Music Technology and Response Measurement

In this chapter, a brief review of related literatures in the general field of response measurement is presented. Following the short rehearsal of the evidence-base is an introduction of the history of the development of the Continuous Response Measurement Apparatus (CReMA) by Himonides (2011), a creative integration of traditional analog synthesizer technology with a biomedical data acquisition system that was originally developed as part of a doctoral research investigation that was centred on the understanding and/or construction of beauty in a vocal performance (Himonides and Welch, 2005; Himonides, 2009). The main focus is then placed on the development of a novel software tool, inspired by the CReMA, that has been designed upon request by members of the research community who had expressed an interest in identifying a simple way to capture, process, and analyze affective response data. This new software tool, CReMA MIDI, enables any researcher that has access to any MIDI information generator (i.e. a controller and/or instrument) and any MIDI stream capturing software (i.e. any modern digital audio workstation (DAW) or MIDI enabled mobile device) to process automatically captured MIDI files and extract information components automatically for further analyses using any preferred statistical analyses package.

Background

Traditionally, perceptual testing and measurement of experience in mainstream non-clinical psychological research was usually conducted either through an interview schedule or with a ranking of one's 'experience' or 'opinion' on a printed continuum or numbered scale. In both cases, the testing usually occurred 'post-hoc', i.e. at the end of the listening session (cf. Berliner et al., 1978; Sederholm et al., 1993; Granqvist, 2003). In fewer cases, a research participant might have been asked to perform a number of ratings in response to a session (e.g. at the beginning; midway; and at the end of a session).

In a comprehensive review of the literature, Himonides (2009) presented that the dominant part of the evidence base in the extended field of music and emotion subscribes to a discrete emotion model/theory, and appears to lay on the foundations set by Wilhelm Wundt (1904), the father of experimental psychology (among others see: Ziche, 1999). Researchers in the field utilise *n-Dimensional modelling of emotions* (*n* is the number of dimensions that a researcher decides to utilise, e.g. *unidimensional, two-dimensional, three-dimensional* etc.). Wundt himself employed a three-dimensional model for his work on the description of feelings, the three dimensions being: *pleasantness – unpleasantness*; *rest – activation* and *tension – relaxation*.

Although Wundt's three-dimensional model has been reported as having a strong impact on research regarding the psychology of affect and emotion (Scherer, 2004), the third dimension (tension-relaxation) has been difficult to implement effectively in experimental

testing. Empirical research projects in the field (*see among others* Wedin, 1972) usually require participants (listeners) to report their perception regarding a musical piece's 'emotion evoking properties' by placing appropriate marks either on paper or on a digital graphical model (*cf* Lavy, 2001; Thompson & Williamon, 2003; Thompson, 2005); a process that has been proven to be heuristically as well as ergonomically challenging to perform within spaces that are formed by more than two dimensions. An 'extreme' example of a multi-dimensional instrument for the measurement of affective responses to music is the *9-Affective Dimensions (9-AD)* instrument proposed by Asmus (1985), comprising *evil, sensual, potency, humour, pastoral, longing, depression, sedative* and *activity* dimensions. As Himonides (2009) states: "It would seem that, Asmus (op. cit.) was not in a position to employ rare geniuses that were able to score their feelings in nine-dimensional space for his research; rather he 'distilled' these nine dimensions by performing qualitative analyses and groupings of the adjectives/keywords that his subjects used when they were asked to describe their feelings" (p. 36). These logistical constraints/challenges have led to a simplification of the model to a two-dimensional version comprising the measurement of *valence* on one axis and the measurement of *activation* across the other axis, thus forming a two-dimensional response surface. The *valence/activation* (or *valence/arousal*, as appearing in other research studies) models of emotion mapping have essentially governed the majority of contemporary research studies in affective responses to music (e.g. Schubert, 1999; Schubert, 2003; Juslin & Laukka, 2004; Sloboda & Lehmann, 2001; Witvliet, 1996). As Scherer (2004) reports, although the utilisation of such two-dimensional models offers certain benefits in the mapping of feelings, such as helping us to visualise connections and/or commonalities between mapped feelings and their bordering ones in the two-dimensional space (Feldman Barrett & Russell, 1999), threats and disadvantages do exist. Gabrielsson and Juslin (2003) argue that the fusion of the *rest – arousal* and *tension – relaxation* dimensions into one dimension is especially problematic, since *tension – relaxation* appears to be a very important facet in the morphological (or broader musicological) analyses of musical form.
Scherer (2004) concludes:

"Many of the established techniques have serious shortcomings, as shown above. Inappropriate measurement instruments not only carry the danger of missing essential aspects of the phenomenon or obtaining biased data, they also prevent accumulation and comparability of results in a domain that critically depends on coordinated efforts for its further development" (p. 250).

Continuous Response Measurement

In the early nineties, the development and introduction of innovative technology known as the CRDI (Continuous Response Digital Interface) by the Center for Music Research at Florida State University (FSU) opened new horizons for perceptual testing in music and music performance (see among others: Madsen et al., 1991). Since then, a large number of research studies were conducted using the CRDI, and there is now a substantial body of published research suggesting that the use of such technology renders meaningful research datasets, therefore offers a significant contribution to the overarching research field (Capperella, 1989; Johnson, 1992). With the CRDI, a research participant is asked to rate different elements whilst their ‘rating’ is being recorded/captured using an analogue dial [potentiometer] (which looks like a volume control on an amplifier). The analogue data (i.e. the signal) generated within the CRDI and modulated using the dial are converted into digital information within ‘the box’ (i.e. an analogue to digital conversion section) and available for capturing on a personal computer digitally, for further analyses. The CRDI development team had also created their own proprietary software for the recording of the digital data, that allowed researchers to have some control regarding data sampling frequency, signal smoothing, and digital file location.

Since the introduction of the CRDI, the research world has exploited the possibilities that multi-juncture response measurement offers (as opposed to single juncture rating). A plethora of important works have been published, both within music specific investigations (Fabian, Timmers, & Schubert, 2014; Stevens, et al., 2014; Schubert & Fabian, 2014; Goebl et al., 2014; Schubert, 1999) but also outside the world of music and/or music psychology research (Bioca et al., 1994; Ravaja, 2004; Shapiro & Chock, 2003; Potter & Bolls, 2012) demonstrating that it is possible to utilise technology in order to acquire systematic real-time response datasets. Similar to Capperella’s work (op. cit.) focusing on analyses of real-time recorded data streams, a number of studies have signified the importance of the assessment of how reliable these recordings are, as well as the parameters affecting dataset reliability (Maier et al. 2007), even within the realm of politics and political debate (Schill & Kirk, 2014; Nagel, Maurer, & Reinemann, 2012).

The CReMA

Himonides (2009) introduced a new apparatus for perceptual testing, and later (Himonides, 2011) presented some empirical research methods regarding its application in affective response measurement. This technology was named CReMA (continuous response measurement apparatus). The CReMA was the result of the amalgamation of modern analogue synthesiser control technology with real time physiological response data acquisition technology. Himonides (2011, op. cit.) argued that the employment of the CReMA in experimental research could offer additional benefits to those provided by the CRDI. This new interface acts as a somewhat more intuitive linear control system, thus not requiring the user to jump to a new location on a circular potentiometer. In this way, a one-to-one analogy to linear scoring (graded scales, Likert scales, and scoring continua) is provided in an attempt to retain more closely the ‘like-dislike’ n-point scale linear paradigm. This new technology has additional, innovative features. In addition to left-right hand movement, the controller is able to capture real-time pressure data—an aspect of the data capturing experience which is likely to be outside the listener’s conscious awareness, but also an additional dimension for data acquisition that can be exploited, should a particular research design required an additional ‘axis’ or ‘dimension’ of response.

When comparing the CReMA to the CRDI, Himonides (2011) argued that due to the design characteristics of the CRDI, one could only record quasi-continuous data streams and not absolutely (i.e. truly) continuous. Himonides (op. cit.) argues that although the monitoring is continuous, a potential weakness of this system can be observed: the research participant is able to turn/manipulate the CRDI dial whilst listening, the location of the dial consequently being recorded (in reality, the amplitude of the signal measured being in correspondence with the location of the dial, therefore denoting the rating ‘position’). However, unless the movement is continuously changing, there will be states of apparent stasis (i.e. inactivity) between responses (as presented graphically in Himonides, 2011, pp. 7 & 8). These stationary moments may or may not be intended by the listener. This might, therefore, have a negative impact on the integrity of the recorded dataset. The above mentioned issue, however, is relatively absent in real-time scoring using the CReMA technology. The interface is recording true-positional data only when the participant’s/listener’s finger is in contact with the surface of the ribbon controller.

It is important though to highlight that although the CReMA comprises somewhat more advanced technologies, including medical grade GSR data acquisition technology, as well as a Doepfer R2M Ribbon controller which generates control voltages, its design for recording judge/listener evaluation data in real time is heavily inspired by the original work of the Florida State University team and the development of the Continuous Response Digital Interface (see: http://www.music.fsu.edu/Music-Research-Centers/Center-for-Music-Research/CRDI).

A simplified solution

Regardless of the similarities and differences and also the pros and cons of utilising the CRDI or CReMA in research that involves continuous response measurement, one major logistical constraint for researchers is the ownership and/or acquisition of the interfaces, their calibration, setting up, and integration in different experimental research contexts and projects. After all, this author decided to develop the CReMA exactly because he did not originally have access to the CRDI and needed to employ continuous response measurement technology for his own doctoral research project (Himonides, 2008). The popularity of the CRDI, particularly in research conducted in Northern America, as well as the overwhelmingly positive response that the initial presentation of the CReMA received in an international conference (Himonides, 2006) established the importance of identifying (or developing) a solution that would be accessible to the wider research community. Processing of the available literature suggests that a plethora of ‘controllers’ could potentially be exploited in experimental research in affective response measurement using the much more accessible Musical Instrument Digital Interface (MIDI). MIDI is a well established standard, allowing any researcher to perform time-based recordings of ‘information’ very accurately, economically and systematically, using very common/standard computer systems. Using MIDI for research in psychology, perception and/or education is not, obviously, a stereotypical use of this technology, but rather a creative ‘abuse’ of it (Himonides, 2012), since the interface was developed with music composition and performance using electronic musical instruments in mind. Nevertheless, depending on the research aims and intended research design, a researcher could even use a standard MIDI piano keyboard for recording response data (for example, an 88-key MIDI keyboard controller could offer 88 discreet ‘buttons’ on a like–dislike continuum if all keyboard ‘notes’/keys were used, or 52 discreet choices/buttons/options if only the white keys were to

be used). The detail (i.e. quantisation / resolution) offered (and supported) by the MIDI protocol is more than enough for most empirical research foci in the field.
Due to the ubiquitous nature of MIDI, other than ‘piano-like’ instruments or controllers can potentially be used in order to capture response data. Some examples are (non exhaustively):

- rotary knob controllers / encoders (such as virtual instrument control devices like the Doepfer pocket dial, the MIDI fighter twister, or the Behringer BCR-2000);
- linear encoders / controllers / sliders (like the Mackie control surface, the Korg nano control mixer, or the Doepfer pocket fader);
- blended /multi control surfaces (like the Samson conspiracy controller, the Keith McMillen Instruments QuNeo 3D Pad Controller, the Novation Launchkey, the Arturia BeatStep MIDI Controller, or the AKAI APC40 controller);
- pad controllers / surfaces (like the Novation launchpad, the IK Multimedia iRig PADS Portable MIDI Groove Controller, the Korg padKONTROL, or the Native Instruments’ MASCHINE);
- alternative and/or non conventional controllers (like ROLI's Seaboard RISE, Expressive E's Touché controller, the nu desine AlphaSphere, the Eigenlabs Eigenharp, the Naonext Crystall Ball, or the Skoog controller);
- game controllers (such as Guitar Hero controllers, Joysticks, golf controllers);
- XY control surfaces (like the Korg KAOSS pad series, the amptone lab XY MIDIpad, or even Apple’s Magic Trackpad);
- beam controllers and sensors (like the Soundbeam, the MIDIblock, pandaMidi midiBeam, any Theremin controller fed into a CV to MIDI interface, or a modified Xbox Kinect type sensor);
- foot controllers and switches (like the Behringer MIDI Foot Controller FCB1010, the Keith McMillen SoftStep USB MIDI Foot Controller, the Nord PK27 MIDI Foot Pedal Keyboard, or even a simple MIDI sustain pedal); and, last but not least
- modern tablet computers / devices (such as iPhones, iPads, iPods, Android tablets, Android phones, and/or Microsoft Surface devices).

Using these suggested classes of MIDI controllers in order to record data for research is quite an undemanding task that allows the use of any modern computer with either a built-in or external MIDI interface, the MIDI controller, and appropriate software that enables the user to record MIDI data. Any modern DAW (digital audio workstation) software can be used (for a list of DAWs please see: https://en.wikipedia.org/wiki/Digital_audio_workstation). Most of this software offers users the ability to export Standard MIDI files (SMF files). An additional benefit of using a DAW for this type of research is that due to their ability to perform simultaneous recording and playback of different tracks, the researcher can ensure that the audio stimulus for an experiment is in full synchronization (i.e. in ‘sync’) with the recorded response. Upon the completion of the experimental phase, recording of the research datasets, and creation of the individual MIDI files containing the response datasets, researchers can ‘interpret’ the MIDI data and perform consequent statistical analyses, according to their research project needs. The meaningful ‘interpretation’ of MIDI data, though, could be a somewhat challenging endeavour for many researchers.

CReMA MIDI Free Software

Until early 2015, this author had supported a number of researchers in developing experimental designs using the CReMA for response data recording. A useful example of the use of the CReMA elsewhere is that of Hayley Trower's post-graduate research work (Trower, 2011), also reported in Adam Ockelford's work *Applied Musicology* (Ockelford, 2013). Trower's particular research design generated some hundreds of different MIDI files containing recorded listener response data (on listeners' expectations for particular stimuli/notes). With such projects, the manual conversion of MIDI files (having in mind that MIDI files are complex to decipher/interpret visually) into 'human readable' files (i.e. text files) is a non straight forward procedure. Within a MIDI file, a plethora of different types of information is stored, in chunks, and in both binary and variable length quantities. One way to optimise the MIDI data conversion workflow is to use computer programming code that allows the automation of the format conversion. Since the establishment of the MIDI protocol c. 1983, no other tool than Piet Van Oostrum's computer code has been more successful in the conversion of MIDI information into human readable text (*mf2txt* [MIDI file to text] written in the 'C' programming language) (Milano, 1987; Enders & Klemme, 1989; Huber, 1991; Winsor & De Lisa, 1991). Unfortunately, Piet's code appears to be somewhat difficult to decipher by postgraduate researchers in education that don't have a strong background in computer science (Oostrum, 2002; Conger, 1989), and also documented in highly technical vernacular. This meant that this author had to frequently support students and researchers in compiling, running and exploiting Van Oostrum's code, and consequently merging the resulting datasets in order to be able to equip researchers for performing statistical analyses thereafter.

A more recent development, moving on from Pied Van Oostrum's oft celebrated *mf2txt* utility, —and what this author sees as probably the biggest to date contribution to computational musicology— is the music21 toolkit. music21 is a Python-based toolkit (i.e. a set of programming blocks that perform specific bespoke tasks, a notion similar to what VBA and 'macros' do in Microsoft Excel) for computer-aided musicology, developed by Michael Scott Cuthbert (Cuthbert & Ariza, 2010; Church & Cuthbert, 2014).

The contribution of Cuthbert and his colleagues and collaborators to the extended field of Musicology, and the significance of the music21 toolkit are both immense.

But using music21 for something as 'primitive' as converting a simple MIDI file to meaningful note and controller data, organised in time, is still something that might appear as challenging for the non initiated in programming (or at least 'scripting') researcher.

Between the first presentation of the CReMA at ICMPC 2006 in Bologna, Italy, and the time of writing the present work, this author had received over two hundred requests for an accessible version of the CReMA technology from researchers the world over.

This author, therefore, decided that there was a clear need for the development of a simple tool that can be used by the non initiated researcher, using a graphical user interface, without a need to perform computer programming, and without a need for somebody to be able to understand the structure of MIDI files.

This led to the development of the CReMA MIDI free software tool. CReMA MIDI is nothing more than an easy way to export MIDI note or controller data into a meaningful text file (comma separated values [.csv]) for further statistical analyses using either popular Open

Source or commercial spreadsheet software (OpenOffice, LibreOffice, Microsoft Office), or Open Source or commercial statistical analyses packages (PSPP, R, SPSS, STATA).

CReMA MIDI has been developed by this author as a free resource for the academic, research, enthusiast, experimental, and creative communities. CReMA MIDI is simple to use, robust, very fast, and extremely convenient, especially if researchers need to process a very large number of MIDI files that contain continuous response datasets. As reported above, CReMA MIDI is completely free to use, and has been published under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License[1].

CReMA MIDI has been developed using the Python programming language and has adopted a number of 'classes' that are available openly under the MIT license in the python-midi library[2].

Using CReMA MIDI

CReMA MIDI can be downloaded from the International Music Education Research Centre (iMerc) official website (http://imerc.org/crema). Following the introduction and background, users can find the Download section, where they can locate the appropriate download links, depending on their operating system (e.g. Mac OS, Windows, Linux).
Upon downloading and installation of the software, following the simple guidelines, users can run the program in order to be able to convert their MIDI files containing response datasets. The software has been designed with ease-of-use in mind, therefore the user is presented with a quite minimalist graphical user interface (see figure 1) where they can select an input file (or folder) and an output file (or folder). If the user selects a specific input file, then only that file will be converted. If the user selects a specific input folder (i.e. a directory), then the software will automatically scan and convert all MIDI files that exist within that folder structure and batch process them.

INSERT FIGURE 1 ABOUT HERE

[1] http://creativecommons.org/licenses/by-nc-sa/4.0/ (essentially, users are simply required to provide appropriate credit, provide a link to the license, and indicate if changes were made; users may not use the software for commercial purposes; and if users remix, transform, or build upon the material, they must distribute their contributions under the same license as the original.)
[2] https://github.com/vishnubob/python-midi

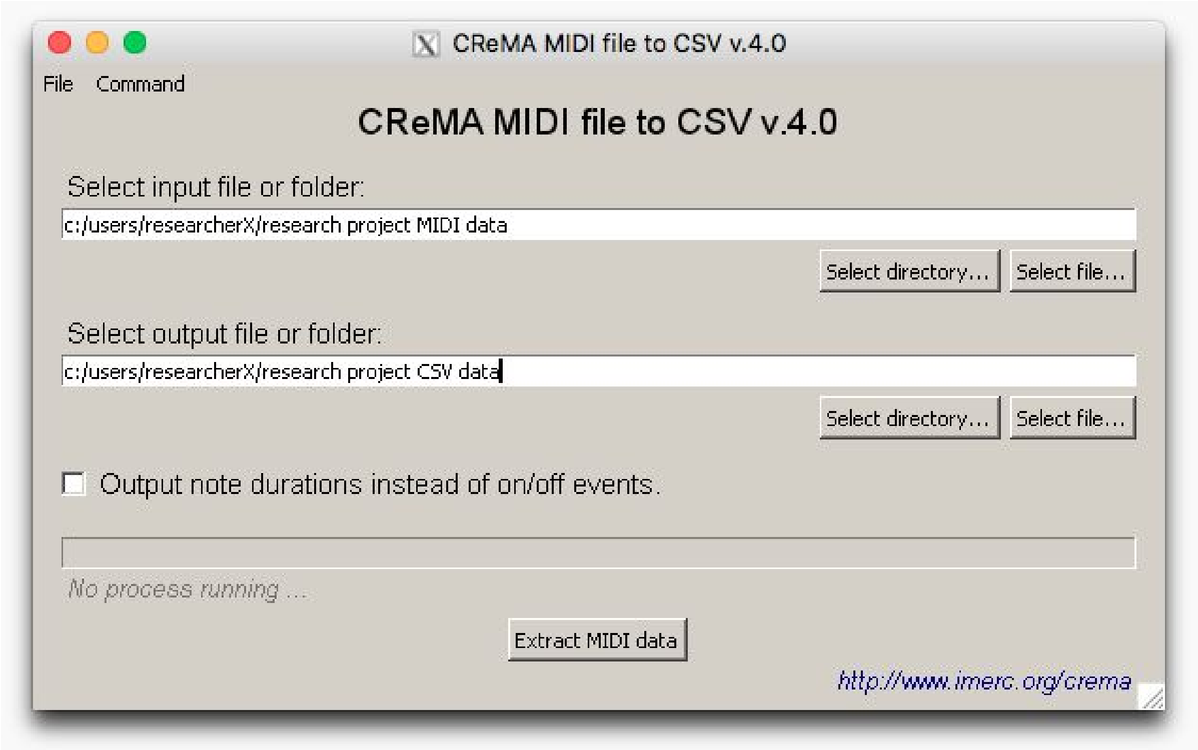

figure 1: the CReMA MIDI graphical user interface

Similarly, for the output section, if the user decided to assign an output folder, then the software would convert a single MIDI file into a comma separated (CSV) text file with the same name; if the input selection was a folder containing MIDI files, and the output selection was a folder, then the software would batch process all MIDI files within the source folder automatically and generate individual corresponding CSV files; lastly, a powerful feature of the CReMA MIDI software is that if the input selection is a folder containing MIDI files and the output selection is a single CSV file, the program is going to batch process all MIDI files within the source folder and generate a single composite CSV file that will contain the complete corpus of data (i.e. a concatenation of all translated MIDI information). Last, depending on the nature of the analyses that a researcher might be interested in performing, the software allows the user to decide whether they would prefer to have event durations calculated automatically for them, instead of event 'on-off' timecodes (e.g. a MIDI file does not include note 'duration' information, but note-on and note-off events, the timing of which can allow the computation of note duration). Whatever the user's choice about input and output files or folders, almost instantly upon pressing the 'Extract MIDI data' button, the resulting file(s) structure is a human readable comma separated values (CSV) text file that can be opened on any computer/device, either using a text editor, or a spreadsheet application, or statistical analysis software. The information/data extracted from the MIDI files are: file name; track number; event type (i.e. controller or note); delta tick (i.e. how many ticks ahead of the previous event); the MIDI channel; the note or controller number; the note velocity or controller value; the cumulative tick; and the cumulative time in seconds.

Epilogue

A creative 'abuse' of MIDI allows researchers to utilise music performance technology in order to record real time response data reliably and systematically. This technology is accessible, inexpensive, and does not require specialist knowledge in operating. Captured MIDI information can be translated into human readable information, for further statistical analyses, using a free novel software tool developed by this author for the academic and research community. This offers an exciting new window of opportunity to developing researchers and students to conduct research and/or engage in free experimentation in continuous response measurement, without the need to invest in proprietary research technologies. The use of ubiquitous MIDI technology instead of expensive analog signal processing units, in tandem with a robust new way to interpret the recorded MIDI information quickly and efficiently is also hoped to enable researchers to look deeper into the specifics offered by the different MIDI devices available in the market and how these could foster more effective research in specific contexts.

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