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Music chills: The eye pupil as a mirror to music's soul

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ABSTRACT

This study evaluated whether music-induced aesthetic "chill" responses, which typically correspond to peak emotional experiences, can be objectively monitored by degree of pupillary dilation. Participants listened to self-chosen songs versus control songs chosen by other participants. The experiment included an active condition where participants made key presses to indicate when experiencing chills and a passive condition (without key presses). Chills were reported more frequently for self-selected songs than control songs. Pupil diameter was concurrently measured by an eye-tracker while participants listened to each of the songs. Pupil size was larger within specific time-windows around the chill events, as monitored by key responses, than in comparison to pupil size observed during 'passive' song listening. In addition, there was a clear relationship between pupil diameter within the chills-related time-windows during both active and passive conditions, thus ruling out the possibility that chills-related pupil dilations were an artifact of making a manual response. These findings strongly suggest that music chills can be visible in the moment-to-moment changes in the size of pupillary responses and that a neuromodulatory role of the central norepinephrine system is thereby implicated in this phenomenon.

1. Introduction

1.1. Music chills

Strong affective experiences when listening to music is a common aesthetic phenomenon, characterized by positive feelings that tend to reach peak intensity at precise moments during musical listening of familiar, especially favorite, musical pieces. What seems common to the various descriptions given to these phenomena is (a) a cognitive state of intense absorption and full focus or concentration on the relevant musical events (Bicknell, 2009; Gabrielsson, 2011); (b) an intense "peak" of pleasure and rapture, a personal "merging" into the musical moment (Benzon, 2001; Sloboda, 1991); and crucially, (c) such strong music-induced experiences can often have a "bodily" component that has been referred to as feeling "chills" or "thrills" at specific moments during the musical auditory stream (Harrison & Loui, 2014; Huron, 2007; Konečni, 2008; Panksepp, 1995; Scherer, Zentner, & Schacht, 2002). In other words, dramatic affective feelings commonly occur in association with emotional and attentional state changes and these can lead to dramatic sensations and physical expressions. Among the most dramatic affective sensations, with potential physical expressions, are the chilling, gooseflesh type of skin sensations, at times accompanied by weeping or moistness of eyes, feeling cold and shivering, dry mouth, piloerection on the arms, heart racing and breathing changes, with feelings of pressure over the chest, sighing, stomach feelings (Gabrielsson,

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2011; Goldstein, 1980; Lowis, 1998). In addition, people report stillness and muscular tension in various parts of the body (e.g., trembles, quivers, shivers down the neck, tingles in the spine and back that may spread down the limbs and body) or the face (e.g., a still expression, tension of the jaw, ecstatic smiling, laughter, etc.). The specific type of sensations and expressions may vary remarkably between persons but for each individual these can be consistently elicited by particular musical pieces (e.g., favorite songs), often at specific key moments. Although sad selections typically evoke more chills than happy music (Panksepp, 1995), it is clear that diverse types of music can evoke the response.

It currently remains unclear which musical affect-modulating elements can evoke "chills" and whether these could be universal to all individuals and musical genres. A few studies (e.g., Gabrielsson, 2011; Grewe, Nagel, Kopiez, & Altenmüller, 2007; Sloboda, 1991) suggest that the acoustic and musical structural elements that are typically related to chills may include: the beginning of a piece, entry of instrumental or human voice, sound volume and dynamic changes in loudness (e.g., a fortissimo, crescendo), melodic appoggiaturas, a particular theme or motive, sudden harmonic changes, acceleration in tempo, changes in rhythm or syncopation, voice contrasts, melodic resolutions and sustained high-pitch tones of instrumental solos or of voice. One example (by David Huron, 2007, p. 25) is a memorable moment in Beethoven's "Ode to Joy", where one of the musical phrases abruptly begins half a beat early, which can typically evoke instant and intense pleasure in many Beethoven's aficionados. Although chills seem to be experienced in relation to specific and identifiable musical patterns, their occurrence and frequency seems to strongly depend on musical preferences, listening situations (e.g., at home, theater, church, outdoors, headphones, etc.) and perhaps even personality traits of the listeners.

Surprisingly, despite chills being a common response among music listeners (Goldstein, 1980; Lowis, 1998), such intense experiences have infrequently been the focus of music psychology research, possibly because in most experiments investigators have pre-selected the musical pieces used as target stimuli, thereby reducing the likelihood that a specific participant's most-moving selections would be included in any particular study (Carter, Wilson, Lawson, & Bulik, 1995). In a large survey of American college students' responses to music, Panksepp (1995) found that musical selections that were most capable to evoking chills were those that individuals had self-selected than those selected by other individuals, suggesting that individual's personal relationship to musical pieces was an important variable. Subsequent studies have confirmed that people react more strongly to music that they are familiar with than unknown music (e.g., Harrison & Loui, 2014; Nusbaum et al., 2014; Rickard, 2004). Still, it is clear that also passively listening to unfamiliar instrumental music can evoke strong positive feelings and brain changes (Brown, Martinez, & Parsons, 2004). Clearly, music has the capacity to automatically evoke not only strong feelings, but various bodily changes, one of the most cherished being the "chills" that seem to reflect peak emotional experiences.

1.2. Pupillary responses

Since emotional arousals are routinely accompanied by autonomic nervous system changes, we wondered if peak emotional experiences of music, such as chills, could be effectively monitored by pupillary dilation. We specifically selected this measure since it has been demonstrated that degree of pupillary dilation follows the neuronal firing pattern of on key noradrenergic nucleus of the brain stem, namely the locus coeruleus, whose activity tracks pupillary dilation remarkably accurately (Gilzenrat, Nieuwenhuis, Jepma, & Cohen, 2010). Thus, our present aim here was to determine whether pupil diameter, which has been little investigated in relation to music and, in particular, the occurrence of intense responses to music, can provide a particularly relevant and possibly universally-applicable measurement of intense emotional responses to music (but please note, that as this paper was being written, Kang and Wheatley (2015) reported that pupillary dilation could be used to identify which of two musical piece was the focus of conscious attention during concurrent dichotic music listening). Changes in pupil diameter are spontaneous physiological responses, with psychological meaning, that can be observed independently of subjective reports. Although changes in pupillary diameter have the main biological function of regulating that an optimal amount of light energy stimulating the eyes' photoreceptors, it is well established that the pupil diameters also change (in small amounts) in relation to internal factors (like interest, and other aspects of mental processing) in the absence of changes in light stimulation (Loewenfeld, 1999). Nowadays, very small pupillary changes (e.g., hundredths of a millimeter) are easy to measure, in a quantitatively highly precise manner, by use of modern videocamera-based eye-trackers.

Thus, there are at least three theoretically-grounded reasons for investigating pupil responses in relation to the phenomenology of intense responses to music: (1) *attentional processing*: the pupil is a sensitive measure of the allocation of attentional resources and focusing of consciousness, which are all cognitive elements that strongly characterize the music chills experience; (2) *emotional/aesthetic processing*: the eye pupil is sensitive to emotional engagement, in particular to the "arousal" aspect of affective experience (ever since Hess & Polt, 1960); indeed, a key element of the response to art in general, and music in particular, is an intense emotional response; (3) *neural/neurophysiological processing:* neurophysiological accounts of intense response to music have specifically implicated distinct modulatory systems of the brain as being highly related and possibly playing a causal role in the response (see Koelsch, 2015; Koelsch et al., 2015).

1.3. Attention and pupils

With regards to attentional processing: one core aspect of music chills, stressed in nearly all studies, is the presence of a strong engagement of attention during the experiences: Increased focus and concentration, to the point of merging into the