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Musically-Induced Chills: The Effects of "Chills Sections" in Music

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ABSTRACT

Musically-induced chills, the experience of shivers down the spine, gooseflesh or tingling sensations in response to music, have previously been linked to specific musical features such as sudden dynamic changes or unprepared harmonies. However, there currently exists no empirical research that tests these proposed relationships through the manipulation of musical stimuli. In addition, rarely has the phenomenon of chills been contextualised in terms of the causal processes underlying the experience of musical chills in listeners. In the current study, participants (N = 24) listened to two versions (original and manipulated) of three different pieces of music found to elicit chills across numerous listeners in a previous survey on the chills experience (N = 375). The stimuli were manipulated through the removal of "chills sections" highlighted in the previous survey, whilst maintaining a natural musical progression in the pieces. Features in each chills section were contextualised in terms of underlying mechanisms of music and emotion proposed in the BRECVEMAC framework. Results show that the frequency of chills across participants was higher for all original versions, though these differences did not reach statistical significance (p = 0.11). Experiencing chills resulted in significantly higher ratings of being moved and emotional intensity in most original pieces, though ratings of the Geneva Emotional Music Scale were similar in chills and no chills experiences. An analysis of mean scores for skin conductance and continuous measurements of chills intensity showed a significant difference between chills sections compared with a control section of equal duration in the same piece; this difference was found for each original piece, supporting the idea that these specific sections are emotionally salient across different listeners. The possible role of underlying mechanisms is also discussed. The current project is a first empirical assessment of the causal processes in the elicitation of chills in music, providing some evidence for a causal relationship between a specific section in a piece of music and intense emotional experiences such as chills.

I. INTRODUCTION

The expression of human emotions in music has been studied and acknowledged in research for some time (Gabrielsson, 2002; Hevner, 1936). However, a more contentious issue is whether music can elicit emotional responses in listeners (Konečni, 2008). Interestingly, a growing body of research indicates that music can induce emotions in listeners (Juslin and Sloboda, 2010), and that this is in fact a prevalent motivation for engaging in music listening activities (DeNora, 2000; Juslin and Laukka, 2004; North, Hargreaves and Hargreaves, 2004; Sloboda, O'Neill and Ivaldi, 2001). Many different emotions can be experienced whilst listening to music, either associated with the music itself or other extra-musical factors such as memories. A specific emotional phenomenon is the experience of chills, defined here as a response involving subjective feelings and physiological activity such as shivers down the spine, gooseflesh or tingling sensations across the body (Grewe et al., 2007; Guhn et al., 2007; Huron and Margulis, 2010). Although chills can be elicited through other mediums such as films (Hanich et al., 2014), research has suggested that listening to music is particularly effective in eliciting chills (Goldstein, 1980).

The experience of chills may be an indicator of strong or peak emotional responses to music. Shivers and gooseflesh are reported by roughly 15% of reports collected by Gabrielsson (2011) in his work on strong experiences with music; furthermore, chills have been linked to the motor-sensory ecstasy factor of aesthetic peak experiences proposed by Panzarella (1980). However, the emotional characteristics of chills are still not fully understood; for example, it is not yet clear whether chills are just a general indicator of peak experiences, or instead have distinct emotional qualities not to be confused with emotions often defined by higher levels of arousal (Rickard, 2004). Some recent research has linked art-elicited chills to the state of being moved (Benedek and Kaernbach, 2011; Wassiliwizky, Wagner, and Jacobsen, 2015), an enigmatic concept characterised by a combination of joy and sadness (Menninghaus et al., 2015); the state of being moved has elsewhere been suggested to mediate the pleasure some listeners experience when listening to sad music (Eerola, Vuoskoski, and Kautiainen, 2015; Vuoskoski and Eerola, 2017). Therefore, chills may reflect a more specific mixed emotional response, as opposed to indicating a more general level of peak or strong experiences.

In the music and emotion literature, different aspects of musical chills have been investigated, such as physiological activity, effects of the individual and listening context, and finally the relationship between musical features and chills. In terms of physiological indices, chills have been shown to activate the sympathetic nervous system; this activation is usually evident in peaks of skin conductance levels in listeners (Craig, 2005; Egermann et al., 2011; Guhn et al., 2007; Salimpoor et al., 2009). Recent research further suggests that chills might be approximated through a pupil dilation response (Laeng et al., 2016). Similar approaches have been taken to assess brain activity during chills. The influential work of Blood and Zatorre (2001) found that the experience of chills was marked by an increase in cerebral blood flow in areas linked to the dopaminergic system of reward and motivation such as the ventral striatum. More recently, Salimpoor et al. (2011) detected a release of dopamine in the striatum during peak emotional experiences during music, but further suggested a distinction in brain activity in the anticipatory and experiential phases of chills, with the caudate more involved during the anticipation of chills and the nucleus accumbens implicated during the actual experience.

Characteristics of the individual may mediate who experiences chills with music, and how often they are experienced. Individuals who score highly on the openness to experience dimension derived from the Big Five model of personality (Costa and McCrae, 1992) appear to experience chills more frequently (Colver and El-Alayli, 2016; McCrae, 2007; Nusbaum and Silvia, 2011). Conversely, Grewe et al. (2007) found an association between chills and 'reward dependence', similar in some ways to the agreeableness dimension of the Big Five; this finding has rarely been replicated however. Familiarity with a piece of music may also mediate emotional experiences in general (Pereira et al., 2011; Peretz et al., 1998; Schellenberg et al., 2008), with such effects possibly associated with the mere-exposure phenomenon (Zajonc, 1968), or the modulation of collative variables linked to aesthetic appraisal such as complexity of novelty (Berlyne, 1971). Familiarity effects on chills are not fully understood, with contradictory effects of familiarity implied in numerous studies (Benedek and Kaernbach, 2011; Laeng et al., 2016; Panksepp, 1995; Rickard, 2004). A final extra-musical factor to consider is the listening context, likely to impact any emotional experience with music. The effect of social listening contexts on the experience of chills has been empirically tested, with results suggesting that chills are more frequent in isolated listening episodes as opposed to listening with friends (Egermann et al., 2011; Sutherland et al., 2009). These studies however suffer from low ecological validity, with the laboratory setting unlikely to represent every day, realistic musical contexts. To target these realistic listening situations, Nusbaum et al. (2014) utilised the experience sampling methodology (see Sloboda, O'Neill and Ivaldi, 2001) to better understand the experience of chills in everyday life. Interestingly, results showed that listening to music alone was not a significant predictor of chills, whereas listening to music chosen by the participant did significantly predict chills.

The final and most common approach in musical chills research is the attempt to establish relationships between various musical features and chills. Sloboda (1991) found that specific musical sections that elicit shivers in listeners often contained sudden dynamic or textural changes. Panksepp (1995) found that a certain song (Pink Floyd's 'The Final Cut') was closely associated with the experience of chills in participants, with the piece containing a notable dynamic change from quiet to loud. More recently, Grewe et al. (2007) analysed chills in response to various pieces of music, and offered a case study of Bach's 'Toccata BWV 540'; in the analysis, the highest number of chills were found for a section of the piece described by the authors as containing a melody in the register of the human voice, modulation, and repetition of a motif. Additionally, participants were asked to pinpoint the most pleasurable sections of the piece listened to, which included the beginning of the piece, entry of new instruments or voices, and changes in volume. Guhn et al. (2007) identified various 'chills sections' in three pieces, with similarities across each section, including a slow movement, contrast between solo instruments and orchestras, and a gradual increase from quiet to loud dynamics.

As of currently, most studies investigating the phenomenon of musically-induced chills have proposed several correlations between the experience and musical features. However, rarely has the elicitation of chills through music been discussed in terms of the psychological processes that might underlie musical emotions, although some theories have been developed (Huron, 2006; Panksepp, 1998). It is important to explore the causal processes that may be implicated in music and emotion, and one way in which this direction of work can be contextualised is with the framework of underlying mechanisms developed by Juslin and colleagues (Juslin, 2013; Juslin and Liljeström, 2010; Juslin and Västfjäll, 2008). In what might be labelled the BRECVEMAC framework, there exists a set of 9 testable mini-hypotheses or mechanisms of music and emotion; these are *brain stem reflexes, rhythmic entrainment, evaluative conditioning, contagion, visual imagery, episodic memory, musical expectancy, aesthetic judgment,* and *cognitive appraisal.* The mechanisms differ in terms of ontogenetic development, availability to consciousness, survival value and possibly areas of brain activity (Juslin, 2013). Some of the processes are extra-musical, such as episodic memory, describing the way in which music can remind a listener of a past and personally valuable event (Belfi, Karlan and Tranel, 2016), eliciting emotions tied to this event (Janata, 2007). Other mechanisms however are very much linked to features within the music, such as musical expectancy, referring to the implicit expectations by listeners as to what would come next in a musical progression (Narmour, 1990, 1992); the fulfilment, delay or violation of these expectancies can elicit emotions (Huron, 2006; Meyer, 1956). Interestingly, existing findings linking musical features to chills can be understood in terms of underlying mechanisms. For example, the link between sad music and chills (Panksepp, 1995) may reflect contagion mechanisms, the phenomenon in which listeners sometimes experience the same emotion as that expressed in the music (Davies, 2011). New or unprepared harmonies (Sloboda, 1991) may suggest a role of musical expectancy processes, whereas sudden dynamic changes (Grewe et al., 2007) could implicate brain stem reflexes, an automatic emotional response to potentially urgent or important changes in one's environment. Therefore, although the proposed underlying mechanisms have rarely been tested (although see Juslin, Barradas, and Eerola, 2015; Juslin, Harmat and Eerola, 2014), the framework is an encouraging starting point for contextualising approaches to causal processes in musically-induced emotions, and in turn the experience of chills.

A review of the musically-induced chills literature suggests that various factors such as the music, listener and listening context are significant. With regards to the associations between pieces of music and chills, several studies highlight the link between features such as unprepared harmony and sudden dynamic changes and chills. However, there exists no research that has empirically tested these suggestions, nor has any study attempted to manipulate pieces of music, and in turn the experience of chills. Because of this, numerous aspects of the association between chills and music are not well understood. To our knowledge, the current project is the first of its kind, and is an attempt to address the current gaps and lack of development in the literature. The project aims to better understand the links between musical features and chills, to assess the effect on chills when these features and sections are removed, and to compare moments in different pieces of music that have been reported to elicit chills in listeners. Additionally, although not an empirical test of possible mechanisms underlying musically-induced chills, the project seeks to contextualise findings in terms of potential causal processes of music and emotion, with the hope of developing future research in this direction.

II. METHOD

A. Design

A listening experiment was carried out, with participants listening to two versions of three pieces of music said to elicit chills across different people in a previous survey (Bannister and Eerola, in preparation). During listening, skin conductance measurements were taken to indicate the chills response (Craig, 2005; Grewe et al., 2007), and continuous measurements regarding the intensity of participants' chills and emotions were collected via a simple up/down slider. After each piece, self-reports were collected regarding the experience, in terms of emotions felt (see the GEMS model, Zentner, Grandjean and Scherer, 2008), emotional intensity, being moved, and role of underlying mechanisms (see the MecScale instrument, Juslin, Barradas, and Eerola, 2015). Stimulus presentation order was pseudo-randomised and individualised for each participant to reduce any ordering effects, and a set of distractor questions were administered to separate the experiment into two listening sessions including three pieces each, limiting effects of fatigue and intra-experiment familiarity.

B. Participants

A total of 24 participants took part in the experiment (17 Female), aged 18-46 years (M = 25.2, SD = 5.9). Participants were screened prior to the experiment to target those who experience chills relatively frequently, and have had chills with music within the last three months.

C. Materials

1) *Stimuli Selection.* Selection of the musical stimuli was informed by a previous survey (Bannister & Eerola, in preparation) into the experience of chills in music listeners (N = 375). From a total of 419 pieces of music linked to chills by participants, three were chosen as stimuli for the experiment in accordance with a set of criteria: Firstly, the piece of music needed to be mentioned by multiple participants. Secondly, participants had to be able to specify a specific moment in the piece that elicited chills. Finally, the piece needed to be suitable for manipulation and of an appropriate duration. The three stimuli chosen were '*Glosoli*' by Sigur Ros, '*Jupiter*' by Gustav Holst, and '*Ancestral*' by Steven Wilson. All pieces had 'chills sections' as identified by participants in the earlier survey. For Glosoli, this was a climax following a gradual crescendo, marked by distinct dynamic and textural changes; it is possible that these changes in the chills section activate underlying mechanisms such as brain stem reflexes and musical expectancy. For Jupiter, the chills section refers to a progression on strings in the middle of the piece; given the instruments used and the adaptation of this section in western popular culture, possible mechanisms are suggested to be contagion and episodic memory. Finally, for Ancestral, the chills section consisted of a guitar solo towards the end of the piece; considering the tone of the guitar and virtuoso technique in playing, contagion and aesthetic judgment mechanisms were hypothesised to be activated in this section.

2) *Stimulus Manipulation.* To create two conditions in the experiment, the musical stimuli were manipulated, resulting in a second version of each piece. The identified chills sections of each piece were edited out and removed in a non-disruptive way, maintaining a natural and logical musical progression, such that a participant hearing the piece for the first time would not register any kind of manipulation. This method has relatively high ecological validity, with the use of real music and a minimal level of manipulation, but comes at a cost of control over the variables in a piece of music.

3) *Chills Measurement.* To capture the chills experience, participants were firstly able to confirm after each piece whether they had experienced chills whilst listening. To support this data, skin conductance response measurements (SCR) were captured with the NeXus-10 MKII and BioTrace software (www.mindmedia.info); research has suggested that peaks in skin conductance can be a reliable indicator of chills (Craig, 2005; Grewe et al., 2009), although the measurement may have considerable variation across listeners (Khalfa, 2002). To further support the self-report and SCR data, continuous measurements of chills intensity were collected with a simple slider that participants could move up or down; this changed the amplitude of an incoming sine wave which was recorded into ProTools, and exported as audio files in mono mp3 format.

4) *Data Analysis.* All data analysis was performed in R (https://cran.r-project.org). SCR data were normalised and de-trended within stimuli before statistical analyses. The audio data from continuous measurements were transformed to a linear signal for use with self-reports and SCR. The analysis was planned to have two distinct epochs within each original stimulus, namely the *chills section* and a "*control section*", a different moment in the piece of the same duration. This was to allow for comparisons of SCR and continuous measurements between the chills sections in the stimuli with other sections hypothesised to be less significant in the chills experience.

D. Procedure

Participants were each tested in isolation, and were asked to relax, get comfortable and familiarise themselves with the experiment through a participant information sheet. After informed consent of participation was obtained, the investigator explained the procedure. In the first listening session, participants listened to three musical stimuli; during listening, SCR and continuous measurements of chills intensity were collected. After each piece participants completed self-reports consisting of numerous Likert scales for emotional descriptors and for statements referring to underlying mechanisms of music and emotion; additionally, participants reported whether they had experienced chills during the piece. When ready for the next piece participants were instructed to say 'ready' or 'okay' into a microphone, so that the investigator (sat in an adjacent room) knew to administer the next stimulus. After the three pieces, an interval questionnaire was completed, rating the pieces in terms of familiarity, enjoyment, and asking participants to describe their favourite moments. The questionnaire also collected basic demographic information and musical preference data via Likert scales for genre labels (Rentfrow and Gosling, 2003). Additionally, numerous distractor questions (general hobbies) were administered, to help reset and separate the participant from the previous listening section, before the next block of listening. After the interval, participants listened to the three remaining stimuli, following the same procedure as the first listening session. The experiment ended with the same questions of familiarity, enjoyment and favourite moments, with additional questions regarding the openness to experience personality trait and musical sophistication (Müllensiefen et al., 2014).

III. RESULTS

1) *Frequency of Chills*. Across all listening episodes (6 x 24 = 144), participants reported experiencing chills 51 times in total. In original and manipulated conditions, Glosoli resulted in 17 instances of chills (10 for original), Jupiter resulted in 18 instances (10 for original), and Ancestral resulted in 16 experiences of chills (10 for original), see Table 1.

Table 1: Frequency of chills across stimuli and condition.

Stimulus (Condition)	Chills (N)
Glosoli (Original)	10
Glosoli (Manipulated)	7
Jupiter (Original)	10
Jupiter (Manipulated)	8
Ancestral (Original)	10
Ancestral (Manipulated)	6

To assess whether the frequency of chills was significantly different between original and manipulated conditions, a chi-square test was carried out on the sum of chills experienced across all stimuli. These differences in frequency did not reach statistical significance (p = 0.11); this could either suggest that the chills sections in the different pieces do not have a large effect on the experience of chills, or that other moments in the music not uncovered in the earlier survey are also effective in eliciting chills; this may be plausible given that the original and manipulated conditions are similar beyond the chills sections identified. However, to investigate this further, the self-reports of chills from participants will be integrated with the skin conductance and continuous measurement time series, to assess the consistency between self-reports and other measurements, and the more detailed relationships between chills sections in the pieces and chills.

2) *Being Moved and Emotional Intensity.* For ratings of being moved, there was a significant effect of experiencing chills for Glosoli (t = 3.5, p <.01) and Jupiter (t = 2.99, p <.01); the effect was marginally significant for Ancestral (t = 2.13, p = .05). Additionally, the experience of chills produced significantly higher emotional intensity ratings for Glosoli (t = 4.04, p <.001), Jupiter (t = 2.78, p = .01), and Ancestral (t = 3.15, p <.01), see Figure 1. With regards to the GEMS factors targeting emotional characteristics of the experience, there were no significant differences in most ratings (e.g. happy, sad, power, energetic, tension) between the experience of chills and not experiencing chills. For the original version of Glosoli, chills experiences were rated as significantly more nostalgic (t = 2.83, p <.01) and inspiring (t = 2.76, p <.01). For Glosoli and Jupiter, participants reported feeling happy as opposed to sad, whereas the opposite was true for Ancestral.

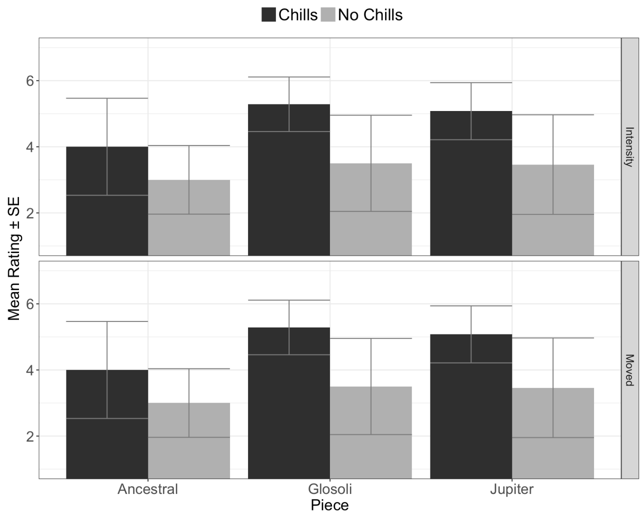

Figure 1. Difference in ratings for emotional intensity and being moved between chills experiences and experiences without chills.

3) *Underlying Mechanisms*. For the chills sections in each piece the activation of various mechanisms of music and emotion was hypothesised. Data were collected regarding mechanisms of music and emotion through and updated MecScale instrument (2 different scales for most mechanisms), looking at all mechanisms (including lyrics), apart from aesthetic judgment, given its many facets and need to address the process in numerous ways. The chills sections in different pieces were suggested to have the potential for activating certain underlying mechanisms: For Glosoli these were brain stem reflexes and musical expectancy; for Jupiter, contagion and episodic memory were proposed; and for Ancestral, contagion and aesthetic judgment mechanisms were possibly activated. However, across the MecScale ratings collected from participants no significant differences were found for the elected mechanisms in each piece between original and manipulated conditions, suggesting either that these mechanisms are implicated in various other moments in each piece and are not overly significant in the experience of chills, or that the chills sections do not display the appropriate features for activating various processes of listening.

4) *Skin Conductance*. Skin conductance measurements were collected for each participant, though two datasets were discarded due to an absence of markers syncing the data to start and end points of the stimuli; this resulted in SCR data for 22 participants. Data were first normalised within each stimulus to accommodate for individual differences in baseline, room temperature, and response measurements, then de-trended to correct for the artefact of a gradual decrease of skin conductance averages throughout each stimulus for all participants. Firstly, the mean SCR value for all participants was collected with regards to the *chills section* (Glosoli = 65 secs, Jupiter = 107 secs, Ancestral = 60 secs) in each stimulus; this value was compared with a mean SCR value for a *control section* in the piece of equivalent duration (see Figure 2). Results from one-way ANOVA tests show a significant

difference of SCR means between chills sections and control sections for Glosoli (*p* <.001), Jupiter (*p* <.001) and Ancestral (*p* <.001). To go beyond the analysis of mean SCR ratings, the SCR response will eventually be broken down into phasic and tonic components, to look at the occurrences of phasic components across the chills and control sections.

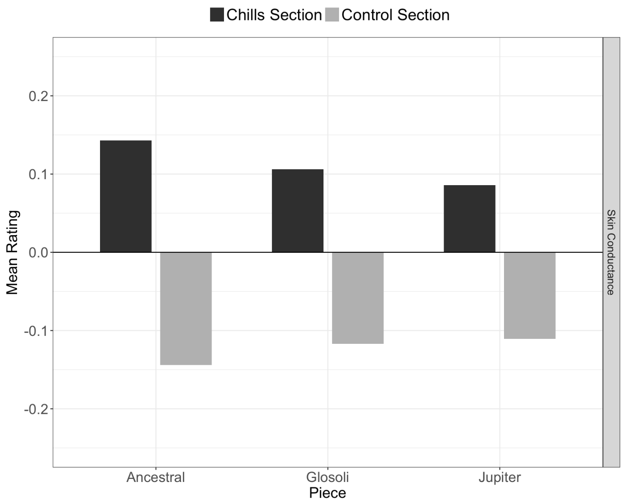

Figure 2. Mean ratings of normalised SCR for chills sections and control sections within each stimulus.

5) *Continuous Measurements*. Continuous measurement data that reflect the intensity of chills during the listening experience was collected as a series of amplitude changes in a sine wave signal, converted to a scale from 0 to 100. Some participants neglected the continuous measurements either due to distraction or task complexity, and so for 144 listening episodes, 121 corresponding datasets were collected. Initial data analysis followed the principles described for the skin conductance where the continuous ratings of chills were compared between the chills sections and control sections within the stimuli (see Figure 3). Results from a one-way ANOVA test resemble the results found for SCR ratings, such that there is a significant difference of mean continuous measurement ratings between the chills sections and control sections for Glosoli (*p* <.001), Jupiter (*p* <.001), and Ancestral (*p* <.001).

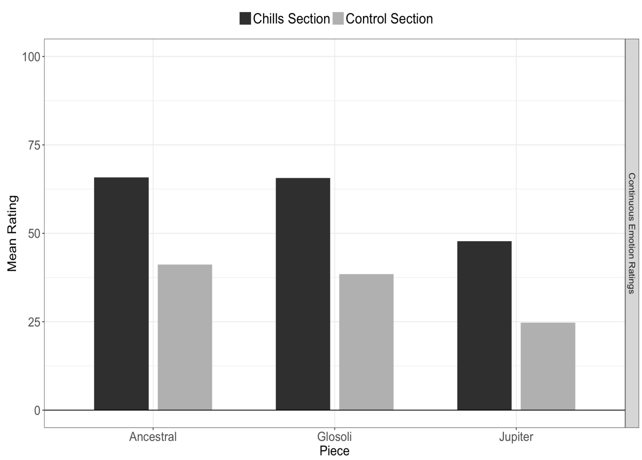

Figure 3: Mean values for continuous ratings of chills intensity during the chills sections and control sections within each stimulus.

IV. CONCLUSION

The current research project has been developed to provide a first empirical investigation into the experience of chills with regards to different musical features and sections within a piece of music. Previous research has highlighted numerous correlations between the experience of chills and musical characteristics (Grewe et al., 2007; Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991), however no study has empirically tested these associations. This study utilised the findings from a previous survey (Bannister and Eerola, in preparation) to manipulate pieces of music and test for effects on the experience of chills in participants. Of three pieces of music selected, chills sections described by participants in the survey were removed from the pieces with minimal disruption to the overarching musical progression. Findings suggest that removing these chills sections and creating manipulated versions of the music reduced chills in participants, compared to the original versions. Although this effect did not reach statistical significance, the patterns of data across all conditions are worth highlighting. Possibly the three pieces used in the study have multiple moments in which chills could be linked; alternatively, it may be that the identified chills sections are not overly effective in eliciting chills across listeners, although skin conductance and continuous measurements of chills intensity suggest that this is not likely the case. Future analysis of the data alongside time-series analysis will be carried out to understand in detail the effects of the chills sections on the frequency of chills across participants. To assess the likely locations of these chills within the pieces of music, skin conductance and continuous measurements of chills intensity were collected. Interestingly, for the original pieces both measurements were significantly higher in the chills sections as opposed to control sections of equal duration in other points in the pieces. Although future time-series analysis will confirm the temporal position of chills across participants, the current results suggest that these chills sections are moments in the music in which emotions experienced are at their most intense, possible resulting in chills. The connection between intense, peak emotional experiences and chills (Gabrielsson, 2011; Panzarella, 1980; Rickard, 2004) is further supported through the finding that across participants the chills experience is rated as significantly more intense than listening experiences in which no chills were elicited.

The experience of chills has been linked to qualitatively distinct feelings such as mixed emotions, or states of being moved (Benedek and Kaernbach, 2010; Wassiliwizky et al., 2015), proposed as an amalgam of joy and sadness (Menninghaus et al., 2015). Current ratings of being moved were significantly higher during the experience of chills, lending some support to these claims. However, results from the GEMS factors and ratings show few significant differences of emotional qualities reported for chills or no chills experiences. This could reflect the vagueness of the state of being moved, such that people may approach the concept differently, and that participants' ratings of being moved are not necessarily indicative of mixed emotional states involving feelings of happiness and sadness simultaneously. Further research is required to further understand the conceptualisation of being moved across populations (see Kuehnast et al., 2014), and to address the possible link between musically-induced chills and mixed emotional states.

A key question regarding any emotional experience with music is the role of various psychological processes, and causal links between music and emotion. Often studies highlight correlations between different musical qualities and emotional states or expressions, but only recently has the focus turned to explaining these associations, in terms of perceptual and cognitive processes taking place during music listening. A useful starting point for contextualising the possible causal processes underlying musical emotions is the set of mini-hypotheses developed by Juslin and colleagues (Juslin, 2013; Juslin and Liljestrom, 2010; Juslin and Vastfjall, 2008). The identified chills sections in the current project involved several distinct musical features, some previously implicated in the elicitation of chills; these include sudden dynamic and textural change in Glosoli, a transition to a solo melody on strings from a rich orchestral background in Jupiter, and the introduction of a new instrument in the guitar solo of Ancestral. Each section was contextualised in terms of what possible mechanisms might be activated, such as brain stem reflexes and musical expectancy for Glosoli, contagion and episodic memory for Jupiter, and contagion and aesthetic judgment mechanisms for Ancestral. Although not explicitly tested or controlled for, a self-report instrument was used to assess for preliminary links between the chills and underlying mechanisms. Generally, when chills sections were removed, there were no significant differences in mechanism ratings collected from participants. This might indicate that the proposed mechanisms are activated at various points within the music, or that the assumptions were incorrect with regards to the qualities of the chills sections in the pieces. Neither can be concluded in this study, but given the focus of the current experiment, and the complimentary nature of the MecScale, this outcome was not unforeseeable. However, as this investigation is the first of its kind, a preliminary understanding of the relationships between different features in a piece of music and chills is required before further, more detailed and controlled studies can establish the possible causal processes underlying the phenomenon.

Interestingly, the chills sections across each piece differed in terms of musical and acoustic characteristics, but all were associated with moments of intense emotional experience in listeners, suggesting a variety of musical features that may elicit chills. However, the diversity across different chills sections raises the question of possibly differentiating between peak experiences; for example, recent work has explored the phenomenological and physiological differences between the two peak experiences of chills and tears (Mori and Iwanaga, 2017), and how they sometimes overlap and co-occur (Wassiliwizky et al., 2017). If we consider that there are differences between various strong and peak emotional responses to music, particularly in terms of emotional quality, then perhaps the musical differences found across the ‘chills sections’ in the current study correspond to strong emotions of different character, such as chills or tears. This remains as conjecture, but is worth considering when analysing specific moments in music that are emotionally salient.

The current study is not without its limitations. Laboratory and experimental procedures are often favoured for the high levels of control over numerous variables, but this often comes at a cost of low ecological validity, such that realistic situations may be quite different to those explored in a laboratory setting. The current project aimed to maintain a relatively high level of ecological validity, firstly by using real pieces of music from a previous survey, and secondly by performing minimal manipulations on the pieces, maintaining the holistic musical progression and listening experience. Predictably however, this results in a lower level of control for variables within the music; this is especially evident when considering preliminary associations between chills and underlying mechanisms of music and emotion. A further limitation is the sample used in the experiment. Participants were generally university students, meaning that the sample is not fully representative of a population. Also, participants were selected on the basis that they experienced chills with music relatively frequently; in this case however, the sample selected was the most appropriate for the aims of the current project. Despite the various shortcomings, results have emerged that are interesting with regards to specific sections in pieces of music that are points of emotional intensity, and the chills experience.

This study has demonstrated for the first time that the chills experience can be manipulated with experiment-selected pieces, and that across different participants, there exists a set of testable associations between moments in different pieces of music and intense emotional experiences such as chills. Possible future directions include full comparisons of experiences between the original and manipulated stimuli, and a time-series analysis of skin conductance and continuous measurements. Because of a current lack of understanding with regards to musically-induced chills, future research can move in various directions; the link between chills and being moved could be investigated, and the causal processes and roles of underlying mechanisms in chills could be empirically tested.

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