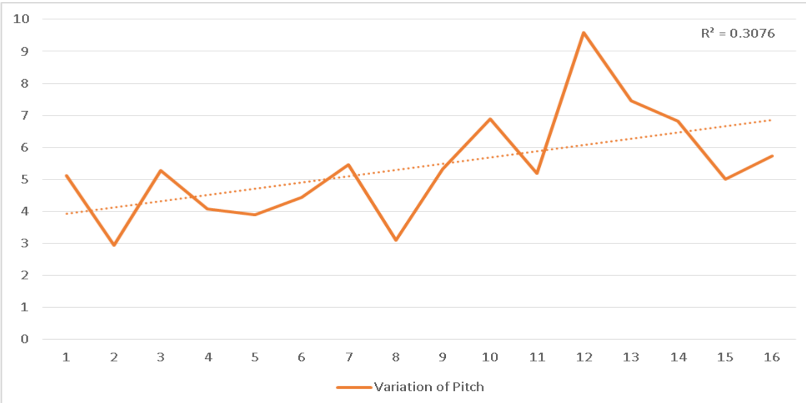

FIGURE 12. A trendline and R-squared value of the Variation of Pitch for Participant 1.

TABLE 4. The goodness of fit of the trendline to the data of Temporal Evolution for all the participants.

Features	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**	**Participant 6**	**Average**
Duration	0.18	0.16	0.26	0.25	0.39	0.05	0.22
Note Count	0.16	0.03	0.12	0.00	0.05	0.00	0.06
Tempo	0.09	0.01	0.07	0.00	0.13	0.02	0.05
Clarity of Pulsation	0.02	0.00	0.10	0.01	0.05	0.00	0.03
Centroid of Velocity	0.00	0.02	0.17	0.00	0.15	0.01	0.06
Variation of Velocity	0.00	0.01	0.04	0.00	0.22	0.03	0.05
Centroid of Pitch	0.01	0.03	0.07	0.02	0.14	0.05	0.05
Variation of Pitch	0.31	0.01	0.02	0.05	0.09	0.00	0.08
Strength of Modality	0.17	0.08	0.10	0.29	0.00	0.08	0.12
Average	0.10	0.04	0.11	0.07	0.14	0.03	

A visual form of presentation was chosen as the most appropriate for the temporal aspect. A single graph incorporating all the features was created. Data normalisation was performed, by scaling between 0 and 1 (TABLE 5), in order to compare values measured on different scales.

TABLE 5. Normalised data set for Participant 1.

	ACTIVITY		**PULSATION**		**DYNAMICS**		**PITCH**		**MODALITY**
Session	**Duration**	**Note Count**	**Tempo**	**Pulse**	**Centroid**	**Variation**	**Centroid**	**Variation**	**Strength**
1	1	1	0.20	0.00	0.55	0.65	0.37	0.33	0

2	0.14	0.10	0.41	0.37	0.30	0.48	0.24	0	0
3	0.01	0.10	0.48	0.25	0	0	1	0.35	0.89
4	0.06	0.19	0.93	0.57	0.55	0.55	0.21	0.17	1
5	0.09	0.17	0.25	0.31	0.94	0.87	0.52	0.15	0
6	0.09	0.14	0.80	0.72	0.67	0.66	0.35	0.22	0
7	0.23	0.17	0.36	0.09	0.23	0.30	0.50	0.38	0
8	0	0	0	0	0.38	0.37	0	0.03	0
9	0.16	0.28	0.57	0.63	0.96	0.88	0.55	0.36	0
10	0.10	0.16	0.45	0.58	0.25	0.37	0.86	0.59	0
11	0.13	0.31	0.82	0.30	1	1	0.53	0.34	0
12	0.14	0.24	1	1	0.42	0.58	0.44	1	0
13	0.01	0.11	0.56	0.29	0.53	0.55	0.18	0.68	0
14	0.09	0.17	0.71	0.24	0.42	0.50	0.69	0.59	0
15	0.09	0.09	0.54	0.26	0.21	0.27	0.21	0.31	0
16	0.06	0.03	0.51	0.30	0.32	0.34	0.33	0.42	0

Verbal descriptions of *Temporal Evolution* outlined the sessions that were exceptional. Sessions where more than one feature reached an extreme value were reported. Troughs and peaks were evaluated separately. Some features e.g. Strength of Modality, which was frequently evaluated as 0, reached the extreme more than once and therefore was eliminated from the results.

3.4.3. Individual Tendencies

Individual Tendencies presents a set of correlations between features that are specific to each participant. These values are the product of Pearson's Correlations between Centroid of Pitch, Strength of Modality, Tempo, Clarity of Pulsation, Centroid of Velocity and Notes per Second. Data in the correlation matrices display the linear dependence between features. For example, Centroid of Velocity is negatively correlated with Centroid of Pitch and positively correlated with Tempo. These correlations are also presented verbally, e.g. when the participant performs in a higher register or slower, he plays more quietly as well.

4. RESULTS

The Musical Profile model was applied to the clinical improvisations of six participants. The Musical Profile of each participant is presented in three separate parts: *Typical Performance*, *Temporal Evolution* and *Individual Tendencies*. Each part consists of a verbal description which provides information in a comprehensible form and a table or a graph which contains more detailed visual or numeric information. In sections 4.1. to 4.6. six Musical Profiles are presented in the way that a music therapist or researcher would see them. In section 4.7. the validity of the method is tested by comparing participants' profiles to each other. The testing is conducted in order to evaluate if the Musical Profile reveals individual differences in the performing manner – it would not be presented to users as the part of the model.

4.1. Participant 1

4.1.1. Typical Performance

The average duration of improvisations (TABLE 6) is 6 min 15s, producing approximately 381 notes. Tempo is fast (124 bpm), pulse clarity is not expressed strongly (0.13). Dynamics are extremely soft (29.96) and the pitch centroid is around D4. The variation of dynamics (6.44) and pitch (5.39) are similar. Modality is not expressed strongly (0.02).

TABLE 6. *Typical Performance* of Participant 1.

ACTIVITY	**Duration**	368.25	In seconds
	Note Count	381.13	
PULSATION	**Tempo**	123.90	In beats per minute
	Clarity	0.13	From 0 to 1, where 1 is the clearest pulsation
DYNAMICS	**Centroid**	29.96	
	Variation	6.44	
PITCH	**Centroid**	62	
	Variation	5.39	
MODALITY	**Strength**	0.02	From 0 to 1, where 1 is the strongest modality
	Mode	Major	

4.1.2. Temporal Evolution

In five sessions more than one feature reaches extreme values (FIGURE 13). Troughs occurred in sessions 3 (Centroid of Velocity, Variation of Velocity) and 8 (Centroid of Pitch, Tempo, Clarity of Pulsation, Duration, Note Count). Peaks occurred in sessions 1 (Duration, Note Count), 11 (Centroid of Velocity, Variation of Velocity) and 12 (Variation of Pitch, Tempo, Clarity of Pulsation).

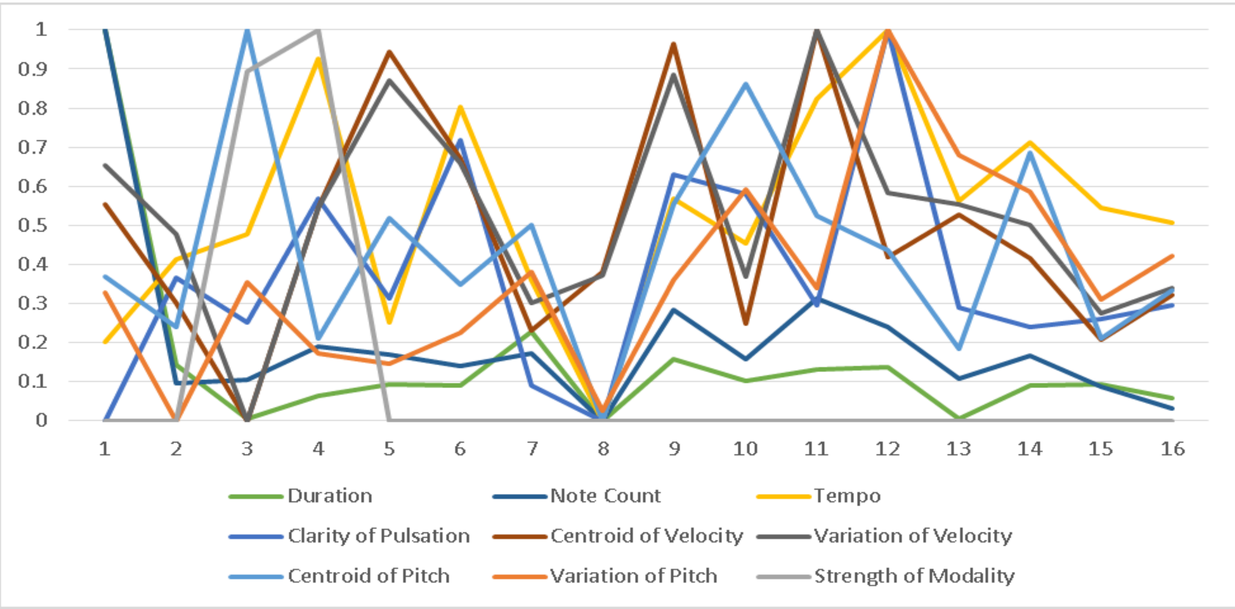

FIGURE 13. *Temporal Evolution* of musical features for Participant 1.

4.1.3. Individual Tendencies

There are three significant correlations in the manner of performing (TABLE 7). First, the participant plays quieter in higher registers. Second, the beat is clearer when tempo is fast. Third, when the tempo is fast, the improvisation is quieter.

Table 7. *Individual Tendencies* for Participant 1.

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
1 Centroid of Pitch	-					
2 Strength of Modality	.22	-				
3 Tempo	.13	.25	-			

4 Clarity of Pulsation	.15	.07	.74**	-		
5 Centroid of Velocity	-.52*	-.26	-.58*	-.43	-	
6 Notes per second	-.14	-.26	.18	.20	-.36	-

Note. * p<.05, ** p<.01.

4.2. Participant 2

4.2.1. Typical Performance

The average duration of improvisations (TABLE 8) is 2 min 45 s, producing approximately 818 notes. Tempo is fast (128 bpm), pulse clarity is not expressed strongly (0.16). Dynamics are moderately soft (64.67) and the pitch centroid is around B2. The variation of dynamics (35.30) is much greater than of pitch (5.58). Modality is not expressed strongly (0.09).

Table 8. *Typical Performance* of Participant 2.

ACTIVITY	**Duration**	163.6	In seconds
	Note Count	818.35	
PULSATION	**Tempo**	128.34	In beats per minute
	Clarity	0.16	From 0 to 1, where 1 is the clearest pulsation
DYNAMICS	**Centroid**	64.67	
	Variation	35.30	
PITCH	**Centroid**	47	
	Variation	5.58	
MODALITY	**Strength**	0.09	From 0 to 1, where 1 is the strongest modality
	Mode	Major	

4.2.2. Temporal Evolution

In three sessions more than one feature reaches extreme values (FIGURE 14). A trough occurred in session 9 (Centroid of Velocity, Variation of Velocity). Peaks occurred in sessions 9 (Centroid of Pitch, Variation of Pitch) and 20 (Clarity of Pulsation, Duration).

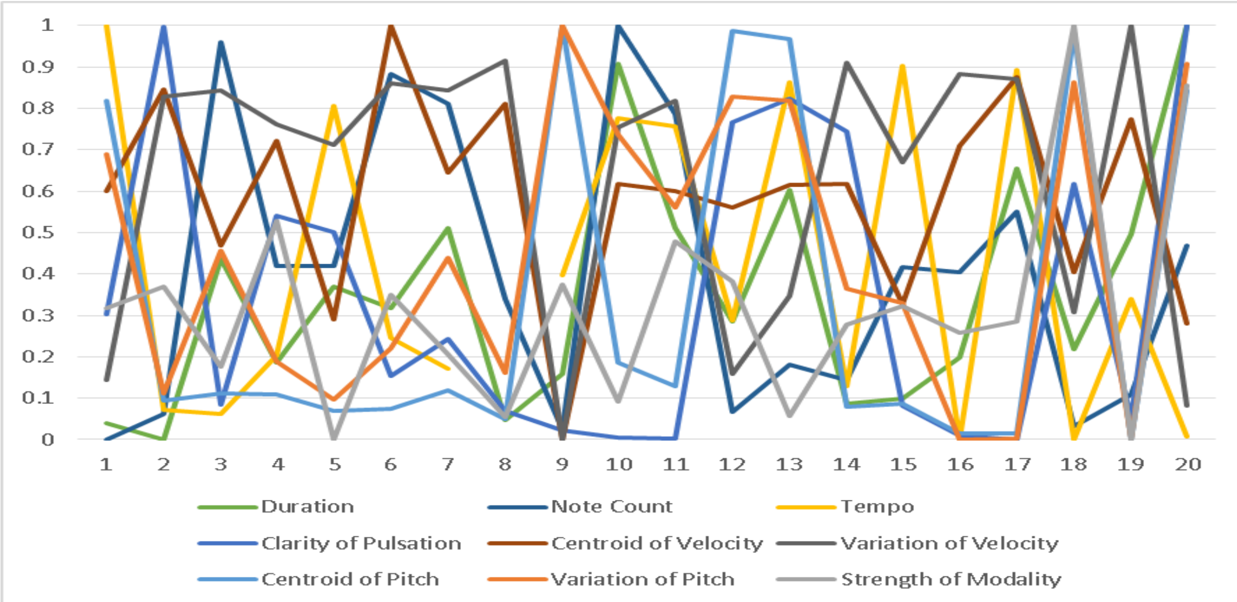

FIGURE 14. *Temporal Evolution* of musical features for Participant 2.

4.2.3. Individual Tendencies

There are three significant correlations in the manner of performing (TABLE 9). First, the modality is stronger when the register is higher. Second, participant plays quieter in the higher register. Third, when the register is high, the improvisation is more dense (more notes per second).

Table 9. *Individual Tendencies* for Participant 2.

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
1 Pitch Centroid	-					
2 Strength of Modality	.46*	-				
3 Tempo	.01	-.43	-			
4 Clarity of Pulsation	.44	.39	-.33	-		
5 Velocity Centroid	-.53*	-.27	-.06	-.10	-	
6 Notes per second	.76**	.22	.01	.33	-.32	-

Note. * p<.05, ** p<.01.

4.3. Participant 3

4.3.1. Typical Performance

The average duration of improvisations (TABLE 10) is 7 min 10 s, producing approximately 1582 notes. Tempo is at the walking pace (98 bpm) and pulse clarity is not expressed strongly (0.2). Dynamics are soft (49.15) and the pitch centroid is around A#3. The variation of dynamics (22.81) is much greater than of pitch (5.79). Modality is not expressed strongly (0.07).

Table 10. *Typical Performance* of Participant 3.

ACTIVITY	**Duration**	432.44	In seconds
	Note Count	1582	
PULSATION	**Tempo**	98.02	In beats per minute
	Clarity	0.20	From 0 to 1, where 1 is the clearest pulsation
DYNAMICS	**Centroid**	49.15	
	Variation	22.81	
PITCH	**Centroid**	58	
	Variation	5.79	
MODALITY	**Strength**	0.07	From 0 to 1, where 1 is the strongest modality
	Mode	Major	

4.3.2. Temporal Evolution

In four sessions more than one feature reaches extreme values (FIGURE 15). Troughs occurred in session 1 (Centroid of Pitch, Duration) and 6 (Variation of Pitch, Clarity of Pulsation, Note Count, Centroid of Velocity, Variation of Velocity). Peaks occurred in sessions 7 (Clarity of Pulsation, Centroid of Velocity, Variation of Velocity) and 12 (Centroid of Pitch, Variation of Pitch, Note Count).

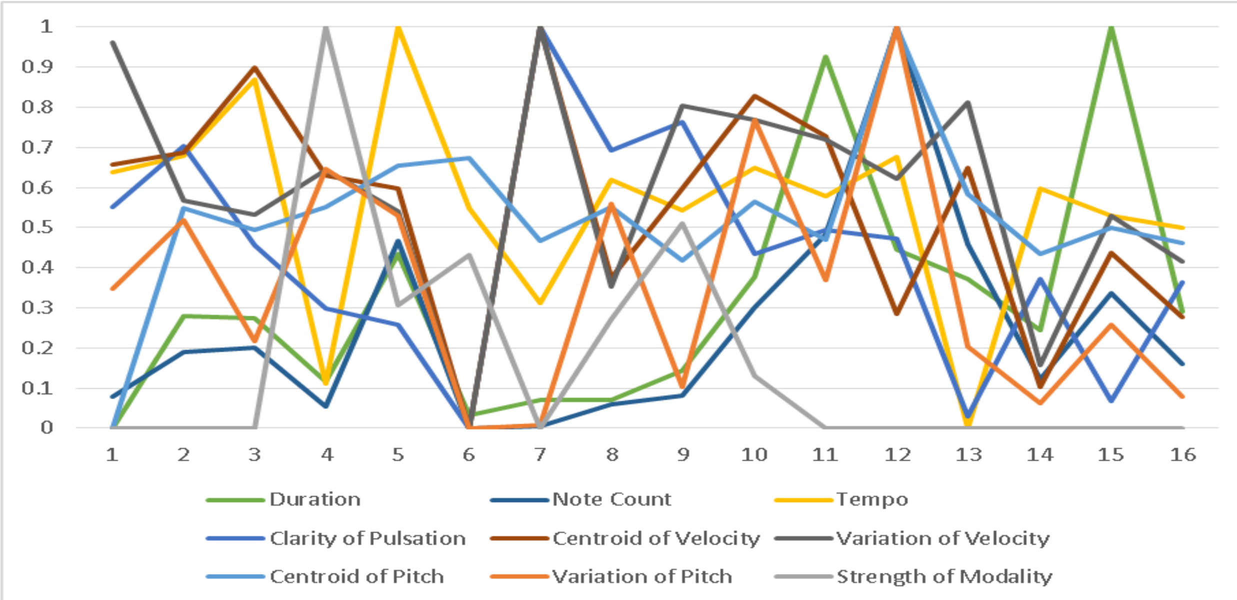

FIGURE 15. *Temporal Evolution* of musical features for Participant 3.

4.3.3. Individual Tendencies

There is one significant correlation in the manner of performing (TABLE 11). The participant plays louder when the pulsation is clear.

Table 11. *Individual Tendencies* for Participant 3.

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
1 Pitch Centroid	-					
2 Strength of Modality	.08	-				
3 Tempo	.08	-.10	-			
4 Clarity of Pulsation	-.19	-.22	.25	-		
5 Velocity Centroid	-.25	-.18	.03	.53*	-	
6 Notes per second	-.10	.15	-.31	.07	-.09	-

Note. * p<.05, ** p<.01.

4.4. Participant 4

4.4.1. Typical Performance

The average duration of improvisations (TABLE 12) is 7 min 40s, producing approximately 1078 notes. Tempo is fast (123 bpm) and pulse clarity is not expressed strongly (0.13). Dynamics are soft (53.87) and the pitch centroid is around C4. The variation of dynamics (16.80) is greater than of pitch (6.36). Modality is not expressed strongly (0.04).

Table 12. *Typical Performance* of Participant 4.

ACTIVITY	**Duration**	458.59	In seconds
	Note Count	1078.65	
PULSATION	**Tempo**	123.36	In beats per minute
	Pulse	0.13	From 0 to 1, where 1 is the clearest pulsation
DYNAMICS	**Centroid**	53.87	
	Variation	16.80	
PITCH	**Centroid**	60	
	Variation	6.36	
MODALITY	**Strength**	0.04	From 0 to 1, where 1 is the strongest modality
	Mode	Major	

4.4.2. Temporal Evolution

In three sessions more than one feature reaches extreme values (FIGURE 16). Trough occurred in session 17 (Duration, Note Count). Peaks occurred in sessions 5 (Centroid of Pitch, Note Count, Variation of Velocity) and 14 (Variation of Pitch, Clarity of Pulsation, Centroid of Velocity).

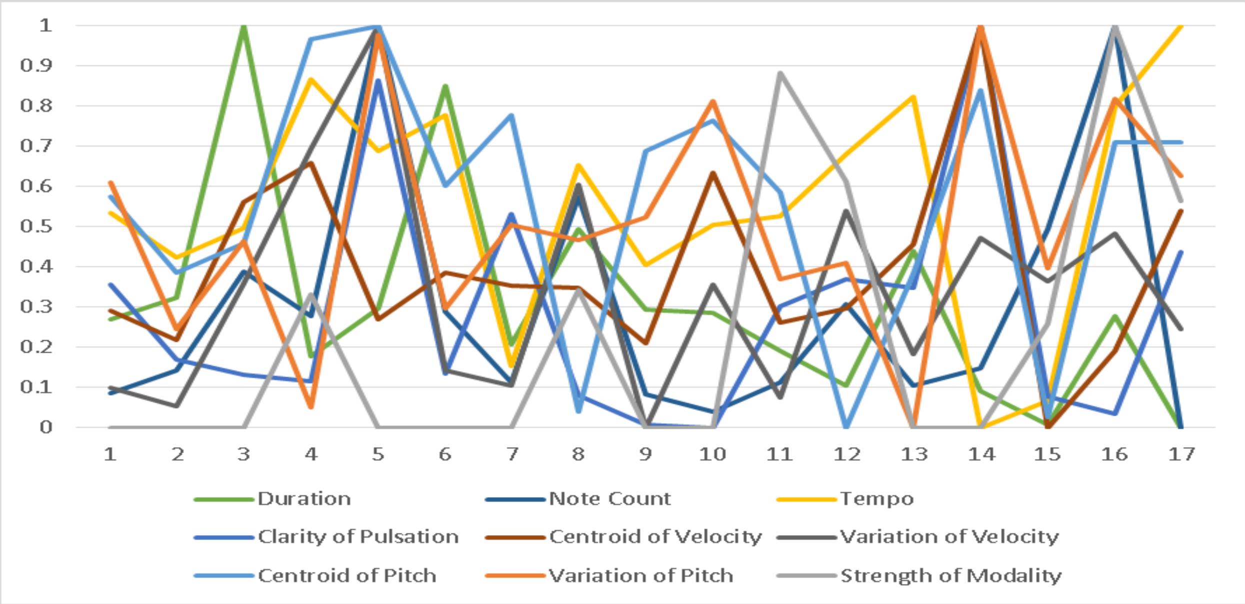

FIGURE 16. *Temporal Evolution* of musical features for Participant 4.

4.4.3. Individual Tendencies

There are no significant correlations in the manner of performing (TABLE 13).

Table 13. *Individual Tendencies* for Participant 4.

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
1 Pitch Centroid	-					
2 Strength of Modality	-.16	-				
3 Tempo	.11	.37	-			
4 Clarity of Pulsation	.36	-.20	-.24	-		
5 Velocity Centroid	.45	-.26	-.01	.40	-	
6 Notes per second	.15	-.47	.09	-.24	.25	-

Note. * p<.05, ** p<.01.

4.5. Participant 5

4.5.1. Typical Performance

The average duration of improvisations (TABLE 14) is 4 min 25 s, producing approximately 314 notes. Tempo is at the walking pace (93 bpm) and pulse clarity is not expressed strongly (0.10). Dynamics are extremely soft (28.94) and the pitch centroid is around B3. The variation of dynamics (6.80) and pitch (4.98) are similar. Modality is not expressed strongly (0.07).

Table 14. *Typical Performance* of Participant 5.

ACTIVITY	**Duration**	263.37	In seconds
	Note Count	313.53	
PULSATION	**Tempo**	93.04	In beats per minute
	Clarity	0.10	From 0 to 1, where 1 is the clearest pulsation
DYNAMICS	**Centroid**	28.94	
	Variation	6.80	
PITCH	**Centroid**	59	
	Variation	4.98	
MODALITY	**Strength**	0.07	From 0 to 1, where 1 is the strongest modality
	Mode	Major	

4.5.2. Temporal Evolution

In six sessions more than one feature reaches extreme values (FIGURE 17). Troughs occurred in sessions 6 (Centroid of Velocity, Variation of Velocity), 7 (Variation of Pitch, Tempo, Note Count) and 13 (Centroid of Velocity, Variation of Velocity). Peaks occurred in sessions 3 (Note Count, Centroid of Velocity, Variation of Velocity) 4 (Tempo, Clarity of Pulsation) and 17 (Variation of Pitch, Duration).

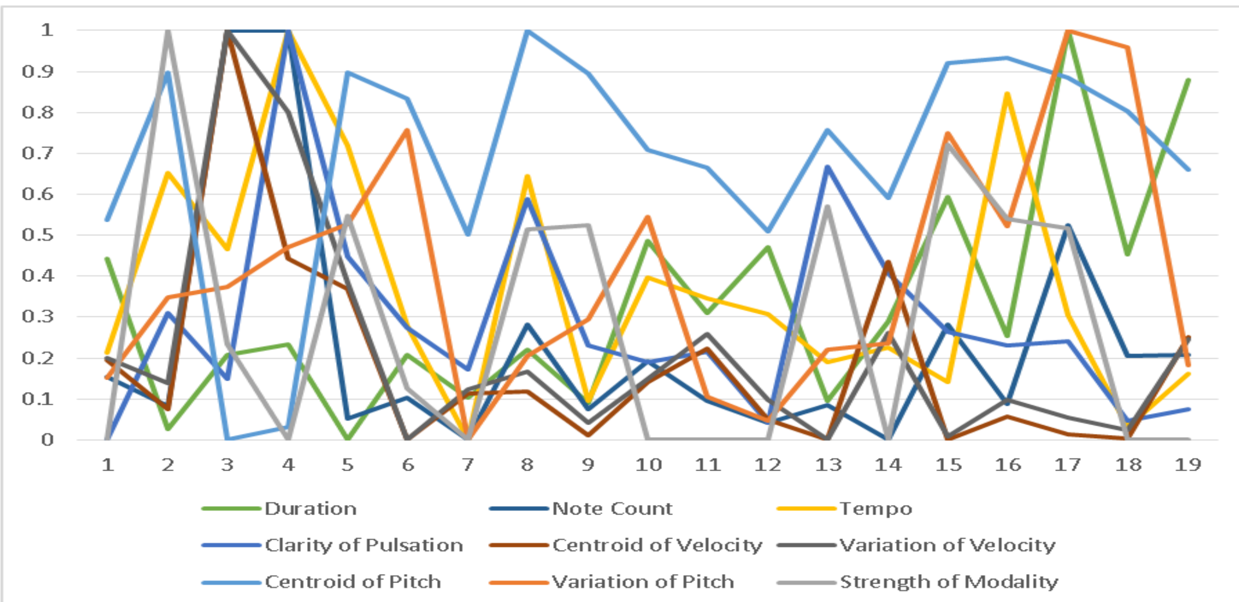

FIGURE 17. *Temporal Evolution* of musical features for Participant 5.

4.5.3. Individual Tendencies

There are three significant correlations in the manner of performing (TABLE 15). First, the modality is stronger when the register is higher. Second, participant plays quieter in the higher register. Third, the beat is clearer when tempo is fast.

Table 15. *Individual Tendencies* for Participant 5.

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
1 Pitch Centroid	-					
2 Strength of Modality	.56*	-				
3 Tempo	-.15	.27	-			
4 Clarity of Pulsation	-.15	.23	.58**	-		
5 Velocity Centroid	-.75**	-.25	.31	.13	-	

6 Notes per second	.05	-.44	-.45	-.40	-.19	-

Note. * p<.05, ** p<.01.

4.6. Participant 6

4.6.1. Typical Performance

The average duration of improvisations (TABLE 16) is 4 min 15 s, producing approximately 331 notes. Tempo is moderate (111 bpm) and pulse clarity is not expressed strongly (0.08). Dynamics are very soft (37.75) and the pitch centroid is around B3. The variation of dynamics (13.23) is greater than of pitch (5.66). Modality is not expressed strongly (0.05).

Table 16. *Typical Performance* of Participant 6.

ACTIVITY	**Duration**	256	In seconds
	Note Count	330.94	
PULSATION	**Tempo**	111.10	In beats per minute
	Clarity	0.08	From 0 to 1, where 1 is the clearest pulsation
DYNAMICS	**Centroid**	37.75	
	Variation	13.23	
PITCH	**Centroid**	59	
	Variation	5.66	
MODALITY	**Strength**	0.05	From 0 to 1, where 1 is the strongest modality
	Mode	Minor	

4.6.2. Temporal Evolution

In four sessions more than one feature reaches extreme values (FIGURE 18). Troughs occurred in sessions 10 (Variation of Pitch, Duration) and 11 (Centroid of Velocity, Variation of Velocity). Peaks occurred in sessions 4 (Tempo, Centroid of Velocity, Variation of Velocity) and 14 (Variation of Pitch, Duration, Note Count).

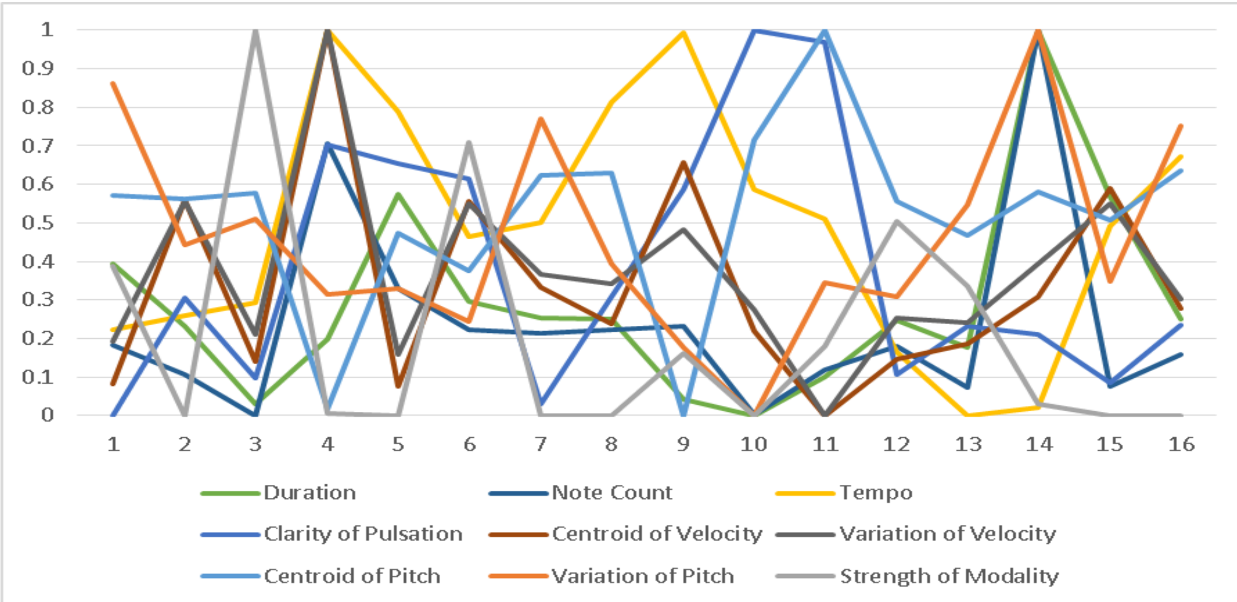

FIGURE 18. *Temporal Evolution* of musical features for Participant 6.

4.6.3. Individual Tendencies

There are two significant correlations in the manner of performing (TABLE 17). First, participant plays quieter in the higher register. Second, the beat is clearer when tempo is fast.

Table 17. *Individual Tendencies* for Participant 6.

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
1 Pitch Centroid	-					
2 Strength of Modality	-.02	-				
3 Tempo	-.43	-.39	-			
4 Clarity of Pulsation	-.02	-.22	.51*	-		
5 Velocity Centroid	-.77**	-.23	.44	.11	-	
6 Notes per second	.20	-.01	-.30	-.44	-.04	-

Note. * p<.05, ** p<.01.

4.7. Evaluation of the model

4.7.1. Typical Performance

Typical Performance data revealed information about the performance of each participant. If the features selected for the profiling were suitable, the results of the individual participants should differ significantly. A one-way ANOVA was performed in order to determine how representative these measures were.

ANOVA revealed that there were significant differences between participants on eight out of nine features. Variance of Pitch was the only feature that did not vary significantly, but the Duration, Note Count, Tempo, Clarity of Pulsation, Centroid of Velocity, Variation of Velocity, Centroid of Pitch, and Strength of Modality did (TABLE 18).

TABLE 18. Significant results of the ANOVA test between six participants on eight features.

	Duration	**Note Count**	**Tempo**	**Clarity of Pulsation**	**Centroid of Velocity**	**Variation of Velocity**	**Centroid of Pitch**	**Strength of Modality**
Welch *F*	8.612**	7.394**	5.938**	5.039**	43.090**	34.264**	7.872**	3.106*
df1	5	5	5	5	5	5	5	5
df2	43.296	45.495	44.586	45.920	44.427	44.890	42.648	46.184

Note. * p<.05, ** p<.01.

Post hoc analysis using Games-Howell testing revealed specific details about significant (*p*<.05) differences between participants (FIGURE 19). The interesting finding is that one participant is always different from the others – Participant 2. He differed significantly from at least one other participant in all features, whilst in Variance of Velocity and Strength of Modality he was significantly different compared to all the other participants. The feature that revealed the most differences amongst participants was Variance of Velocity: Participant 2 differed from everyone, Participant 1 differed from Participants 3, 4, and 6, Participant 3 differed from Participants 5 and 6, and Participant 4 differed from Participant 5.

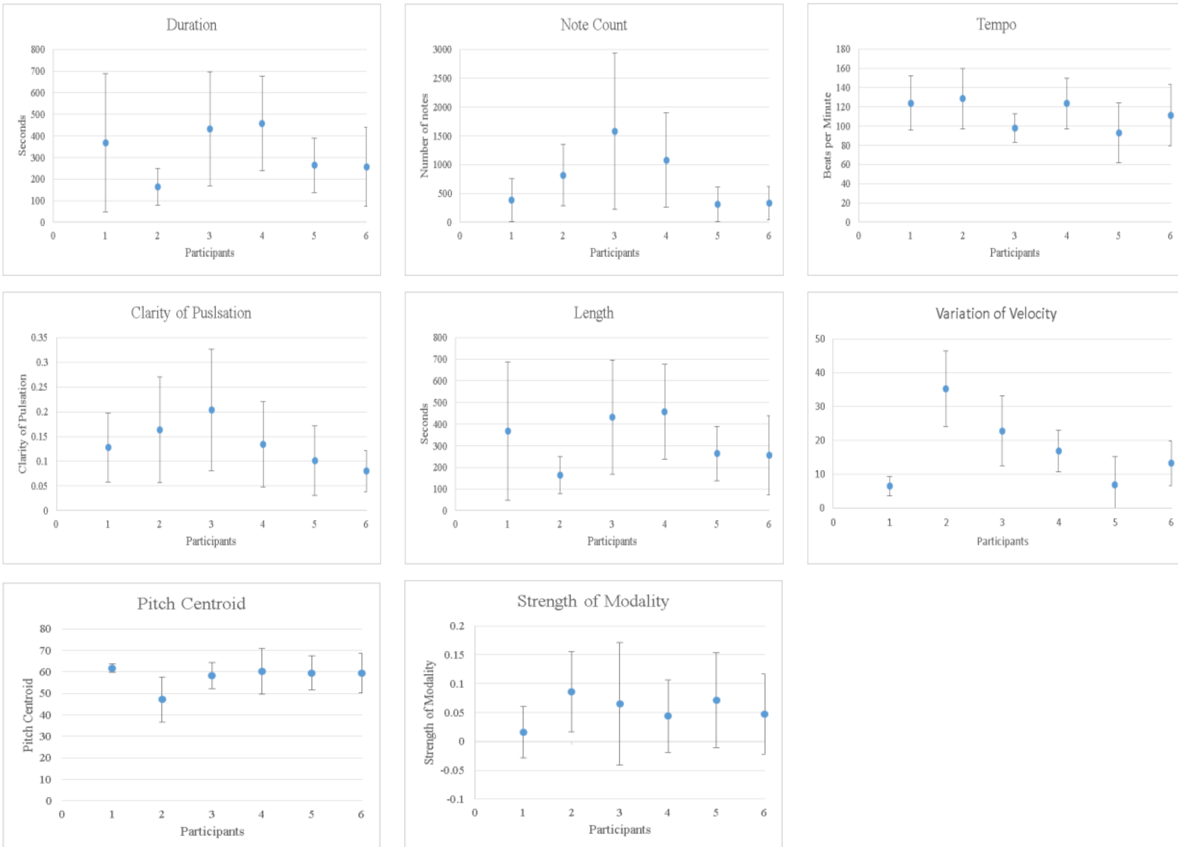

FIGURE 19. Differences between *Typical Performances* (averages plus and minus one standard deviation) of six participants.

4.7.2. Temporal Evolution

Temporal Evolution revealed changes in the musical material over a period of time. There were no significant differences between R-squared values that show the goodness of fit of the trendline to the data. One possible explanation might be the unstructured nature of clinical improvisations in psychodynamic approach, but this hypothesis has to be tested with a larger number of participants. Despite the lack of statistical significance there are some observable differences. Participants 2 and 4 had least simultaneous troughs and peaks of the features and participant 5 had the most (FIGURE 20).

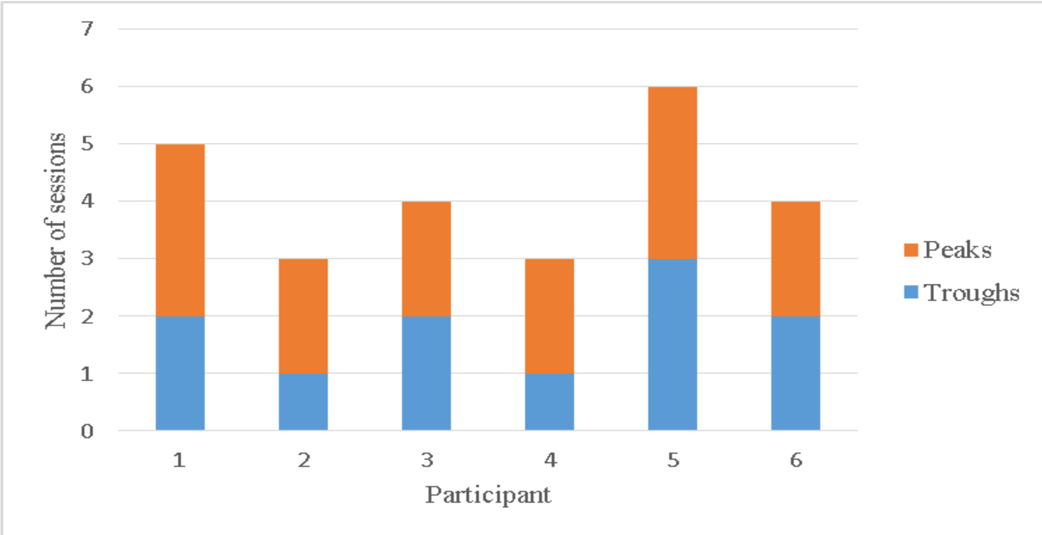

FIGURE 20. Number of sessions with coincidental peaks and troughs for all six participants.

4.7.3. Individual Tendencies

Individual Tendencies revealed a set of correlations between features that are specific to each participant. Participant 4 had no correlations between features whilst Participants 1, 2 and 5 had three correlations each (TABLE 19). The most interesting finding is that none of the participants had the same set of correlations between the features. The negative correlation between Centroid of Pitch and Centroid of Velocity was the most common between participants. This is the tendency to play quieter in the high register.

Table 19. Significant Pearson's Correlations for all six participants.

Parameters		**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**
1 Centroid of Pitch	2 Strength of Modality		.46			.56	
1 Centroid of Pitch	5 Centroid of Velocity	-.52	-.53			-.75	-.77
1 Centroid of Pitch	6 Notes per Second		.76				
3 Tempo	4 Clarity of Pulsation	.74				.58	.51
3 Tempo	5 Centroid of Velocity	-.58					
4 Clarity of Pulsation	5 Centroid of Velocity			.53			

5. DISCUSSION AND CONCLUSIONS

5.1. Summary of the background

This study investigated current standards of assessment in music therapy. The analysis of literature revealed the requirement for a formalised assessment method, and suggested the underlying reasons why such a method had not yet been adopted. Based on these findings a methodology for a new model was constructed. The proposed model was tested by analysing the clinical improvisations of depressed clients during the course of improvisatory psychodynamic music therapy. The analysis of individual Musical Profiles showed significant differences in the manner of improvisation and demonstrated the applicability of the extracted data to therapeutic analysis.

Music therapy as a profession emerged and advanced based mainly on clinical work. Consequently, the importance of scientific method to the field has been underestimated (Wosch & Wigram, 2007). The literature review revealed that even though music therapy research is growing as a field, the body of knowledge related to the effect of music therapy interventions is still insufficient (Sabbatella, 2004). The majority of published texts are based on therapists' qualitative observations, therefore conclusions about the general effect of music therapy treatment cannot be drawn (Maratos et al., 2011). This thesis proposes to overcome these issues by establishing a systematic method of measuring and representing musical processes.

Requirements for the assessment method were investigated from both clinicians' and researchers' positions. Clinicians prioritize flexibility and individualized approaches to assessment (Gregory, 2000). Researchers, on the other hand, seek to compare and evaluate the effect of treatment objectively, and therefore prioritize systematic evaluation and controlled procedure (Wheeler, 1995). The Musical Profile meets both requirements: it provides objective data extracted from improvisations that can be interpreted based on the therapists' observations.

Another challenge revealed by the background investigation was the perceived distance between music therapy and music information retrieval practice. The majority of music therapy clinicians have no training in technology and fail to see the benefits of integrating it into their work (Hahna et al., 2012). The Musical Profile was designed to be used by clinicians without any technical skills or knowledge. The results are presented in a user-friendly manner that avoids complicated terms and excessive information. In consequence, numeric values and graphs are accompanied by verbal descriptions that explain the most important results in commonly used terms.

5.2. Construction of the model

Tonality, tempo, dynamics, and pitch, common musical parameters in IMTAP, IAP, and Indexing, were included in the Musical Profile. Rhythmic and melodic organisation were excluded because they cannot be retrieved with satisfactory accuracy. Timbre, texture and instrumentation were not encoded into the material that this study was based upon and was excluded from the profile as well. Strength of modality was extremely low for all participants. Therefore, tonal centre was not included in the descriptions. Compared to the existing computational tools, all of the musical features used in CAMTAS, MTTB, and Logbook were included in the Musical Profile except dissonance (MTTB). In the current study, extracted features were grouped into five classes: Activity (Duration and Note Count), Pulsation (Tempo and Clarity), Dynamics (Centroid and Variation), Pitch (Centroid and Variation), and Modality (Strength and Mode).

Musical processes and individual trends were analysed and presented in three forms: *Typical Performance, Temporal Evolution* and *Individual Tendencies. Typical Performance* provides an overall description of the performing manner. The improvisation that deviates greatly from client's *Typical Performance* could indicate psychological changes that might benefit from further exploration. *Temporal Evolution* measures the changes in the musical material over a period of time. Changes, or lack of, in the manner of improvising might be therapeutically important. *Individual Tendencies* represent a set of relations between features that are specific to each participant. The significance of these results will depend on the insights of the therapist. The Musical Profiling model is not intended to eliminate the role of the therapist, but rather to simplify the process of evaluation by providing musical material in concise form, and to highlight changes in improvising manner.

5.3. Implications of the model

The information presented in the Musical Profile of the client's performing manner might be used by therapists and researchers in various ways. For example, a clinician might notice from the *Temporal Evolution* graph that the client's tempo was slowing down for the last three sessions and the duration and dynamics of the improvisations decreased as well. If the therapist has an insight that client might be restrained, he or she might challenge the performing manner by introducing faster and louder music in the next session in order to see how the client manages being outside of his comfort zone. Researchers, for example, might choose to investigate the variation and commonalities of the musical expression by clients who are diagnosed with specific disorders. Instead of starting a new trial they can collect Musical Profiles from therapists that already work with the target client population. Since music therapy is a very expensive and time consuming process, generalisations about the effect of the disorder on the manner of improvising have not been established yet, but that could change if the Musical Profile were adopted into practice.

The Musical Profile was tested on six depressed clients who participated in the Erkillä et al. (2011) study. Psychological measures show positive changes in the mental state of four participants after the course of psychodynamic improvisatory music therapy. The scores of Participants 4, 5, and 6 improved in all psychiatric tests (MADRS, HADS, GAF), and Participant 3 improved in two (MADRS and GAF). The current study analyzes a very small sample so generalisations cannot be made, but the results are in agreement with the literature (Maratos 2008; Gold, 2009), that music therapy interventions have a positive effect on a depression.

The differences between Musical Profiles were established with an ANOVA test. There were significant differences between at least two participants on every parameter except Pitch Variation. Participant 2 was found to be the most different from the other participants. The parameter that revealed the most significant differences in the improvising manner was the Variance of Velocity. This test confirmed that the measures used in the Music Profile model are sensitive to differences in improvising manner and could serve as a basis for a tool that implements an individualised approach to music analysis. The most consistent manner of improvising as revealed by goodness of fit to the trendline was that of Participant 5, whist Participants 2 and 6 performed in a more chaotic manner. Individual Tendencies varied from 3 (Participants 1, 2 and 5) to none (Participant 4). The most common tendency was to play quieter in the higher register (total of four participants).

These results are evidence of the necessity for an individual approach to the evaluation of musical processes in clinical improvisations, supporting the general approach of music therapy clinicians. However it also demonstrates that it is possible to analyse these individual differences in objective and systematic ways.

The study's main limitations were a result of the material used. MIDI improvisations do not have timbral qualities, and mallet instruments do not facilitate variations in articulation or texture so these features were excluded from the profile. There were technical issues as well. Some of the values in the MIDI files were constant throughout the session (e.g. Participant 5 in sessions 5 and 13 Velocity of 24) which could have occurred because of errors in setting up the instruments since it is highly unlikely that a human participant could maintain this level of consistency. In addition to the musical material challenges, Participants 1 and 2 scored so low in the initial depression measurement, that they should have been excluded from the study.

5.4. Future directions

The next developmental stage of the Musical Profile will expand the selection of musical features (e.g. timbre, texture) and include more options for instrumentation (e.g. drums, piano) that are considered necessary for evaluation but could not be included in this study because of the limitations of material it was based on. Musical analysis will also be complemented by computer-based video analysis, since video material is often collected in music therapy settings, but is not explored to its full extent yet. A successful analysis method from MTTB called Imitation Profiles that signifies the interaction between client and therapist will be incorporated as well. Subsequently the Musical Profile will be provided to music therapists for the in-depth investigation of the applicability of this method in practice.

The future development of the Musical Profile will work towards the creation of a full-featured software package that functions as a database with options for automatic analysis of audio, MIDI and video material captured during the course of music therapy. Finally the software and the manual with the guidelines for setting up the sessions and performing the most appropriate analysis will be released.

Music therapy has developed rapidly as a discipline over the last 60 years. There are hundreds of studies documenting the positive effect of therapeutic intervention, but the majority of these studies were performed on a small sample of clients, therefore generalisations could not be established. Since then music therapy has become part of health care practice in many countries worldwide, and multiple education systems have started preparing music therapy clinicians and researchers. We have reached a point where there are substantial human resources and technology available to carry out studies that systematically investigate the processes involved in music therapy. However, some formalisation of approach is required in order to facilitate this investigation. The Musical Profile, in its current state, can be seen as the first step towards this goal. It is an extraordinary time to work in music therapy research, knowing that the results of our investigations can shed light on the ways that musical experiences help us to live our lives to the fullest.

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APPENDIX 1

A set of extracted features for Participant 2.

Session	ACTIVITY		PULSATION		DYNAMICS		PITCH		MODALITY
	Duration	Note Count	Tempo	Pulse	Centroid	Variation	Centroid	Variation	Strength
1	68	170	178.81	0.15	65.25	18.40	60	6.49	0.09
2	56	268	98.50	0.35	76.89	41.93	41	4.41	0.10
3	188	1711	97.66	0.08	58.96	42.44	41	5.65	0.05
4	112	843	109.87	0.22	71.03	39.59	41	4.68	0.14
5	168	844	162.09	0.21	50.47	37.95	40	4.35	0
6	152	1589	113.56	0.10	84.23	43.02	40	4.80	0.09
7	210	1472	107.09	0.13	67.42	42.46	41	5.58	0.06
8	70	714	undefined*	0.08	75.28	44.88	40	4.59	0.01
9	104	209	126.57	0.07	36.70	13.50	64	7.60	0.10
10	330	1775	159.43	0.06	66.08	39.36	43	6.65	0.02
11	210	1434	157.78	0.06	65.25	41.59	42	6.02	0.13
12	142	278	117.25	0.29	63.37	18.93	64	6.98	0.10
13	238	459	167.04	0.30	65.97	25.45	64	6.95	0.02
14	82	401	103.50	0.28	66.01	44.69	40	5.31	0.08
15	86	839	170.46	0.08	52.22	36.50	41	5.19	0.09
16	116	820	92.38	0.06	70.44	43.78	39	4.00	0.07
17	254	1053	169.46	0.06	78.30	43.33	39	4.01	0.08
18	122	220	92.33	0.24	55.9	24.08	64	7.11	0.27
19	206	346	121.76	0.08	73.49	47.79	38	4.01	0
20	358	922	93.02	0.36	50.08	16.32	60	7.27	0.23

* The algorithm failed to estimate the tempo of the improvisation.

A set of extracted features for Participant 3.

Session	ACTIVITY		PULSATION		DYNAMICS		PITCH		MODALITY
	Duration	Note Count	Tempo	Pulse	Centroid	Variation	Centroid	Variation	Strength
1	114	643	104.37	0.27	55.60	38.34	41	5.92	0
2	382	1269	106.43	0.34	56.99	22.62	59	7.37	0
3	376	1322	116.62	0.23	67.29	21.26	57	4.80	0
4	226	514	76.29	0.16	54.25	25.65	59	8.45	0.33
5	530	2808	123.57	0.15	52.76	21.50	63	7.46	0.10
6	146	213	99.60	0.03	24	0	63	2.95	0.14
7	182	237	87.02	0.47	72.07	39.87	57	3.01	0
8	180	545	103.37	0.33	41.99	14.11	59	7.73	0.09
9	252	659	99.28	0.36	52.76	32.08	55	3.82	0.17

10	476	1886	104.94	0.22	63.77	30.69	60	9.51	0.04
11	1000	2901	101.14	0.25	59.00	28.75	57	6.10	0
12	540	5769	106.34	0.24	37.70	24.83	74	11.48	0
13	470	2768	70.33	0.05	55.21	32.38	60	4.68	0
14	348	885	102.14	0.19	29.01	6.25	55	3.47	0
15	1070	2080	98.55	0.06	45.00	21.08	58	5.14	0
16	392	1097	96.96	0.19	37.29	16.57	56	3.63	0
17	514	1165	66.75	0.07	41.66	20.29	57	4.12	0
18	586	1715	100.68	0.06	38.35	14.26	57	4.64	0.30

A set of extracted features for Participant 4.

Session	ACTIVITY		PULSATION		DYNAMICS		PITCH		MODALITY
	Duration	Note Count	Tempo	Pulse	Centroid	Variation	Centroid	Variation	Strength
1	424	497	121.66	0.15	46.77	11.29	61	7.06	0
2	468	650	111.16	0.10	41.59	10.27	54	4.64	0
3	1022	1308	118.12	0.09	65.77	17.24	57	6.09	0
4	348	1009	153.01	0.08	72.74	24.89	74	3.34	0.06
5	446	2931	136.15	0.30	45.07	31.84	75	9.50	0
6	900	1039	144.61	0.09	53.38	12.33	62	4.98	0
7	372	570	85.81	0.21	51.03	11.46	68	6.36	0
8	608	1804	132.68	0.07	50.66	22.83	42	6.12	0.06
9	444	490	109.49	0.05	40.91	9.051	65	6.48	0
10	436	379	118.82	0.05	70.96	17.17	67	8.40	0
11	360	570	120.80	0.14	44.60	10.74	61	5.47	0.16
12	288	1089	135.32	0.16	46.99	21.33	41	5.73	0.11
13	562	551	148.78	0.15	58.44	13.22	54	3.01	0
14	278	668	71.24	0.34	96.79	19.84	70	9.64	0
15	208	1584	77.60	0.07	26.07	17.34	42	5.64	0.04
16	430	2928	146.42	0.06	39.62	20.09	65	8.44	0.17
17	202	270	165.38	0.18	64.34	14.65	65	7.17	0.11

A set of extracted features for Participant 5.

Session	ACTIVITY		PULSATION		DYNAMICS		PITCH		MODALITY
	Duration	Note Count	Tempo	Pulse	Centroid	Variation	Centroid	Variation	Strength
1	314	230	75.87	0.02	29.24	6.37	55	3.81	0
2	120	158	124.22	0.11	26.01	4.41	65	4.72	0.26
3	204	1093	103.76	0.06	50.82	31.87	40	4.83	0.06
4	216	1092	162.68	0.30	35.91	25.47	41	5.28	0
5	108	126	131.59	0.15	33.90	12.24	65	5.54	0.14
6	204	180	83.16	0.10	24	0	64	6.61	0.03

7	156	74	52.21	0.07	27.01	3.90	54	3.10	0
8	210	362	123.50	0.19	27.19	5.33	68	4.05	0.13
9	150	150	62.74	0.08	24.27	1.36	65	4.46	0.13
10	334	269	95.97	0.07	27.79	4.79	60	5.62	0
11	252	170	90.33	0.08	29.99	8.29	59	3.59	0
12	326	116	86.29	0.03	25.30	3.12	54	3.32	0
13	152	160	73.07	0.21	24	0	61	4.13	0.15
14	242	76	77.10	0.13	35.66	8.31	57	4.20	0
15	384	361	67.83	0.09	24.03	0.29	66	6.57	0.19
16	226	163	145.65	0.08	25.50	3.10	66	5.52	0.14
17	572	608	85.90	0.09	24.35	1.70	65	7.74	0.13
18	318	282	55.69	0.03	24.09	0.74	63	7.55	0
19	516	287	70.14	0.04	30.75	7.81	59	3.94	0

A set of extracted features for Participant 6.

Session	**ACTIVITY**		**PULSATION**		**DYNAMICS**		**PITCH**		**MODALITY**
	Duration	**Note Count**	**Tempo**	**Pulse**	**Centroid**	**Variation**	**Centroid**	**Variation**	**Strength**
1	332	268	84.24	0.03	28.16	8.21	61	7.74	0.09
2	216	185	87.98	0.07	46.22	18.61	61	5.57	0
3	70	65	91.38	0.04	30.40	8.77	62	5.93	0.23
4	192	850	163.46	0.12	62.83	31.33	40	4.92	0
5	462	432	141.78	0.11	27.99	7.30	58	5.00	0
6	262	313	108.81	0.11	46.09	18.45	54	4.56	0.16
7	230	304	112.51	0.03	37.60	13.24	63	7.27	0
8	228	314	144.29	0.07	34.03	12.51	64	5.33	0
9	78	324	162.89	0.11	49.86	16.54	40	4.22	0.04
10	48	67	121.46	0.16	33.31	10.59	67	3.30	0
11	120	197	113.43	0.16	25.07	2.72	78	5.07	0.04
12	226	264	78.47	0.04	30.63	9.96	61	4.89	0.12
13	176	146	61.55	0.06	32.15	9.62	57	6.12	0.08
14	770	1177	63.77	0.06	36.72	13.98	62	8.44	0.01
15	458	148	111.58	0.04	47.38	18.43	59	5.09	0
16	228	241	130.02	0.06	35.61	11.37	64	7.16	0

APPENDIX 2

The literature review did not reveal any sources that would provide verbal descriptions of MIDI velocity, Tempo in Bpm and MIDI notes in a commonly used language. Different sources were combined together in order to establish these scales. For example, tempo values from the metronome (e.g. 80 is Andante) were linked to the descriptions of the musical terms in the encyclopaedia (Andante is ‘at the walking pace’).

Descriptions of MIDI velocity

Midi level	**Description**
16	Extremely soft
33	Very soft
49	Soft
64	Moderately soft
80	Moderately loud
96	Loud
112	Very loud
126	Extremely loud

Descriptions of Tempo in Bpm

Bpm	**Description**
40	Extremely slow
60	Very slow
66	Slow
72	Rather slow
80	At the walking pace
108	Moderate
112	Rather fast
120	Fast
168	Very fast
200	Extremely fast

Description of MIDI Notes

Notes	**Octaves**										
	-1	0	1	2	3	4	5	6	7	8	9
C	0	12	24	36	48	60	72	84	96	108	120
C #	1	13	25	37	49	61	73	85	97	109	121
D	2	14	26	38	50	62	74	86	98	110	122
D #	3	15	27	39	51	63	75	87	99	111	123
E	4	16	28	40	52	64	76	88	100	112	124
F	5	17	29	41	53	65	77	89	101	113	125
F #	6	18	30	42	54	66	78	90	102	114	126
G	7	19	31	43	55	67	79	91	103	115	127
G #	8	20	32	44	56	68	80	92	104	116	
A	9	21	33	45	57	69	81	93	105	117	
A #	10	22	34	46	58	70	82	94	106	118	
B	11	23	35	47	59	71	83	95	107	119	